The Paradox of Conservative Haircuts*

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Abstract

Collateral requirements affect counterparty selection. I show empirically that conservative Central Counterparty (CCP) repo haircuts push low-risk borrowers away from the CCP and into the over-the-counter (OTC) repo market. When a CCP increases repo haircuts, its policy change applies to all participants uniformly but most strongly affects borrowers whose funding constraints are binding. Affected borrowers with high credit ratings are more likely to switch to borrowing over the counter due to the risk preferences of OTC repo lenders. As a result, conservatively high haircuts induce negative selection in the CCP repo market, potentially threatening its stability.

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Central Counterparties (CCPs) are financial intermediaries created to provide centralized clearing to their members and thus to decrease the counterparty credit risk in financial markets (Menkveld and Vuillemey (2020)). Unlike an over-the-counter (OTC) deal, a centrally cleared deal is novated. A novated deal is separated into two identical back-to-back transactions, each with a CCP, which becomes a counterparty to each party of the initial deal. Therefore, traders in a centrally cleared market are no longer exposed to each other's potential insolvency: If one participant of the original deal defaults, the CCP fulfills its liabilities to the other participant. Centralized clearing is becoming ubiquitous, spreading across countries and contract types following the 2009 G20 Pittsburgh Summit, which mandated the clearing of standardized derivatives. Currently, over 75% of interest rate derivatives and over 55% of CDS are centrally cleared (Aramonte and Huang (2019)). The centralized clearing of repo is also growing, with CCP repo representing 70% of the European repo market (ECB (2021)).

Despite the significant size and systemic importance of centrally cleared markets, empirical evidence on the stability of CCPs is scarce. While Mancini et al. (2015) and Vuillemey (2020a) provide examples of CCPs' securing the financial system in crises, the evidence in Boissel et al. (2017) and Bignon and Vuillemey (2020) raises concern about the CCPs' own resilience. In September 2018, the Sweden-based Nasdaq Clearing Commodities, being on the verge of failure, had to use approximately 60% of its guarantee fund following the default of an electricity futures trader (Bell and Holden (2018)). Since the default of a CCP, especially during a crisis, can cause severe financial turmoil, it is crucial to identify and properly address risk factors for the CCP stability.[1]

To protect themselves, CCPs impose multi-level risk-management systems, consisting of the individual collateral, a guarantee fund, and the CCPs' dedicated capital. Following the Principles for Financial Market Infrastructures (PFMI, published by Bank for International Settlements (BIS) (2012)), CCPs adopt conservative (i.e., high) collateral requirements (Cap-

[1] According to Paul Tucker, Deputy Governor for Financial Stability at the Bank of England, "... it is an understatement that it would be a disaster if a clearing house failed" (Tucker (2011)).

poni et al. (2020)). Overall collateral is considered an unconditional stability factor for the CCP: The more collateral the CCP takes, the more stable it is. In this paper, I challenge this view by showing empirically that conservative margins may, in fact, induce a negative selection of clearing members, decreasing the quality of the average clearing member and potentially harming the CCP stability.

The mechanism is the following. When a CCP increases collateral requirements (measured by the haircut), this change applies to all market participants uniformly.[2] However, their sensitivities to the haircut increase vary in the cross-section. If the sensitivities are correlated with the traders' credit quality, higher haircuts can push low-risk traders away from the CCP market and into a substitute market. This negative selection undermines the second pillar of the CCP's risk management system – the guarantee fund – one of the main factors of CCP stability (Koeppl and Monnet (2010), Biais et al. (2012), Biais et al. (2016), Wang et al. (2020), and Kuong and Maurin (2021)). The guarantee fund is a risk-mutualization arrangement; its performance is sensitive to the quality of the insured agents. If safest participants refrain from trading in the CCP market, the quality of the insurance provided by the CCP deteriorates.

To empirically identify the selection effect, one must overcome two main challenges. First, it is necessary to observe the trading activity both in the centrally cleared and the substitute markets. Second, proxies for the traders' sensitivities to the changes in collateral requirements have to be found. I address these issues by using a novel transaction-level dataset of CCP and OTC interbank repo deals from Moscow Exchange (MOEX). The data covers the period from January 2013 to July 2016 and represents all interbank ruble-denominated CCP and OTC repo transactions registered by MOEX. In the data, the observable segment of the OTC repo market is a natural substitute market for the CCP repo, and the proxies for the sensitivities to the changes in collateral requirements can be deduced from the banks' balance sheets. I document the main result in three steps, each of which represents a separate

[2]A haircut (or margin) is a parameter of the repo, which describes by how much the transaction is overcollatralized, i.e., by how much the price of the collateral exceeds the loan size.

contribution.

The first contribution is to demonstrate the effect of the borrowers' credit risk on their choice between the OTC and the CCP repo. Theoretically, the allocation of borrowers across the markets, the collateral requirements, and the interest rates depend on the degree of adverse selection. On the one hand, Bester (1985) demonstrates that when adverse selection is severe, haircuts and rates may serve to create a separating equilibrium. He finds that riskier market participants are more reluctant to pledge collateral; as a result, the safest borrowers choose the market with higher haircuts and pay lower rates in equilibrium. If in the CCP repo market haircuts are higher than in the OTC market, one would expect the average credit risk of the CCP borrowers to be lower than in the OTC market (and vice versa). On the other hand, if the borrowers' credit ratings are sufficiently informative about their credit quality, lenders in the OTC market may condition the contracts on the borrowers' credit risk. Risk-averse lenders may refuse to trade with risky borrowers over the counter, inducing them to decrease their idiosyncratic risk, for example, by trading through a CCP.[3] Thus, if insurance is the main role of the CCP (Biais et al. (2012) and Biais et al. (2016)), one would expect that riskier borrowers are more likely to trade in the CCP market.[4]

In line with the insurance role of CCPs, I find that borrowers with lower credit ratings are more likely to borrow in the CCP repo market.[5] I further argue that this selection effect is partially due to the lenders' risk aversion. This conclusion comes from two lines of evidence. First, I exploit the heterogeneity of the CCP repo market to show that the effect of the borrower's credit risk on market selection varies with the amount of information that the lender has about the borrower. In the data, the CCP repo market consists of two

[3]More specifically, lenders may offer conditions that the borrowers will not accept, preferring to trade through the CCP instead. This mechanism is central to the market selection model in Appendix B.

[4]This mechanism is also similar to cream-skimming, in the spirit of Lee and Wang (2018). While in the CCP market lenders cannot condition the collateral requirements on the borrowers' identities, they may do so in the OTC market. This could allow the OTC lenders to cream-skim the best borrowers from the CCP market, for example, by offering them lower haircuts.

[5]This finding is in contrast to the results of Cenedese et al. (2020), who show that in the European IRS market safer entities are more likely to use central clearing. The divergence is likely due to the institutional differences: MOEX CCP easily admits banks to repo clearing, while in most European markets, CCPs' requirements are strict.

segments: bilateral CCP and exchange-traded CCP. In the bilateral CCP segment, borrowers and lenders negotiate directly and therefore know each other's identity; by contrast, the exchange-traded CCP is implemented as an anonymous limit order book. The effect of the borrower's credit risk on the market selection decision is stronger for the bilateral CCP repo segment, where the counterparty's identity is known than for the anonymous exchange-traded CCP repo. Second, I show that lenders perceive the borrower's credit rating as a noisy signal about the credit quality. The most recent credit rating has the largest effect on the repo market choice. As the credit rating gets older, its effect substantially decreases: The difference in the effect of the best and worst credit ratings on the repo market choice drops roughly by 42 % over a year. This result is consistent with lenders updating their prior beliefs about the borrower's credit quality and is harder to reconcile with borrower-driven selection models (Akerlof (1970) and Myers and Majluf (1984)).

The second and most important contribution of this paper is showing that higher CCP haircuts push the safest borrowers from the CCP and into the OTC repo market. To claim causality, one has to resolve several important endogeneity concerns. First, it is possible that the CCP changes haircuts in response to the time-varying selection of borrowers. To address this, I make use of an important institutional detail: The MOEX CCP sets the same security-specific haircuts for all traders in line with its officially disclosed methodology. Even though theoretically this methodology can be updated in response to the changes in the traders' credit quality, frequent updates may introduce uncertainty and antagonize market participants. Therefore, although in the long run haircuts are endogenous, in the short run (i.e., at the collateral-month level), haircuts are plausibly exogenous. Second, the haircut variation may be driven by the time-varying collateral properties (i.e., price volatility), which may also affect the borrowers' collateral holdings. To be confident that the estimated effect is not driven by changes in security properties, I use the difference between the CCP and OTC haircuts as a measure of CCP's overreaction to security-specific information. While the CCP commits to respond to security-specific shocks in a particular way, the OTC market

reacts to the same shocks without a single methodology. Therefore, the average OTC haircut represents a decentralized view of OTC market participants on what the haircut should be. For a particular security, when the average CCP-OTC haircut difference increases, it affects all CCP borrowers, making the OTC repo more attractive to them. But when the lenders are risk-averse, safer borrowers get better contracts in the OTC market, and therefore are more likely to leave the CCP repo in response to the haircut change. As a result, an increase in the CCP haircut relative to the OTC haircut should push the safest borrowers out of the CCP repo market and into the OTC market. Testing this hypothesis, I find that a change in the CCP-OTC haircuts difference leads to an increase in the borrowers' average credit risk in the CCP repo market and a decrease in the average borrower's credit risk in the OTC repo market. In terms of the magnitudes, I show that an 8.8 p.p. increase in the CCP haircut relative to the OTC haircut raises the average credit risk in the CCP market by 1 point (e.g., from Baa3 to Ba1 in Moody's rating scale) and decreases the credit risk in the OTC segment by 0.65 points.

The third contribution is the study of the role of collateral constraints in market choice. Intuitively, a haircut limits the amount that can be borrowed against a specific portfolio of collateral. The tightness of the borrowing constraint depends on the amount of unencumbered collateral. I find that higher haircuts in the OTC market are associated with the borrowers' decisions to choose the CCP repo. Using the borrower's and collateral-time fixed effects, I estimate counterfactual OTC haircuts and rates for each CCP repo deal and find that the effect of haircuts on the market choice is stronger for constrained borrowers. It follows that collateral constraints affect the borrowers' individual sensitivities to the changes in collateral requirements. According to the previous result, the effect of changes in the CCP-OTC haircut difference should be the strongest for constrained borrowers, who are most sensitive to haircut changes. In line with this proposition, I find that the selection effect is the strongest among constrained borrowers.

These results speak to the stability of CCPs within and outside of the repo market. First,

the selection effect that I identify should be taken into account by CCPs when they design their collateral frameworks, as well as by regulators.[6] In the model, developed in Appendix B, I show that the selection effect can be sufficiently large to decrease the safety benefits of a haircut increase, or even to exceed them. Second, the results suggest an additional rationale for mandatory central clearing as implemented, for example, in the standardized derivatives market. If regulators are aware of the negative selection effect between the OTC and the CCP markets, they may demand centralized clearing to ensure the stability of the CCP. However, even when clearing is obligatory, wherever a potential non-cleared market for a substitute product exists, selection may arise.[7] Third, the results show that the differential reactions of market participants to margin requirements are determined not only by their individual properties but also by the comparative characteristics of the centrally cleared and the substitute markets. For example, in the data that is used in this study, the OTC lenders' preferences make the selection effect depend on borrowers' credit ratings, while the strength of this effect depends on the tightness of the borrowers' funding constraints.

The paper proceeds as follows. Section 1 provides an overview of the related literature; Section 2 introduces the data and the institutional details; Section 3 studies the role of lenders' preferences for the repo market selection; Section 4 shows the effect of CCP haircuts on the selection of the repo market participants; Section 5 studies the role of borrowers' funding constraints; Section 6 discusses the implications of the results, and Section 7 concludes.

[6] In a related paper, Cenedese et al. (2020) show that bilateral clearing becomes relatively more common in periods of market stress. They suppose that this may be a consequence of the procyclicality of CCP margins.

[7] For example, in the case of standardized derivatives, this may be an OTC market for synthetic contracts that would be economically similar to centrally cleared products. Ungaro (2018) shows that high CCP costs in the French repo market in 1898 boosted the development of alternative contracts. In the case of the derivatives market, the regulators are aware of this risk and are actively monitoring it (FSB (2017)).

1 Related literature

This work addresses the literature on CCPs, their stability, and risk management practices. Appearance of a CCP decreases the price volatility and increases the value of stocks (Menkveld et al. (2015) and Bernstein et al. (2019)), reduces the counterparty credit risk (Loon and Zhong (2014) and Vuillemey (2020b)), mitigates fire sales (Vuillemey (2020a)), increases transparency (Acharya and Bisin (2014)), lowers the demand for collateral (Duffie et al. (2015)), and decreases the level and the dispersion of repo rates (Ungaro (2018)).[8] On the other hand, the concentration of risks within CCPs raises concerns about their systemic stability (Pirrong (2011)). Boissel et al. (2017) find that during the sovereign debt crisis in Europe the conditional default probability of the CCP was big enough to affect the CCP repo rates.

To protect themselves, CCPs implement a sophisticated risk-management system, which consists of collateral requirements, guarantee funds, and the CCP's own capital.[9] Collateral requirements are used to mitigate the counterparty risk for the CCP by decreasing the traders' moral hazard (Biais et al. (2016) and Wang et al. (2020)). However, high margins are costly; that is, they create a deadweight loss for society. In general, the existing literature suggests that the optimal margin resolves the trade-off between the costs that it imposes on market participants and the default protection that it provides (Brennan (1986) and Shanker and Balakrishnan (2005)). By contrast, in this paper, I uncover an additional downside of conservatively high margins: When the sensitivity to the collateral requirements varies in the cross-section of traders, haircuts affect the composition of market participants. If this sensitivity depends on the traders' credit quality, as in our case, then collateral requirements have a differential effect on high- and low-risk traders. Then, high CCP margins may push the best market participants away from the centrally cleared market.

[8] Menkveld and Vuillemey (2020) provide a review of the effect of central clearing on the functioning of financial markets.

[9] For a detailed description of the organization of a CCP, see Pirrong (2011). Duffie (2014) describes the CCPs' risk-management and resolution mechanism.

The findings in this paper address the regulatory debate on optimal CCP haircuts. Currently, CCPs in different markets set conservative collateral requirements, following the PFMI (BIS (2012)), that prescribe "forward-looking and relatively stable and conservative margin requirements." Empirically, Capponi et al. (2020) show by back-testing that the ICC CDS margins are orders of magnitude more conservative than standard benchmarks (such as Value-at-Risk) imply. In a recent paper, ISDA (2021) provides the results of the survey of CCPs' risk-management performance during the Covid outbreak. They find no evidence of insufficient collateral but document high procyclicality of margins. Following Brunnermeier and Pedersen (2008) and the PFMI, they recommend increasing CCP margins in stable times to prevent the increases of margins during the crisis. In this paper, I present evidence suggesting that increasing already conservative haircuts may weaken CCPs by affecting the composition of clearing members.

A series of related results was previously derived in the literature studying the effects of margin increases in stock and derivatives markets. It has been shown that an increase in margins lowers the market activity, market participation and the price volatility (Tomek (1984), Hartzmark (1986), Hardouvelis (1990), and Hardouvelis and Kim (1995)) but does not affect prices (Seguin and Jarrell (1993)). Estrella (1988) suggests that high margins may not only harm liquidity but also influence the composition of traders in the market. Hartzmark (1986) proposes that different groups of traders have different sensitivities to margin changes; however, the identification of those groups and their respective sensitivities pose a challenge. He further suggests that traders with the highest margin costs should be most sensitive to margin changes.[10] In line with Hartzmark (1986), I show that traders whose funding constraints bind are more affected by changes in margins. Besides, I show that the type of selection also depends on the properties of the centrally cleared market and of its substitute.

[10]In another related case study, Mayhew et al. (1995) show that an increase in options margins in 1986 lead to a decrease in bid-ask spreads in the options market and an increase in bid-ask spreads for the underlying stocks, consistent with uninformed traders being more sensitive to margins changes.

Closest to this paper is the recent literature on the determinants of central clearing. Onur et al. (2021) show that the regulation of minimal collateral requirements in the OTC market increased the incentives for centralized clearing in cash-settled FX swap markets.[11] Cenedese et al. (2020) study the pricing of interest rate swaps both in the OTC and the CCP markets in Europe, also touching upon the question of endogenous market choice. Contrary to my results, they find that the counterparty credit risk is negatively related to the probability of trading in the CCP market. This difference may reflect diverse CCP policy across markets: While MOEX CCP easily admits commercial banks to clearing, the European CCPs typically set high requirements when clearing is not mandatory, as, for example, in the case of repo. By contrast, using the data on European single-name sovereign CDS, Bellia et al. (2019) show that riskier traders have a higher probability of choosing centralized clearing. In line with the insurance role of CCPs, the probability of clearing the deal is more sensitive to the seller's credit risk. The contradiction between the results of Cenedese et al. (2020) and Bellia et al. (2019) may be explained by potential trader-level endogeneity present in one of the markets. For example, access to clearing may be easier for safe counterparties, while the incentives to clear may be stronger for riskier traders. Using individual borrowers' fixed effects, I show that a rise in the credit risk of the same borrower increases her probability of trading in the CCP repo market, similar to Bellia et al. (2019). Moreover, I show that the changes in CCP collateral requirements have a diverse effect on borrowers with different credit risk levels.

The findings in this paper are also related to the literature on the stability of different segments of the repo market. Studying the bilateral OTC repo market, Gorton and Metrick (2012) identify a potential channel of the propagation of the 2008 crisis – the run on repo. An increase in haircuts for repo collateralized by asset-backed securities (ABSs) resulted in liquidity problems for "shadow banks" and for the banking system itself. These findings started a regulatory debate on the procyclicality of haircuts and the systemic stability of the

[11] After the first stages of the implementation of this regulation known as the Uncleared Margin Rule, the majority of swaps still remain uncleared.

repo market. Copeland et al. (2014) and Krishnamurthy et al. (2014) use broader samples of tri-party and bilateral repo transactions to show that the run on repo was unlikely to play a key role in the crisis, being limited to a relatively small fraction of the market.[12] On the other hand, Mancini et al. (2015) show that during the 2008 crisis the CCP repo market in Europe acted as a shock absorber in the wholesale funding market, increasing the turnover while the haircuts and spreads remained stable. By contrast, Boissel et al. (2017) find that at the peak of the sovereign debt crisis in 2011, market participants priced the default risk of the CCP in the interest rate, indicating its sizeable default probability. Close to my paper is the work of Dieler et al. (2021), who theoretically analyze the efficiency of the CCP and OTC repo markets and show that the CCP is more resilient to small funding shocks. On the other hand, the CCP repo market is prone to systemic runs under significant funding shocks, which induces inefficient liquidation of high-quality assets. I contribute to this literature by demonstrating the relationship between the OTC and the CCP repo market existing in parallel, and showing how the CCP haircuts affect the traders' repo venue choice.

Finally, this work is related to the strand of literature studying the endogenous decision to participate in the centralized or OTC market. Most of the papers in this literature explain venue choice by differences in participants' search costs related to the gains from trade (e.g., Gehrig (1993), Rust and Hall (2003), and Miao (2006)), in the quality of participants' informedness (e.g., Yoon (2018) and Lee and Wang (2018)), or in their trading capacity (i.e., Dugast et al. (2019)). My setting significantly differs from these studies, since, as I demonstrate, borrowers' credit quality is an important venue choice factor in the repo market. Conceptually, this work is closest to that of Lee and Wang (2018), who show that the non-anonymity of contracts in the OTC market allow OTC dealers to cream-skim the least informed traders from the centralized markets by offering them discounts. As in Lee

[12] Copeland et al. (2014) also distinguish between the two sub-segments of the OTC repo market: the bilateral repo, where the settlement and collateral management are performed by the deal members, and the tri-party repo, where those services are outsourced to a third party. They show that while in bilateral repo, haircuts are indeed used to limit the credit, in tri-party repo the credit is rationed directly, while the haircuts often remain unchanged.

and Wang (2018), the ability of OTC lenders to condition contracts on borrowers' identities, including their credit risk, plays an important role in my analysis.[13] Unlike Lee and Wang (2018), I focus on the liquidity-driven repo market, where the counterparty credit risk is an important factor of pricing and market selection.

2 Institutional details and data

In this section, I introduce the source of the data. First, I provide the institutional details of the market. Then, I describe the sample and give summary statistics.

2.1 Repo

The repo market is a market for short-term borrowing, which is used by banks, funds, brokers, insurance companies, and other financial intermediaries. In the repo market, a borrower obtains a sum of money and pledges a portfolio of financial securities as collateral. If at the end of the deal the borrower does not repay the sum plus the interest rate (also known as the repo rate), the lender can liquidate the collateral to cover the loss, returning the remaining sum to the borrower. Since the price of the securities in the collateral can change over time, at the moment when the borrower appears to be insolvent, the collateral value may be insufficient to cover the amount outstanding. To limit the market risk of the collateral, the counterparties typically agree to overcollateralize the deal, that is, to pledge more collateral than the loan size.[14] The degree of overcollateralization is captured by the haircut (or margin) of the repo deal; it shows by how much the price of the collateral exceeds the loan size.

Repo should be distinguished from security lending deals. Although the contractual

[13] In centrally cleared markets, the observability of the counterparty's identity does not matter, since each transaction is novated. Therefore, the key friction in the centrally cleared market is that the CCP is unable (or unwilling) to fully condition the contracts on traders' identities.

[14] Other reasons to use collateral discussed in the theoretical literature include moral hazard (e.g., Stiglitz and Weiss (1981), Boot et al. (1991), Geanakoplos (2003), Kuong (2020)) and adverse selection (Stiglitz and Weiss (1981), Bester (1985), Chan and Kanatas (1985), and Besanko and Thakor (1987a), etc.).

form is often the same, while repo is a collateralized loan, security lending is originated by a market participant who is willing to obtain the security (i.e., a broker-dealer) in order either to sell it short or to fulfill her existing liability to deliver the security. While in repo, the borrower's credit risk is the main concern, in security lending the money lender's credit risk shapes the parameters of the transaction. In repo deals, money lenders typically disagree to lend below the risk-free rate and haircuts are usually positive, while in security lending, the interest rate is often below the riskless rate and the haircuts are usually negative.

In this paper, I classify repo deals into the CCP repo and the OTC repo. As the data comes from the National Clearing Center (NCC), the Central Counterparty of Moscow Exchange (MOEX), I observe the entire CCP repo market and a part of the OTC repo market; that is, all repo transactions registered through MOEX. Below I characterize each of the two markets separately.

2.2 CCP repo

The Central Counterparty repo on MOEX was launched in February 2013 to ensure the resilience of the Russian repo market. The deals originated on MOEX are cleared by the National Clearing Center (NCC), which is the Central Counterparty of MOEX. In the beginning, only government bonds were admitted as collateral, but soon the collateral list was augmented by most liquid stocks, corporate bonds, and eurobonds. The generalized collateral repo was introduced in early 2016; until then, all repo deals were specials.[15]

The CCP repo market in Russia consists of two segments: the limit order book repo (LOB) and the bilateral interdealer CCP repo (BL). The former is a typical exchange-traded repo, where the haircut is set by the CCP, and the repo rate is determined by the order matching algorithm similar to the limit-order book in the stock market. On the contrary, the BL repo market resembles the OTC trading mode: The counterparties match

[15]ICMA defines general collateral (GC) as "a set or basket of security issues which trade in the repo market at the same or a very similar repo rate, which is called the GC repo rate." (ICMA (2019)) By contrast, a special repo deal is collateralized by a single security issue.

and negotiate directly (over the phone or through a trading terminal) and later register the deal within the MOEX CCP trading platform. Unlike the LOB segment, the BL mode is more flexible: Participants can set the repo term, the interest rate, and the haircut as they want. However, if the chosen haircut is below the CCP haircut for the pledged security, the borrower needs to post additional collateral to compensate for the difference. Thus, both LOB and BL CCP repo segments have the same effective collateral requirements.

Each repo transaction cleared through the CCP is replaced with two deals so that the CCP becomes the borrower to the initial lender and the lender to the initial borrower in the process that is called "novation." As a result, market participants are exposed not to the credit risk of the initial counterparty, but rather to the risk of the CCP default. The CCP's risk management system requires participants to post collateral and to contribute to the guarantee fund. NCC sets requirements for the participants to be admitted to central clearing, which are relatively mild for domestic banks since they are supervised and monitored by the Russian Central Bank (CBR). However, the NCC can reject a participant from clearing if she shows signs of potential insolvency.

All CCP repo deals are margined bilaterally; that is, the lender also faces marginal requirements if she decides to withdraw all borrower's collateral from her account. After the first leg of the deal is executed, the CCP treats the remaining part as a forward contract, checking collateral sufficiency and making margin calls on a daily basis. The margin requirements are set in line with the haircuts calculated by the CCP according to its methodology that is published on the official web page.[16] These haircuts are security-specific; that is, they do not depend on the counterparty's identity and can change intraday in case of large fluctuations of the price.

Despite a higher commission compared to the OTC repo market, the CCP repo attracts

[16]For bonds, CCP haircuts equal the initial margin requirements, while for stocks the initial margins are $\sqrt{2}$ times bigger than the haircuts. It means that to withdraw the entire borrowed sum from the account, the borrower has to pledge additional collateral on top of what is transferred to the lender. Alternatively, without pledging additional collateral, she can withdraw $1/\sqrt{2} \approx 70,7\%$ of the borrowed amount. In what follows, I focus on haircuts; conducting the same analysis based on the initial margins does not change the results.

participants due to the low credit risk, novation, and better regulatory coefficients for the calculation of risk-weighted assets. The latter is a very important factor for banks that have to satisfy the regulation of the CBR, including the capital adequacy ratio, which has risk-weighted assets in the denominator. By setting a low risk weight for the CCP (5%, as compared to 20% or 100% for OTC repo deals) the CBR supports the CCP-based trading. Another advantage of centralized clearing is multilateral netting, which allows the market participants to pledge collateral and pay the variation margin only for the net position vis-à-vis the Clearing Center.

2.3 OTC repo

The sample covers a part of the OTC repo market that is composed of all OTC deals registered at MOEX. MOEX provides the settlement service as well as standardized contracts and pricing, and a well-described risk management mechanism.[17] To get access to these services, participants pay a commission fee. MOEX OTC repo deals are not included in the clearing pool; instead, bilateral netting within a pair of counterparties takes place.

The main advantage of OTC over the CCP repo mode is the flexibility of the trading process. Counterparties are free to set any haircuts and repo rates they would like to, while in the centrally cleared repo market the effective haircut is chosen by the CCP. OTC deals have a lower commission than CCP transactions, and the requirement for the collateral quality is different from the CCP repo market. That is, the participant of the OTC repo can pledge bonds and stocks, including those that are not in the CCP collateral list. On the other hand, in the OTC repo market counterparties take risks on each other; therefore, they usually monitor each other's credit quality. Typically, all OTC transactions are restricted by counterparty credit limits, which are set by the company's risk management. If two repo participants exhaust their OTC repo limit capacity, they can continue trading bilaterally in

[17] In the OTC market outside MOEX, participants use the General Agreement (GA) formulated by the National Financial Association. It is similar to the Global Master Repurchase Agreement developed by the International Capital Market Association (ICMA).

the CCP repo market.

2.4 Sample

The dataset consists of both OTC and CCP repo deals from January 2013 to June 2016. For each deal, I obtain the date, volume, haircut, repo rate, borrower's and lender's identities, and the repo term. Among all counterparties, I identify banks and match them to their financial reports published on the CBR web page. I take monthly intermediate balance sheets (F-101) and monthly regulatory ratios (F-135). I obtained historical credit ratings by web-scrapping a practitioners' web resource, bankodrom.ru, and selectively cross-checked the history of ratings with the official web pages of several banks that keep the entire history of ratings to verify the accuracy of the data.

Since the dataset starts before the origination of the CCP repo market when the OTC repo prevailed, the fraction of the CCP trades in the total sample changes over time. Figures A-1 and A-2 in Appendix A plot the average number of daily originated repo deals (in units) and average daily open interest (in bln. rubles) for each month. Throughout the sample, the CCP repo market is gaining popularity both in the number of transactions and in the share of the total open interest. Bilateral CCP deals are larger than the OTC or CCP LOB deals. This is confirmed by summary statistics provided in Table A-1. OTC deals are on average smaller than CCP deals, are arranged for a longer term, have a higher repo rate and a lower haircut. Approximately 2/3 of OTC transactions are backed by stocks and 1/3 by bonds. By contrast, for both segments of the CCP market, more than 2/3 of the deals are collateralized by bonds.

There are also important differences between the market participants of the three markets. While the size of the average lenders in the bilateral CCP and OTC repo markets are comparable, a typical exchange-traded CCP repo lender is three times smaller. On average, OTC repo borrowers are larger, less risky, and less collaterally constrained than those who fund through the CCP. I measure the credit risk using the long-term foreign currency credit

ratings provided by the three international credit rating agencies: Moody's, S&P, and Fitch. I choose international rating agencies because for the period that I study, domestic credit rating agencies in Russia were still young and their methodology was changing together with the industry regulation. The foreign currency long-term rating is the most common credit rating obtained by Russian banks from international agencies. Wherever the domestic currency rating is also available in the sample, it almost always coincides with the foreign currency rating. I convert the ratings by the three agencies to one scale (Moody's) and assign a credit risk index from the least risky (1) to the riskiest (13), as shown in Table A-3 in Appendix A.

I trim the sample along several important dimensions. First, I focus only on the interbank repo market, where I have both borrowers' and lenders' characteristics. Second, I delete deals made by state-owned development banks, as their special status may imply different risk-taking behavior and their credit rating is difficult to interpret. Third, while I focus on liquidity-driven repo deals, which are economically equivalent to collateralized lending, sometimes repo contracts are used for security lending. Security lending is often associated with short-selling activity, a channel that may trigger endogeneity concerns in my analysis. To avoid it, I drop deals that have strong signs of security lending: a negative haircut or a very low repo rate. I drop a deal if the haircut is less than -2 or if the repo rate is less than the RUONIA interbank rate by more than 3 percentage points.[18]

The first criterion is designed to take into account that in security lending it is the cash that serves as collateral, not the security itself. While in repo the security price fall is the main market risk, in security lending the risk comes from the appreciation of the traded asset. Being untypical for repo, a negative haircut can be used as a signal of security lending. However, I set a threshold of (-2) to allow for potential differences in securities prices used by OTC market participants when calculating haircuts.

The second criterion is designed to filter out the security-driven (as opposed to the

[18]RUONIA is "a weighted average interest rate on overnight interbank ruble loans (deposits) offered by active banks with high credit-ranking" (http://ruonia.ru/about), calculated by the CBR.

liquidity-driven) deals with abnormally low interest rates. Such interest rates can mean that the security is "on special" as defined by Duffie (1996). This situation often indicates a "squeeze" in the market, when some participants have uncovered liability to deliver the security and are trying to borrow it (Buraschi and Menini (2002) and Baklanova et al. (2019)), which may be a result of abnormal short-sellers activity. To find such deals, I compare the repo rate with RUONIA, the uncollateralized overnight borrowing rate in the safest interbank segment, often used as a proxy for the ruble riskless rate. If the repo rate is lower than RUONIA by more than 3 percentage points, I label this deal "collateralized lending" and exclude it from the sample. I need to ensure, however, that this criterion is mild enough; that is, it does not throw out crisis periods when the uncollateralized interest rate can deviate from the collateralized benchmark. To ensure this, I compare RUONIA with overnight RuREPO, an indicative repo rate at which safest banks are ready to lend to each other against the safest collateral, that is, Russian government bonds.[19] Throughout the sample, the difference between RUONIA and RuREPO exceeded 3 p.p. only once, in a rather extraordinary case.[20] In general, RUONIA follows RuREPO closely. Therefore, the RUONIA-based rule is a good benchmark for the identification of security lending.[21]

3 The role of lenders' risk preferences

Theoretically, it is not certain whether the haircuts in the OTC repo market should be higher or lower than in the CCP repo market. In the model of Koeppl and Monnet (2010), a CCP is able to reduce collateral requirements as compared to the OTC market due to factoring-in the risk-decreasing effects of mutualization and novation; Biais et al. (2016) come to a similar conclusion. However, these results address the CCPs for derivative contracts, which

[19]This indicator is calculated daily by the National Financial Association and published online at http://rurepo.ru.

[20]On December 17, 2014, the CBR increased the key borrowing rate (the main monetary policy indicator – the repo rate at which CBR extends loans to commercial banks) by 6.5 p.p., which triggered a shock wave in the Russian credit market.

[21]Using the entire sample of interbank loans does not alter the results: Most security lending deals are filtered out when limiting the set of borrowers to banks.

have a different nature: While for a CDS or IRS trader the counterparty credit risk is an unfortunate by-product of the transaction that decreases the price of the instrument (Loon and Zhong (2014)), in a repo deal it is the main risk that is priced directly in the interest rate. Below, to establish the hypotheses about haircut levels and the allocation of borrowers across the markets, I draw on the literature on collateralized debt.

One of the key frictions in the existent literature on debt is adverse selection. If the information about the borrowers' credit quality is their private knowledge (i.e., if the credit ratings are not informative), the two types of debt contracts (CCP and OTC repo) may serve to help form a separating equilibrium between different classes of borrowers. For example, according to Bester (1985), since better borrowers default less, they are more willing to pledge collateral. Therefore, an equilibrium may exist in which low-quality borrowers pay higher rates and pledge less collateral (i.e., choose a lower haircut), while high-quality borrowers may separate themselves by accepting higher haircuts. Then the allocation of borrowers between the CCP and the OTC repo markets is determined together with the haircuts: If the best borrowers fund themselves through the CCP repo market, then the CCP haircut is higher (and vice versa).[22] Thus, according to Bester (1985), haircuts are bigger in the market where the borrower's quality is higher.

Table A-1 shows that the CCP requires higher margins than what is pledged in the OTC repo market. This observation is in line with the recommendations of international organizations, such as the Bank for International Settlements (BIS) and the World Federation of Exchanges (WFE), that CCPs maintain conservative margins (BIS (2012) and Gurrola-Perez (2020)). The difference in summary statistics however can be driven by differences in traded securities or specific non-overlapping subsamples of borrowers. To compare haircuts and repo rates across the venues, I focus on a sample of securities admitted in the OTC and CCP repo and on the set of borrowers that trade in both markets. For each deal

[22] According to Menkveld and Vuillemey (2020), CCPs may fulfill the role of the venue with high collateral requirements. This can happen, for example, if market participants are unable to commit to not reinvest the collateral, while the CCP is considered a safer venue for collateral management.

traded in the CCP market, I calculate a counterfactual CCP haircut and rate using the OTC market as a training sample. Figure 1 shows the distribution of differences between the predicted counterfactual (OTC) and actual (CCP) haircuts and repo rates for every CCP deal, averaged at the security-month level.[23]

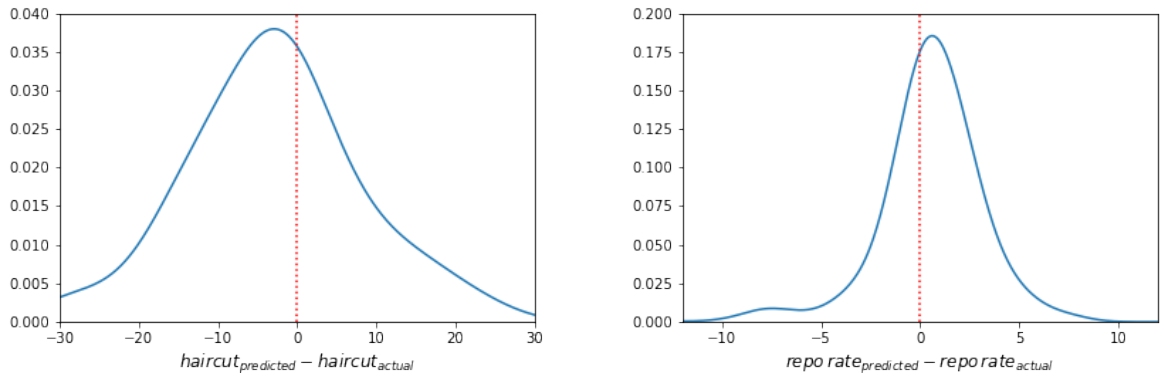

Figure 1: The kernel density of the difference between the OTC (counterfactual) haircut and the CCP (actual) haircut at the deal level on the left panel, and the kernel density of the difference between the OTC (counterfactual) repo rate and the CCP (actual) repo rate at the deal level on the right panel.

Figure 1 shows that for an average (and median) collateral-month, the predicted OTC haircut is lower than the actual CCP haircut, while the opposite relation holds for the predicted OTC and actual CCP repo rates. In terms of Bester (1985), this pattern suggests that safer borrowers trade in the CCP markets, pledging more collateral and receiving a lower interest rate.

***Hypothesis* 1A.** *Safer borrowers trade in the CCP repo market.*

By contrast, if credit ratings are sufficiently informative, OTC lenders can use them to infer the borrowers' credit quality. As a result, lenders may prefer to trade with the best

[23] I use a sample of repo deals where both borrower and lender are banks. I select securities that have at least 40 OTC repo trades in each calendar month of observations when admitted to trading, and only borrowers who made more than 15 transactions with any of the selected securities in the sample. This leaves me with 44 unique borrowers and 147 unique securities. First, I run a regression of haircut and repo rate on observable borrower, lender, and deal characteristics, as well as borrower-month and security-month fixed effects. Then I use the estimated coefficients to predict the counterfactual OTC haircut and repo rate for each deal made in the CCP repo market. Finally, for each CCP repo deal, I take the difference between the predicted OTC and actual CCP haircut (rate) and average at the security-month level to obtain the graphs.

borrowers over the counter, where the default risk is taken directly, and to induce the worst borrowers to insure their idiosyncratic default risk, for example, by trading though the CCP market. In this case, CCP fulfills the role of an insurance company (Biais et al. (2012)) due to the risk mutualization property of the guarantee fund. Notice that this explanation does not require the lenders to explicitly ration the borrowers. In the model presented in Appendix B, low-risk borrowers get higher utility from their endogenous OTC contracts, while the unique CCP contract brings the same utility to every borrower. Comparing the utility from trading in the OTC and the CCP repo markets, better borrowers are more likely to choose the OTC repo. Therefore, if the borrower's credit risk is observable, one would expect the borrowers in the CCP repo market to have a lower credit rating.

***Hypothesis* 1B.** *Safer borrowers trade in the OTC repo market.*

Consistent with Hypothesis 1B, Table A-1 suggests that the average borrower's credit risk in the CCP repo market is higher than in the OTC repo market.[24] As noted before, the summary statistics provide an unconditional result, not taking into account borrowers, lenders, and security characteristics. To check whether the effect of the credit risk is robust when using a set of controls and fixed effects, I estimate the linear probability model (1), as follows:

$$\mathbb{1}\{\mathbf{OTC}\} = \beta * Cred\_risk_{b,t} + C_i + \gamma_l + \nu_{s,m} + \epsilon_i, \tag{1}$$

where $\mathbb{1}\{\mathbf{OTC}\} = 1$ if the deal i is made in the OTC repo market and $\mathbb{1}\{\mathbf{OTC}\} = 0$ otherwise, $Cred\_risk_{b,t}$ is the credit risk of borrower b at day t, C_i is a set of borrower-, lender- and deal-level controls, γ_l is the lender's fixed effect, and $\nu_{s,m}$ is the security-month fixed effect.

Column 1 of Table 1 shows that the same lender is more likely to trade with a safer borrower in the OTC repo market than in the CCP repo market. This result is a conditional counterpart to the comparison of average credit risk in Table A-1. However, a significant

[24]Here and later, I consider the average rating weighted by the number of deals.

Dep.Variable	$\mathbb{1}\{$**OTC**$\}$	$\mathbb{1}\{$**OTC**$\}$	$\mathbb{1}\{$**OTC**$\}$	$\mathbb{1}\{$**OTC**$\}$
cred_risk	-0.073***	0.004		
	(-5.43)	(0.15)		
cred_risk_tercile			-0.155**	
			(-2.51)	
cr_risk_tercile_2				-0.132*
				(-1.78)
cr_risk_tercile_3				-0.330***
				(-2.95)
Controls	✓	✓	✓	✓
Lender fe	✓			
Borrower fe		✓	✓	✓
Col x month fe	✓	✓	✓	✓
Num Obs	795229	795229	795229	795229
$\mathbf{R^2}$	0.275	0.057	0.079	0.080

Table 1: The effect of credit risk on repo market choice. $\mathbb{1}\{OTC\}_i = 1$ if the deal i is made in the OTC repo market and $\mathbb{1}\{OTC\}_i = 0$ otherwise. The controls include the logarithms of borrower's and lender's size, capital adequacy ratio, logarithms of short-term and middle-term liquidity ratios, the logarithm of borrower's volume of interbank funding, borrower's collateral constraint level, and deal-level controls (repo term, logarithm of loan size). The standard errors are double-clustered at the security and borrower level. T-statistics are in parentheses.

negative β in (1) does not mean that a downgraded borrower is more likely to leave the OTC repo. Rerunning regression (1) with borrower fixed effects in Column 2, I find that the effect of the credit rating goes away. This may have several explanations. If the downgrade is not too severe, a borrower may be capable of staying in the OTC market even after being downgraded, preferring to bargain with the lender, or even to change the counterparty if necessary. It is also possible that small within-borrower variation in the credit risk does not affect market selection, as lenders possess additional information about the borrower's credit quality, and downgrading by one point does not sufficiently update the lender's information set. Some support for this conjecture is given in Column 3, where I regress the OTC indicator on the credit risk tercile, controlling for the borrower's fixed effects.[25] Getting riskier by one

[25]Since I have multiple trades for each borrower across time, I first average the credit risk of each borrower

tercile, the borrower becomes 15.5% less likely to trade in the OTC repo market. Column 4 shows that the tercile effect is monotonic.

Two further pieces of evidence are in line with the lenders' active role in the borrowers' market choices. First, I explore the difference between the CCP BL and the CCP LOB markets. In the BL market, the borrower and the lender know each other's identities, while trading in the LOB market is anonymous. If the selection is indeed lender-based, one would expect the effect of the credit rating in the bilateral market to be stronger than in the anonymous market. As there is no difference in the average borrowers' credit rating between the two CCP repo trading modes, while the margining policy is roughly the same, the difference between BL and LOB credit risk coefficients should not follow from the difference in means across the two samples. The result of estimating (1) with the CCP sample restricted to just one market is shown in Columns 1 and 2 of Table 2, respectively. Clearly, the effect is the strongest for bilateral CCP deals, where lenders are aware of the borrower's identity. If a lender is matched with a risky borrower over-the-counter and is reluctant to trade, she can suggest that they register the deal in the CCP BL market instead, which may strengthen the selection effect. This does not apply in the CCP LOB market, since the probability of matching with the same borrower in the limit order book is negligible in most cases. This result is consistent with lenders' risk preferences affecting the choice of where to execute a particular deal, in line with the insurance role of the CCP.

However, since the difference between the CCP ET and the bilateral CCP markets is bigger than just the anonymity, the argument above is not conclusive. To further indicate the role of lenders' awareness of the borrowers' level of credit risk, I resort to the properties of credit ratings. Since a rating is a signal of the borrower's credit quality, it is characterized not only by its information contents (i.e., the rating is equal to BBB+ as opposed to BB-) but also by its precision. The latter can be proxied by the time since the credit rating was issued: The older the rating is, the less informative it is about the current state of the

across her deals and then use the terciles of the resulting credit risk vector.

bank's balance sheet. While it is unlikely that the age of the credit rating affects borrowers' preferences, its effect on the market selection may indicate a strong role of lenders in the repo venue choice.

Dep.Variable	$\mathbb{1}\{$**OTC**$\}$	$\mathbb{1}\{$**OTC**$\}$	$\mathbb{1}\{$**OTC**$\}$
cred_risk	-0.080***	-0.021**	-0.083***
	(-5.38)	(-2.20)	(-7.23)
rat_age			-0.144
			(-1.23)
cred_risk*rat_age			0.035***
			(2.65)
Sample	**OTC+CCP$_{\mathbf{BL}}$**	**OTC+CCP$_{\mathbf{LOB}}$**	**OTC+CCP**
Controls	✓	✓	✓
Lender fe	✓	✓	✓
Col x month fe	✓	✓	✓
Num Obs	734669	653750	795229
R²	0.301	0.097	0.278

Table 2: The effect of credit risk on repo market choice. $\mathbb{1}\{OTC\}_i = 1$ if the deal i is made in the OTC repo market and $\mathbb{1}\{OTC\}_i = 0$ otherwise. The sample of CCP repo deals consists of deals made in the Bilateral CCP repo market (CCP_{BL}) and the Limit order book CCP segment (CCP_{LOB}). The controls include the logarithms of borrower's and lender's size, capital adequacy ratio, logarithms of short-term and middle-term liquidity ratios, the logarithm of borrower's volume of interbank funding, borrower's collateral constraint level, and deal-level controls (repo term, logarithm of loan size). The standard errors are double-clustered at the security and borrower level. T-statistics are in parentheses.

$$\mathbb{1}\{OTC\}_i = \beta_1 * Cred\_risk_{b,t} + \beta_2 * rat\_age_{b,t} + \beta_3 * Cred\_risk_{b,t} * rat\_age_{b,t} + C_i + \gamma_l + \nu_{c,m} + \epsilon_i, \quad (2)$$

where $rat\_age_{b,t}$ is the number of days since the rating was issued. If the rating has the aging property, that is, its effect decreases with time, one would expect β_3 to be positive, offsetting the effect of a negative β_1 as the rating gets older. The estimates of the coefficients are given in Column 3 of Table 2. As expected, the coefficient β_3 is positive and significant. The lower

the rating is, the more likely the borrower is to fund through the CCP repo ($\beta_1 < 0$). Consider the credit ratings on the opposite sides of the spectrum: Moody's Baa1 ($Cred\_risk = 1$) and Moody's Caa ($Cred\_risk = 10$), the estimated difference in the credit risk effect upon the rating issuance is roughly 42% bigger than when both ratings are one year old. This is consistent with lenders treating the rating as a signal of the borrower's credit quality. The higher the rating is, the more willing the lenders are to extend the loan over-the-counter, especially so when the rating is newly issued. It follows that the lenders' risk preferences, that is, their sensitivity to the borrowers' credit risk, is an important determinant of the selection of borrowers across the markets.

4 The effect of haircuts on repo market choice

Since safer borrowers are more welcome in the OTC repo market, changes in costs of CCP trading may affect the actions of safe and risky borrowers differently. Suppose that the CCP exogenously increases its collateral requirements compared to the OTC market. When facing higher trading costs in the CCP market, some traders may consider moving to the OTC repo. The findings above show that this market change will be easiest for safest traders. Thus, CCP collateral requirements may have a potential to change the selection of traders in the CCP market, pushing the safest borrowers into the OTC repo. Empirically, if an increase in the CCP haircut is accompanied by an increase in the credit risk of CCP borrowers, this may indicate a negative selection effect of the CCP margining policy.

***Hypothesis* 3.** *When the CCP increases the haircut for a security, the credit risk of the average trader pledging it in the CCP repo market increases.*

However, a "naive" regression of credit risk on the haircut causes multiple endogeneity concerns.

First, in equilibrium, haircuts and the borrowers' credit risk are jointly determined. Therefore, a simple regression of credit risk on the haircut is subject to the simultaneity bias.

Acknowledging that in the long run haircuts are endogenous, I instead focus on the short-term variation in haircuts. I aggregate the credit risk and haircuts at the collateral-month level for each market and use the collateral-month variation as "high-frequency" changes in haircuts. Although, theoretically, CCP haircuts may be affected by the selection of borrowers in the long run, the CCP methodology cannot adjust monthly to fit the composition of market participants. Thus, in the short run, I can consider haircuts to be plausibly exogenous with respect to the credit risk of the traders.

Second, the estimates in the regression can be biased by global CCP-wide or economy-wide events that would simultaneously affect the haircuts and trading venue selection motifs. Indeed, Figures A-1 and A-2 show that the fraction of the CCP-cleared repo trades increased over time, which could be a result of changes in the CCP methodology. Methodological changes may be an omitted factor simultaneously affecting the composition of traders and the CCP's margining policy. To control for this variation, I use monthly fixed effects. Similarly, I add security fixed effects to control for the average collateral-specific variables that could simultaneously affect the haircuts and traders' selection, for example, through differential holdings of different types of securities.

Finally, some security-specific events can drive both haircuts and the borrower's composition. For example, if a security becomes riskier, its haircut goes up. Meanwhile, this riskiness may affect the likelihood that the security is pledged by high-quality borrowers in the CCP market, for example, if the high-quality borrowers react to the shock by selling risky securities to low-quality borrowers. In this situation, a simple regression (even with security and month fixed effects) can lead to an erroneous conclusion that the CCP haircut drives the best borrowers out of the CCP market, while the result is driven by an omitted time-varying characteristic of the security (i.e., collateral market risk).

To address this concern, I make use of the institutional details of the CCP and the OTC repo markets. Since the CCP's methodology is conservative and rigid, it typically

	haircut_CCP	haircut_OTC	hctdiff	Cr_risk_CCP	Cr_risk_OTC	Cr_risk_diff
count	4629	2099	1794	2838	3159	1613
mean	13.451	9.103	5.084	6.753	4.239	2.153
std	6.975	6.480	6.735	1.520	1.296	1,853
min	3.000	0.811	-25.149	1.000	1.000	-4.023
25%	8.000	5.212	0.880	6.000	3.255	1.004
50%	11.025	7.089	3.999	6.980	4.160	2.204
75%	17.352	10.647	8.844	7.772	5.113	3.380
max	53.141	53.222	37.920	12.444	9.000	7.045

Table 3: Summary statistics at collateral-month level.

applies higher haircuts than those observed over the counter.[26] I focus on the changes in the CCP-OTC haircut difference to identify excessive changes due to the CCP margining policy. The changes in the CCP haircuts are driven by security-specific events that also affect the OTC market participants, but the reaction in the two markets is different. There is neither a single OTC methodology nor a commitment to react to particular events, while the description of the MOEX CCP algorithm is published on the official web page. According to the official description, MOEX CCP haircuts react even to the intraday volatility and in certain situations can change multiple times during the day. Thus, the CCP publicly commits to react to a variety of events that can be completely ignored by OTC repo market participants. Unlike CCP margins, OTC haircuts are determined not only by security-specific features but also by the characteristics and preferences of the traders, both borrowers and lenders. From the point of view of OTC traders, a change in the CCP haircut that is not associated with an equivalent movement in the OTC haircut is an overreaction to the security-specific news by the CCP. In what follows, I use the CCP-OTC difference in haircuts to identify the changes in the relative attractiveness of the OTC market.

The CCP-OTC haircut difference for collateral s and month m is

$$hctdiff_{s,m} = haircut\_CCP_{s,m} - haircut\_OTC_{s,m}.$$

[26]My analysis does not require the CCP haircut to be higher than the OTC haircut. The key assumption is sensitivity of the marginal trader to changes in CCP haircuts (or, equivalently, to the changes in haircut differences between the two markets).

The main specification identifies the effect of the haircut difference on the difference in the credit risk at the collateral-month level, as follows:

$$Cr\_risk\_diff_{s,m} = \beta_1 * hctdiff_{s,m} + \delta_s + \mu_m + \epsilon_{i,m}, \tag{3}$$

where $Cr\_risk\_diff \triangleq Cr\_risk_{CCP} - Cr\_risk_{OTC}$, δ_s and μ_m are the security s and month m fixed effects.

To estimate equation (3), one needs to properly aggregate the deal-level data. I focus on short-term repo (i.e., less than three calendar days), which comprises most of the sample, to abstract from the effect of the deal tenor on haircuts and on the composition of traders. I start by averaging haircuts and credit risk at the security-month level. I add the collateral-month $\{s, m\}$ to the sample if security s is traded on both markets in month m. To calculate the average haircut in the OTC market, I use all repo deals traded in the OTC market, including those where a borrower or a lender is a non-bank. I demand that there are at least five different borrowers who pledge security s in month m in the OTC market.[27] This approach allows me to obtain more stable proxies for average haircuts in the market where all participants have their own methodologies. By contrast, in the CCP market the haircut parameters are security-specific; therefore, I take average haircuts from the CCP LOB market segment without any requirements. Since, as before, I build the tests on the interbank repo market, I require at least two banks to borrow against security s in month m to calculate the average credit risk in each market at the $\{s, m\}$ level. Table 3 shows the summary statistics.

Suppose that the CCP haircut rises while the OTC margin stays the same, leading to an increase in $hctdiff$. If the selection story is correct, safe borrowers start to migrate from the CCP to the OTC repo market, increasing the average CCP borrower's risk; that is, $Credit\_risk\_diff$ goes up. Thus, according to Hypothesis 3, one would expect a positive β_1 in (3). The results presented in Table 4 confirm this intuition: changes in the haircut difference between the two markets are associated with a widening of the credit risk gap

[27] The main results are robust to relaxing this requirement.

Dep. Var.	Cr_risk_diff	Cr_risk_diff	Cr_risk_diff	Cr_risk_diff
hctdiff	0.050**			
	(2.447)			
haircut_CCP		0.118***	0.089***	
		(2.949)	(2.642)	
haircut_OTC		-0.003		0.009
		(-0.141)		(0.456)
Security fe	✓	✓	✓	✓
Month fe	✓	✓	✓	✓
Num Obs	1106	1106	1525	1124
R^2	0.0124	0.0330	0.0216	0.0003

Table 4: The sensitivity of the CCP-OTC credit risk difference to the difference in haircuts. Standard errors are clustered at the security level. T-statistics are in parentheses.

between the markets. Columns 2–4 show that the effect indeed comes from the CCP haircut changes rather than the variation in the OTC haircut.

Although Table 4 demonstrates that the haircut difference affects the selection between the markets, the results say little about whether the effect comes from the changes in the credit market risk in the CCP market. It is possible that this outcome is driven mainly by the fluctuations in illiquid segments of the OTC repo market, while the average CCP borrower's quality remains unaltered. To check this hypothesis, I regress the average credit risk in the CCP and OTC repo markets separately on the average haircuts in both markets. The results in Table 5 show that the effect indeed comes from both markets. In line with Hypothesis **??**, estimates in Column 1 show that when controlling for the OTC haircut, a higher CCP haircut increases the credit risk in the CCP market.

Opposite signs of coefficients in Columns 1 and 2 show that CCP haircut changes have opposite effects on the CCP and the OTC markets. This finding goes against the alternative explanation of the effect, suggesting that safe borrowers get rid of risky securities.[28] As expected, most of the effect of the CCP haircut is going through the credit risk of the

[28]If the CCP credit risk increases because borrowers with different level of risk rebalance their portfolios in opposite directions (i.e, safe borrowers sell risky securities), one would expect to see the same effect in both repo markets.

Dep. Var.	Cr_risk_CCP	Cr_risk_OTC	Cr_risk_diff	Cr_risk_CCP	Cr_risk_OTC
haircut_CCP	0.067**	-0.040**	0.118***		
	(2.116)	(-2.089)	(2.949)		
haircut_OTC	-0.021	-0.014	-0.003		
	(-1.237)	(-1.292)	(-0.141)		
hctdiff				0.039**	-0.007
				(2.245)	(-0.992)
Security fe	✓	✓	✓	✓	✓
Month fe	✓	✓	✓	✓	✓
Num Obs	1122	1727	1106	1122	1727
$\mathbf{R^2}$	0.0158	0.0177	0.0330	0.0110	0.0010

Table 5: The sensitivity of the average credit risk in the OTC repo market and in the CCP repo market to changes in average haircuts. Standard errors are clustered at the security level. T-statistics are in parentheses.

average CCP borrower. I further support this claim in Columns 4 and 5: Comparing the amplitudes of the coefficients of $hctdiff$, one can see that the difference in haircuts affects the CCP repo market more than the OTC market.

The economic effect of the haircut difference in the baseline specification (Column 1 of Table 4) is relatively modest: A difference in haircuts of about 20 p.p. is needed to move the average ratings of the CCP and the OTC repo markets apart by 1 point. This may be due to two factors. First of all, NCC is an optimizing agent that is interested in a high turnover in the repo market. Being bound to react to price changes, it uses the flexibility options in its methodology not to keep the haircut unjustifiably high for a long time. Second, OTC haircuts are affected by multiple factors including the counterparties' preferences, which are not necessarily related to security-specific events. The idiosyncratic changes in the OTC haircut may introduce an attenuation bias in the results, similar to the measurement error in an exogenous variable.

To identify the effect caused by the variation of CCP haircuts, I need to isolate the variation in the haircut differences caused by the change in the CCP haircut. Suppose that the OTC haircut consists of two parts: the component that is also captured in the CCP

methodology and the idiosyncratic noise. If

$$haircut\_OTCs, m = \rho \times haircut\_CCP_{s,m} + \epsilon_{s,m},$$

then the difference in haircuts is

$$hctdiff_{s,m} = (1 - \rho) \times haircut\_CCP_{s,m} + \epsilon_{s,m}. \tag{4}$$

While the coefficient in equation (4) depends on the correlation between the haircuts in the two markets, a projection of $hctdiff$ on $haircut_{CCP}$ identifies the change in the haircut difference induced solely by the CCP component.

Following this logic, I employ a two-step least squares (2SLS) procedure, where I first regress $hctdiff$ on the CCP haircut as in (4) and further use the estimated values in (3). The results are presented in Table 6. Column 1 shows a correlation between the CCP and OTC haircuts of roughly 43% in the collateral-month panel. Columns 2–4 display the second-stage results, for the credit risk in each market as well as for the credit risk difference. According to Column 4, when the change in the haircuts is a result of the CCP haircut variation, the credit rating is more sensitive: A 5 p.p. change in the haircut difference moves the average credit risk difference between the markets by 1 point. This effect comes from both markets, as shown by the coefficients in Columns 2 and 3.

Another potential problem is that in concentrated markets, results may be actions of one big borrower (or a group of large borrowers). During the sample period, the Russian banking system is indeed highly concentrated, with the two largest banks having in total 60% more assets than the sum of the assets of the remaining eight banks in the national top-10.[29] To check the robustness of the results, I delete the deals made by the two most common borrowers (by the number of trades) and redo the tests.

[29]The agreement with the data provider do not allow me to study network properties of the deals in the sample.

Stage	(1)	(2)		
Dep. Var.	hctdiff	Cr_risk_CCP	Cr_risk_OTC	Cr_risk_diff
haircut_CCP	0.570***			
	(34.36)			
hctdiff_fitted		0.113**	-0.074**	0.207***
		(1.995)	(-2.095)	(-2.902)
Security fe		✓	✓	✓
Month fe		✓	✓	✓
Num Obs	1794	1122	1727	1106
R^2	0.3872	0.0140	0.0148	0.0330

Table 6: 2SLS results: The sensitivity of the average credit risk in the OTC repo market and in the CCP repo market to changes in average haircuts difference. Standard errors for the second stage are clustered at the security level. T-statistics are in parentheses.

Table 7 shows that the results are not due to the concentration. If anything, a deletion of the two most common borrowers made the results stronger, increasing both the economic and the statistical significance. These results indicate that the behavior of large borrowers may be affected by other factors, introducing noise in the estimates in Table 5. Their exclusion decreased the sample by almost 20% but highly increased both the values and the significance of the estimates. This observation is in line with large borrowers being less collateral constrained and therefore less sensitive to the haircut variation.[30]

Finally, the results may be potentially contaminated by the simultaneity bias. Since the haircuts in the OTC market are borrower-specific, the change in the OTC haircut may itself be a result of the borrowers' migration. Then, the right-hand side variable in equation 3 is affected by the same selection as the endogenous variable. To alleviate this problem, first, in the baseline specification, I use a security-month (s, t) only if the security s is pledged by at least five different borrowers at month t. This allows me to derive the effect from the most liquid securities, which are less affected by the preferences of individual borrowers. Second, to make a robustness check, I limit the sample for calculating the OTC haircuts. I include

[30]I introduce and discuss the notion of collateral constraint in greater detail in the following section.

Dep. Var.	Cr_risk_diff	Cr_risk_diff	Cr_risk_diff	Cr_risk_diff	Cr_risk_CCP	Cr_risk_OTC
haircut_CCP		0.243***	0.150***		0.174***	-0.048**
		(5.959)	(3.413)		(5.568)	(-2.489)
haircut_OTC		-0.009		0.004	-0.029	-0.006
		(-0.427)		(0.140)	(-1.610)	(-0.641)
hctdiff	0.106***					
	(4.000)					
Security fe	✓	✓	✓	✓	✓	✓
Month fe	✓	✓	✓	✓	✓	✓
Num Obs	903	903	1230	916	927	1625
R^2	0.0418	0.0997	0.0504	0.00001	0.0773	0.0205

Table 7: The sensitivity of the average credit risk in the OTC repo market and in the CCP repo market to changes in average haircuts after deleting two most common borrowers. Standard errors are clustered at the security level. T-statistics are in parentheses.

only those borrowers who did not pledge this security in the CCP market this month, the previous month, or the following month. Although imperfect, this measure is designed to limit the effect of the "switchers" on the OTC haircut. An apparent drawback of this filter is that it decreases the sample of security-months that fit the requirements. Tables 8 and 9 repeat Tables 4 and 5 for the altered sample.

As expected, a considerable drop of the sample size is followed by a decrease in statistical significance. However, the main results still hold. Therefore, the effect of the "switchers" on the OTC haircuts is unlikely to be the main driver of the results.

5 The role of borrowers' funding constraints

The selection effect documented above is brought to life by three assumptions. First, lenders' risk preferences matter: Risk-averse lenders prefer to trade with safer traders over-the-counter. Second, the CCP's methodology matters: The CCP sets security-specific haircuts, ignoring the borrowers' risk (at least in the short run), which incentivises borrowers to seek alternative markets. Third, borrowers' collateral constraints matter: Borrowers react to the changes in the CCP's haircuts because pledging additional collateral is costly.

Dep. Var.	Cr_risk_diff	Cr_risk_diff	Cr_risk_diff	Cr_risk_diff
hctdiff	0.060**			
	(2.168)			
haircut_CCP		0.101**	0.089***	
		(2.070)	(2.624)	
haircut_OTC		-0.033		-0.022
		(-1.028)		(-0.637)
Security fe	✓	✓	✓	✓
Month fe	✓	✓	✓	✓
Num Obs	795	795	1525	807
R^2	0.0161	0.0227	0.0216	0.0014

Table 8: The sensitivity of the CCP-OTC ratings difference to the difference in haircuts. OTC haircuts for collateral-month (s, t) are calculated by using only the borrowers who did not borrow against security s in the CCP market in months $t-1, t, t+1$. Standard errors are clustered at the security level. T-statistics are in parentheses.

In this section I show that the borrower's actions in the repo market are limited by her funding constraint and find an empirical proxy for its tightness. First, I show that when the funding constraint binds, the borrower has a strong preference for a lower haircut. Second, I show that a binding funding constraint makes the borrower more sensitive to the haircut difference between the OTC and the CCP markets.

5.1 Funding constraints and collateral constraints

Although theoretically the haircut and the repo rate may be partially interchangeable (Geanakoplos (2016) and Chebotarev (2020)), they play different roles in repo. While the repo rate represents the price of the loan, the haircut is a key part of the borrower's funding constraint (Brunnermeier and Pedersen (2008)); the higher the haircut, the less money one can attract against the same portfolio of securities. Of course, in the presence of unencumbered collateral, the funding constraint is not binding, as the borrower can increase the debt by pledging additional securities.[31] Therefore, when the constraint is slack, the borrower should be less

[31] This statement is true when the costs of pledging additional collateral in repo are sufficiently small.

Dep. Var.	Cr_risk_CCP	Cr_risk_OTC	Cr_risk_diff	Cr_risk_CCP	Cr_risk_OTC
haircut_CCP	0.058	-0.039**	0.101**		
	(1.467)	(-2.337)	(2.070)		
haircut_OTC	-0.033	-0.002	-0.033		
	(-1.145)	(-0.175)	(-1.028)		
hctdiff				0.043*	-0.017*
				(1.736)	(-1.795)
Security fe	✓	✓	✓	✓	✓
Month fe	✓	✓	✓	✓	✓
Num Obs	801	1273	795	801	1273
R^2	0.0124	0.0136	0.0227	0.0106	0.0044

Table 9: The sensitivity of the average credit risk in the OTC repo market and in the CCP repo market to changes in average haircuts. OTC haircuts for collateral-month (s, t) are calculated by using only the borrowers who did not borrow against security c in the CCP market in months $t-1, t, t+1$. Standard errors are clustered at the security level. T-statistics are in parentheses.

sensitive to the haircut growth.

I use the percentage of pledged securities (stocks and bonds) on the borrower's balance sheet as a proxy for the collateral constraint. A bank typically keeps a portfolio of securities for investment purposes and liquidity management and due to regulatory requirements. In order to cover some current liabilities, or to quickly increase investment in a particular asset, the bank can either sell or pledge a part of this portfolio. I denote the proportion of bank's securities pledged in repo as *col_con*; it is measured at the monthly level and varies from 0 to 1. Assume that $col\_con > 0$. If the borrower urgently needs liquidity, she may decide either to sell or to pledge some part of her unencumbered securities, driving *col_con* up.[32] The higher the *col_con* is, the more constrained the borrower is, which makes her more willing to avoid haircut increases.

Column 2 of Table 10 shows that, as expected, a higher *col_con* is associated with a lower haircut, controlling for the borrower's fixed effects, security-time fixed effects and

[32]I do not address the choice between selling and pledging securities in repo; for a discussion about this trade-off see Parlatore (2019). For a repo borrower, both selling and pledging collateral increases *col_con*.

Dep.Variable	**repo rate**	**haircut**	**repo rate**	**haircut**
col_con	0.224	-5.111***		
	(0.255)	(-2.747)		
col_con $\in [0.25, 0.5]$			-0.984*	-1.610**
			(-1.940)	(-2.122)
col_con $\in [0.5, 0.75]$			-0.627	-3.378***
			(-1.337)	(-3.174)
col_con $\in [0.75, 1]$			1.025*	-5.965***
			(1.729)	(-3.341)
Controls	✓	✓	✓	✓
Borrower fe	✓	✓	✓	✓
Col x month fe	✓	✓	✓	✓
Num Obs	707117	707117	707117	707117
$\mathbf{R^2}$	0.2470	0.0570	0.2494	0.0702

Table 10: The effect of collateral constraints on haircuts and repo rates. The controls include the logarithms of borrower's and lender's size, capital adequacy ratio, logarithms of short-term and middle-term liquidity ratios, the logarithm of borrower's volume of interbank funding, borrower's collateral constraint level, and deal-level controls (repo term, logarithm of loan size). The standard errors are double-clustered at the security and borrower level. T-statistics are in parentheses.

various borrower-, lender-, and deal-level controls. This result is both statistically and economically significant: A fully constrained borrower receives a 5 p.p. lower haircut than a fully unconstrained peer. While one may expect a certain interchangeability between the haircut and the rate, the result of changes in *col_con* on the repo rate is not monotonic. Columns 3 and 4 of Table 10 show that, while the borrower's haircut monotonically decreases in her degree of collateral constraint, the repo rate starts to increase only from the second quartile of collateral constraint. One potential explanation may be the unwillingness of unconstrained borrowers to use their bargaining power in negotiations with lenders.[33]

[33]This may be especially true if those negotiations involve a threat of changing the lender.

5.2 Haircuts, funding constraints, and the repo market choice

The flexible nature of the OTC market allows borrowers with different proportion of unencumbered collateral to tailor the repo contract to their needs. This option is absent in the CCP repo market, which may potentially influence the borrower's choice of where to attract funding. The haircuts in the CCP market are set for all borrowers simultaneously, while in the OTC market both parameters are negotiable. Meanwhile, as shown in Section 4, an increase in the CCP haircut (relative to the OTC haircut) induces the safest CCP borrowers to switch to the OTC market. Given the results in Table 10, one would expect this effect to be more pronounced for collateral constrained borrowers, as they are more sensitive to the haircut increases. This leads to the following hypothesis:

***Hypothesis* 4.** *Collateral-constrained borrowers are more sensitive to changes in haircuts than their unconstrained peers.*

According to Hypothesis 4, among safe borrowers, who are capable of switching between the two markets, collateral-constraint banks are most sensitive to changes in haircuts.

To test this, as in Section 4, I limit the analysis to the securities that were used in both markets in a particular month and focus on short-term deals (with the maturity shorter than three days). I use the dummies *constr* ($col\_con > 0.66$), *unconstr* ($col\_con < 0.33$), and *midconstr* ($0.66 > col\_con > 0.33$) to separate the borrowers into categories by their degree of collateral constraint. I also split the borrowers into terciles by the credit risk as in Table 10 and define the dummy $safe$ as the indicator that the borrower belongs to the lowest credit risk tercile. In a regression of the OTC indicator on the interaction of "safe" and "constrained" dummies, controls, and on the borrower, security, and month fixed effects, one would expect the safe-constrained group to be the most sensitive to changes in $hctdiff$.

The results are presented in Table 11. Column 1 shows that after controlling for the fixed effects, the collateral difference does not affect the probability that a deal is made in the OTC or the CCP market. Column 2 demonstrates the separate effects of dummies

Dep.Variable	**𝟙{OTC}**	**𝟙{OTC}**	**𝟙{OTC}**	**𝟙{OTC}**	**𝟙{OTC}**
hctdiff	-0.002			-0.001	0.001
	(-1.20)			(-0.79)	(0.42)
unconstr		-0.045			
		(-0.95)			
constr		0.089			
		(1.43)			
safe		0.155**			
		(2.03)			
constr_safe			0.262*	0.008	0.183
			(1.71)	(0.08)	(1.25)
midconstr_safe			0.187**		0.201**
			(2.16)		(2.13)
unconstr_safe			0.134**	0.040	0.146**
			(2.17)	(1.23)	(2.12)
hctdiff_constr_safe				0.018***	0.014**
				(2.78)	(2.54)
hctdiff_midconstr_safe					-0.004
					(-1.04)
hctdiff_unconstr_safe				-0.002	-0.003
				(-0.85)	(-1.44)
Controls	✓	✓	✓	✓	✓
Borrower fe	✓	✓	✓	✓	✓
Security fe	✓	✓	✓	✓	✓
Month fe	✓	✓	✓	✓	✓
Num Obs	531590	531590	531590	531590	531590
R^2	0.1679	0.1843	0.1843	0.1788	0.1896

Table 11: The effect of CCP-OTC haircut differences on the repo market choice on the deal level. The controls include the logarithms of borrower's and lender's size, capital adequacy ratio, logarithms of short-term and middle-term liquidity ratios, the logarithm of borrower's volume of interbank funding, borrower's collateral constraint level, and deal-level controls (repo term, logarithm of loan size). The standard errors are double-clustered at the security and borrower level. T-statistics are in parentheses.

"constrained", "unconstrained", and "safe" on repo market choice. When the same borrower gets into the top tercile of credit quality, she is 15.5% more likely to borrow in the OTC repo market, consistent with previous results. On the other hand, the coefficients of dummies "constrained" and "unconstrained" are statistically insignificant. I proceed by testing the

interactions between the groups "safe" and the dummies of different levels of collateral contraints. Column 3 shows that among the safest borrowers, most collateral constrained are the most likely to fund in the OTC repo market. This result is expected, since in our sample the CCP asks for higher haircuts than what is common in the OTC repo market. In Columns 4-5, I test which group is most sensitive to the changes in haircuts by including the interaction of group dummies with the haircut difference and find that among the safe borrowers, the most collateral constrained react stronger to the change in the difference in haircuts. Consistent with Hypothesis 4, this result shows that collateral constraints matter for the borrower's sensitivity to the changes in collateral requirements.

6 Discussion

Below I provide observations and thoughts about the implications of the findings.

6.1 Relevance to the regulatory debate

The selection effect documented in previous sections has practical importance for the understanding and the improvement of the stability of CCPs. The findings in this paper add to the regulatory debate, which currently suggests that CCPs should set conservative collateral requirements. Following the 2008 crisis, both theorists (i.e., Brunnermeier and Pedersen (2008), Geanakoplos (2010), and Gorton and Metrick (2012)) and regulators (i.e., BIS (2010a) and BIS (2012)) became concerned with procyclicality of haircuts, that is, the tendency of haircuts to tighten in crisis. As pointed out by Geanakoplos (2010), "leverage becomes too high in boom times and too low in bad times," causing what he calls "the leverage cycle." Regulators acknowledge that initial margins are inherently procyclical (ESBR (2017) and Gurrola-Perez (2020)) and that there is a trade-off between the procyclicality on the one hand and the risk-sensitivity of the margins on the other hand. Even when present, the overmargining concerns are never central to the discussion of the optimal collateral pol-

icy.[34] For example, Cominetta et al. (2019) discuss the perspectives of setting an upper limit on haircuts in order to reduce procyclicality but reject the idea due to its effect on prudency.

The results presented in this paper introduce an additional cost of conservative margins – endogenous selection of traders between the centrally cleared market and an alternative trading venue. Since excessive collateral requirements can affect the pool of traders, the minimal haircuts recommended by the regulators (BIS (2010b), Cominetta et al. (2019)) may have adverse effects. As demonstrated in the model in Appendix B, when the CCP haircut is already high, a further haircut increase may adversely affect the default probability of the CCP. To the best of my knowledge, this effect is overlooked by the existing regulatory and academic literature.

6.2 Relevance for other markets

The Russian repo market provides an opportunity to observe selection patterns in a repo market, where the CCP does not play a strong role in the counterparty selection. In the data, the borrowers in the CCP repo market are quite diverse, representing banks of different credit quality. In a market where the pool of clearing members is composed of homogeneous and low-risk traders, the selection effect is unlikely to reduce the credit quality of the average CCP trader. For example, since European CCPs have restrictively high membership requirements for repo clearing (Bank for International Settlements (BIS) (2019)), currently the haircut-driven selection effect in the European repo market is likely to be mild. On the other hand, if European CCPs change their admission policies in the future, selection may arise. One reason for such changes is provided by Eisenschmidt et al. (2020), who suggest that admission of OTC repo traders to the centrally cleared repo may increase the monetary policy pass-through.

Although the data that I study comes from the repo market, the effect that I find appears to be more general and may be present in other centrally cleared markets, where the CCP

[34] Exceptionally, some authors point out the need to keep centralized clearing economical (Gurrola-Perez (2020)).

admits risky participants. One may expect the selection on margins to be less salient in markets where centralized clearing is mandated, for example, in the market for standardized derivatives. One may expect the selection on margins to be less salient in the case of standardized derivatives, since in many countries their centralized clearing is mandatory.[35] However, centrally cleared financial instruments often have synthetic substitutes which the market participants will resort to if the clearing costs get excessively high. For example, traders may adjust parameters of a derivative contract to represent it as a "non-standardized" derivative (Financial Stability Board (FSB) (2017)). Ghamami and Glasserman (2017) argue that in the absence of cost advantages, participants may find different ways to circumvent the clearing mandate by coming up with a non-standardized but economically similar contract. A relevant example is described by Ungaro (2018). Studying the introduction of a CCP in the French repo market in 1898, he shows that to support relatively more expensive centrally cleared trading, the fiscal administration made central clearing mandatory for trades with all listed securities. Being a hard blow to the OTC repo trading, this measure boosted a different market: Deposit banks started to grant advances on securities to their clients — an operation economically similar to (but legally different from) repo.

Importantly, different collateral requirements across markets affect the trader's venue choice as a part of the total trading costs in each market. On top of pledging collateral, CCP clearing members have to contribute to the guarantee fund and to provide additional reporting. Additionally, the CCP can have a more restrictive list of eligible collateral as compared to the OTC, where the collateral type can be negotiated. Thus, even if the regulator sets the OTC collateral requirements higher than in the CCP market, as long as there are agents trading in both markets, one can expect the change in the CCP's haircuts to influence the actions of the marginal trader.[36]

[35]Most notable examples of such regulation include the Dodd–Frank Wall Street Reform and Consumer Protection Act in the United States and the European Market Infrastructure Regulation in Europe.

[36]Onur et al. (2021) study the effect of the Uncleared Margin Rule on clearing incentives. The Rule substantially increases centralized clearing of treated assets, but mainly by affecting the actions of large (and less collateral-constrained) entities.

Apart from the difference in the overall trading costs across the markets, the selection effect is brought to life by the institutional difference between the CCP market and the traders' outside option. For example, in an economy where OTC repo lenders have no strong preference for trading with safer counterparties, one would not expect a CCP haircut increase to influence the quality of the average borrower. Similarly, consider the role of collateral constraints: The results of this paper suggest that the selection effect is stronger in times when the best-quality borrowers are most collateral-constrained. The characteristics of the substitute market are, therefore, crucial for understanding the direction and strength of the selection effect.

The case of the MOEX NCC repo provides a convenient setting to study selection because the substitute market is easy to detect: The OTC repo is an apparent candidate in the absence of other (competing) CCPs in Russia. In environments where several CCPs are competing for clients, more complex strategic interactions can arise, complicating the identification. For example, Glasserman et al. (2016) show that the interplay between the haircut policies of different CCPs can lead to a "race to the bottom," when the CCP with the lowest margin drives the competitors out of the market.[37] Empirically, Park and Abruzzo (2016) demonstrate that ICE and CME indeed set futures margins taking into account each other's policies. By contrast, MOEX NCC by publishing its haircut methodology on the official web page committed to react only to security-induced shocks. Although NCC cannot ignore the apparent competition with the OTC market, this step limits its flexibility in reacting to the changes in OTC margins.

6.3 Possible solutions to the selection problem

The findings of this paper crucially depend on two institutional characteristics. First, the entry to both markets is sufficiently simple: Neither CCP nor OTC repo markets in the data

[37] See Krahnen and Pelizzon (2016) for a discussion of "predatory" margining.

have strict eligibility criteria.[38] Second, when setting haircuts, the CCP does not directly take the borrowers' credit risk into account, which allows OTC lenders to cream-skim the best borrowers. Below I focus on each of these two institutional properties and discuss the ways to mitigate the problem of haircut-driven selection in the CCP market. As the mechanism behind the findings in this paper is reminiscent of the adverse selection and cream-skimming in the insurance market, I use examples from the insurance literature to motivate the potential solutions.

First, when individuals are given the flexibility to choose whether to get insured (or which level of coverage to choose), adverse selection may arise. For example, Hackmann et al. (2015) show that the Massachusetts health reform of 2006, which increased the costs of being uninsured, reduced the adverse selection in the insurance market as healthier individuals purchased an insurance. This example suggests that to support the market under adverse selection, the regulator can (and already do) provide additional incentives for low-risk agents to join the pool. For example, to decrease the collateral advantage of the OTC market, regulators introduced the Uncleared Margin Rule, a regulation meant to set the minimal collateral requirement level for OTC market operations (Onur et al. (2021))[39]

In the context of repo, a regulator wishing to support the CCP can create a stimulus by providing additional benefits to those who choose the CCP repo. In line with this idea, the Central Bank of Russia allows for using lower risk-weights for centrally cleared deals when calculating the capital adequacy ratio. Although this measure does not solve the section problem completely, it is likely to attenuate it. Alternatively, the regulators may choose to increase the cost of OTC trading, for example, by implementing standards for OTC collateral requirements. These observations are in line with recent regulatory incentives. According to FSB (2017), the introduction of higher capital charges and margin requirements for non-centrally cleared derivatives, initially intended to mitigate systemic risk, provided incentives

[38]The MOEX CCP has eligibility criteria, but these are not restrictive for the majority of banks. Similarly, the OTC market does not have any formal criteria to be admitted.

[39]The Uncleared Margin Rules are enforced, among other countries, in the United States, the European Union, the United Kingdom, and Canada.

for market participants to move to centralized clearing even for the instruments that were not subjects to the clearing mandate. Pushing the OTC trading costs to the limit, the regulators can simply restrict the trading of particular contract types without the CCP (as is done in the case of the standardized derivatives). However, as discussed above, without cost advantage of centralized clearing, this policy may result in traders switching to economically equivalent but legally different contracts.

Second, the difference in information sets between the insurers may lead to cream-skimming. Cather (2018) describes several examples of the selection caused by some insurers having additional variables that they could condition on. Similar to OTC repo lenders, the insurers, who had access to a larger set of meaningful insurance buyers' characteristics, managed to cream-skim the best agents from their competitors. Naturally, the solution to cream-skimming lies in letting all agents to condition contracts on all (observable) counterparty characteristics.[40] Indeed, since in the insurance market the difference in information sets is not institutionalized, with time, the entire market adopts the new information source.

In the case of repo, equalizing the set of contractable variables between the CCP and OTC markets means enabling the CCP to design borrower-specific haircuts. This measure could potentially attenuate the borrowers' selection. In principle, replacing the single haircut for all CCP repo with a set of borrower-specific haircuts could give the CCP unprecedented flexibility in explicitly shaping the set of borrowers. A perfectly informed CCP could potentially design such an increase in individual haircuts that would affect all market participants equally and thus will not induce selection. However, this idea may be very hard to design and implement as the traders' sensitivities to haircut changes are unobservable and hard to measure. While a complicated rule seems infeasible, a simpler ad hoc approach, making haircuts dependent (e.g., linearly) on the participant's credit quality, is unlikely to fix the problem completely. Moreover, such measures may amplify the procyclicality of haircuts (Domanski et al. (2015) and Gurrola-Perez (2020)). Intuitively, if when a bank becomes

[40] A similar point is made by Cutler and Reber (1998).

riskier it has to pledge more collateral, this can further worsen its state. This problem may aggravate in crisis, when multiple borrowers may simultaneously get riskier, triggering a simultaneous increase in individual haircuts for a category of borrowers. This concern often stops regulators from promoting trader-specific collateral requirements.

Note that I keep the questions of the welfare effect of the counterparty selection and the optimal haircut policy out of the scope of this paper, leaving it to further studies.

7 Conclusion

I study how CCP repo haircuts influence the selection of counterparties across the CCP and the OTC repo markets. To the best of my knowledge, this is the first study to empirically explore the effect of CCP's collateral requirements on the traders' venue choice. I find that a change in haircuts can affect the borrowers' decision whether to borrow in the CCP or the OTC repo market, altering the credit risk of the pool of CCP traders at the extensive margin. Since mutualization of risks through the guarantee fund is one of the main components of the CCP risk management system, an outflow of best clients may undermine its stability.

First, I show that traders with higher credit ratings are more likely to borrow in the OTC repo market. Further evidence suggests that this dependence is rooted in the lenders' risk preferences. Second, I show that a change in the difference of haircuts between the CCP and the OTC repo markets drives the selection of participants across these markets. This effect comes mostly from the changes in CCP haircuts: A growth in the CCP haircut that is not accompanied by the OTC haircut change leads to an increase (fall) in the credit quality of borrowers in the OTC (CCP) repo market. Finally, I find that this relation is stronger for collateral-constrained borrowers, who are more sensitive to the variation in haircuts.

The findings in this paper contradict the common view considering conservatively high haircuts as unconditionally improving the CCP resilience, and introduce another dimension to the problem of designing the optimal collateral requirements for CCPs. I show that when

increases in haircuts induce selection from the centrally cleared market, the exact selection pattern depends on the properties of both the centrally cleared market and the market that receives the "switching" traders. Particularly, due to the risk preferences of OTC lenders, the best CCP borrowers are capable of moving to the OTC market when CCP haircuts increase. These results add to the regulatory debate on the optimal design of the CCP risk management system.

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Appendix A

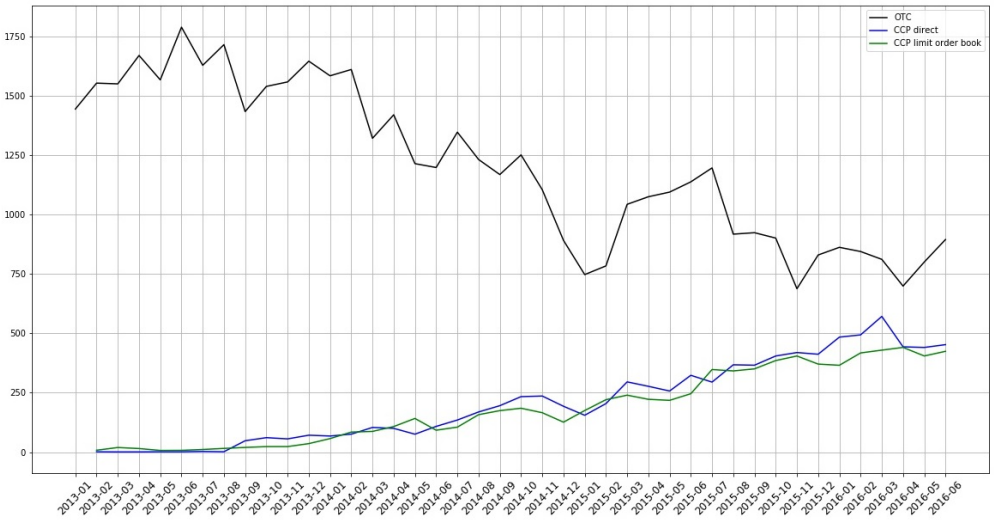

Figure A-1: The average daily number of repo deals in the OTC and the CCP repo market, by segments (daily numbers are averaged at the month level).

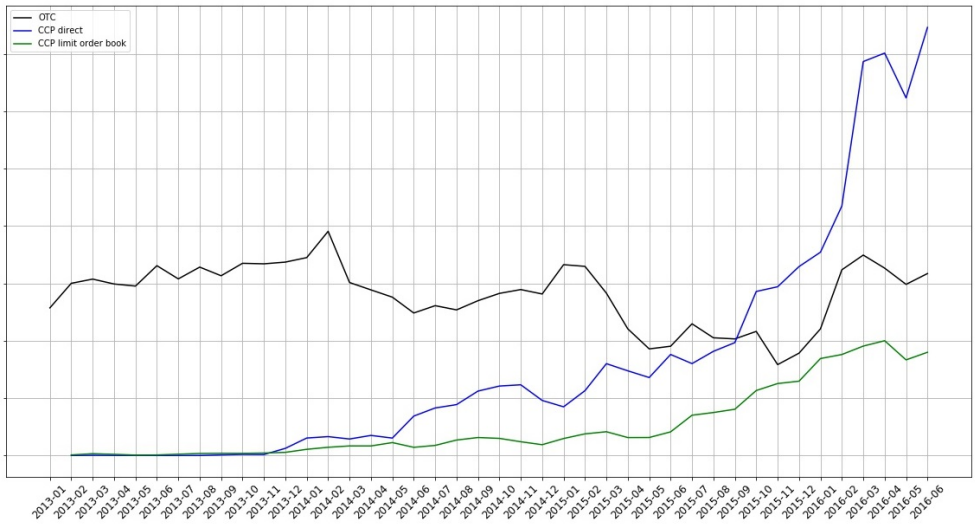

Figure A-2: The average daily open interest in the OTC and the CCP repo market, by segments (daily numbers are averaged at the month level), in bln. rub.

	OTC			Bilateral CCP			Exchange traded CCP		
	mean	std	median	mean	std	median	mean	std	median
haircut, %	4.65	6.85	2.00	8.21	6.18	8.00	10.37	4.54	10.00
loan_size, bln. rub.	0.0582	0.1635	0.0014	0.3337	0.8763	0.1909	0.1369	0.3108	0.0694
repo rate, %	13.00	4.71	15.00	11.59	2.57	11.30	10.76	2.34	11.00
repo_term, days	2.04	3.65	1.00	1.37	1.17	1.00	1.10	0.62	1.00
lend_assets, bln.rub.	2 190.04	2 227.86	1 207.21	2 969.78	6 120.38	457.98	690.74	2 526.62	97.28
lend_n1, %	12.69	4.04	11.93	16.20	13.24	12.64	21.01	19.76	14.21
lend_n2, %	66.26	47.95	57.48	124.90	127.94	89.91	177.12	546.02	100.06
lend_n3, %	115.61	51.73	96.14	172.02	154.21	141.11	223.36	483.14	145.03
rating_age, years	0.27	0.25	0.20	0.26	0.21	0.21	0.28	0.24	0.21
credit_risk, points	4.33	1.93	4.00	6.73	1.45	7.00	6.72	1.90	7.00
borr_assets, bln.rub.	3 203.87	4 151.42	3 188.73	1 321.51	3 017.36	299.91	519.74	1 808.28	54.58
borr_n1, %	13.02	4.82	12.07	14.23	6.62	12.87	17.02	10.21	13.26
borr_n2, %	69.46	49.23	59.41	92.40	75.64	76.82	91.53	101.19	68.50
borr_n3, %	118.90	67.88	95.71	122.58	83.42	104.22	142.43	115.41	115.48
borr_col_con	0.21	0.24	0.11	0.44	0.29	0.42	0.46	0.29	0.46
borr_ibc	171.36	150.01	213.23	131.33	292.52	25.85	44.53	139.48	2.61
stock_dummy	0.66	0.47	1.00	0.31	0.46	0	0.24	0.43	0
sample size	1,043,333			179,680			162,017		

Table A-1: Summary statistics of the interbank repo deals. For the variables' definitions, see Table A-2.

Notation	Variable	Source
haircut	haircut calculated as in Definition (1)	MOEX
loan_size	amount of the loan	MOEX
repo rate	repo rate	MOEX
repo_term	repo deal's tenor	MOEX
lend_assets	lender's total assets	Central Bank of Russia
lend_n1	lender's capital adequacy ratio	Central Bank of Russia
lend_n2	lender's short-term liquidity ratio	Central Bank of Russia
lend_n3	lender's middle-term liquidity ratio	Central Bank of Russia
cred_risk	credit risk metric derived from Moody's, S&P, and Fitch credit rating (see TableA-3)	bankodrom.ru
rating_age	time since the most recent credit rating by Moody's, S&P, or Fitch was issued	bankodrom.ru
borr_assets	borrower's total assets	Central Bank of Russia
borr_n1	borrower's capital adequacy ratio	Central Bank of Russia
borr_n2	borrower's short-term liquidity ratio	Central Bank of Russia
borr_n3	borrower's middle-term liquidity ratio	Central Bank of Russia
borr_col_con	borrower's collateral constraints measure (ratio of securities transferred without interruption of acknowledgement on the balance sheet to total value of securities on the balance sheet)	Central Bank of Russia
borr_ibc	borrower's total amount of acquired interbank credit	Central Bank of Russia
stock_dummy	$\mathbb{1}\{security = stock\}$	MOEX

Table A-2: Variables' definition.

Moody's rating	*credit_risk*
Baa1	1
Baa2	2
Baa3	3
Ba1	4
Ba2	5
Ba3	6
B1	7
B2	8
B3	9
Caa1	10
Caa2	11
Caa3	12
Ca	13

Table A-3: Credit risk score.

Appendix B: Model

In this section, I present a model in which the OTC and the CCP repo markets coexist. The purpose of the model is twofold. First, it provides a formal illustration of the mechanism of selection between the markets. Second, it gives a numerical example, which shows that, for certain combinations of parameters in the model, an increase in the CCP haircut can lead to a higher CCP default probability due to the endogenous selection effect.

B-1 Outline

Consider a two-period model ($t = \{0, 1\}$) with an economy populated by a measure one continuum I of risk-neutral entrepreneurs and one risk-neutral competitive lender.[41] Each entrepreneur has a binomial constant return to scale investment opportunity (pairwise-independent), which pays back $(1 + \rho)$ per dollar invested with probability $(1 - P_i)$ for every $i \in I$ and nothing with probability P_i. The entrepreneur's probability of failure P_i is a draw from a uniform distribution on $[P_{min}, P_{max}]$.

Each entrepreneur has a limited budget of size m, which can be used either for investment or as cash collateral, and possesses one unit of a pledgeable asset, which is worth 1 at time 0 and pays back R at $t = 1$. R is distributed on $[R_{min}, R_{max}]$, with a continuously differentiable cdf $F(R)$. I assume that all borrowers possess units of the same asset and that they cannot sell it in the market at time $t = 0$.

Each entrepreneur can borrow money from a lender to finance his investment opportunity. The (debt) contract has to be arranged in one of the repo markets, either the OTC or the CCP repo market. In the OTC market, borrower i negotiates the terms of the deal (the money amount M_i to be obtained against one unit of the pledgeable asset and the repo rate r_i) with the lender directly, while in the CCP market the risk management parameters (i.e., the amount of collateral) is chosen by the CCP and applies uniformly to all participants.[42]

[41] I assume that there is only one lender for parsimony, since the number of lenders does not alter the result.

[42] Since in my model the entrepreneur pledges the entire asset holding, one can equivalently say that he

Particularly, the CCP chooses the amount M_c that every entrepreneur can borrow against one unit of the pledgeable asset, and the guarantee fund contribution g, which every borrower has to pledge to become a clearing member.[43] Similarly, the lender sets a uniform rate r_c for all borrowers in the CCP repo market. I assume, without loss of generality, that $g = m$, and that the CCP invests the guarantee fund at a rate r_f and passes over the proceeds to the borrowers.[44][45] In addition, I assume that borrowers in the CCP market benefit from the centralized clearing.[46] This clearing benefit is modeled as an additive component to the borrower's profit, proportional to the amount lent: $b \times M_i$.[47] The clearing benefit decreases the costs of pledging the sum m into the guarantee fund, which pays a lower interest rate than the borrower's project.[48] Alternatively, one can assume that the CCP pays a sufficiently higher interest rate on the guarantee fund, that is, sufficiently close to ρ.

The lender finances operations by borrowing from (unmodeled) depositors, who provide her with an infinitely elastic supply of funds at a rate r_f. The lender is competitive in the Bertrand fashion: Unless she receives a zero profit in equilibrium, a new entrant will appear in the market and offer a lower-profit contract.[49] Although the lender has access to an infinite amount of funding, I assume that the loan to an individual borrower is limited by some finite amount $\bar{M}$, which I set sufficiently high in order for it not to bind when the borrowing amount is finite.[50]

I assume, as in Heider et al. (2015), if the entrepreneur's project does not succeed, the liquidation costs will be high enough to wipe out the proceeds from the pledgeable assets as

negotiates the degree of overcollateralization and the repo rate.

[43] In practice, lenders also have to contribute to the guarantee fund. Since the size of this deposit does not depend on the number of borrowers the lender is trading with, in the model the lender's contribution is assumed away.

[44] The assumption about the guarantee fund contribution is relaxed later.

[45] Many CCPs pay interest on the guarantee fund to compensate at least partially the foregone profit.

[46] In practice, these benefits can come in the form of decreased collateral costs due to multilateral netting, lower capital charges, etc.

[47] Replacing the proportional clearing benefit with an additive benefit does not alter the results.

[48] Ghamami and Glasserman (2017) show that mandatory guarantee fund contribution is one of the main factors making CCP trade costly relative to OTC trade.

[49] The assumption about the lender's zero profit in equilibrium can be relaxed. See Section B-5 for a discussion.

[50] As long as the lender requires collateral from the borrower, the loan amount is finite.

well as from the initial money endowment. One can think of these liquidation costs as, for example, legal expenses or default costs. (For the lender, the default is an event when the borrower does not pay back the money, even if the collateral is sufficient to cover the loss.)[51] This assumption is used to ensure that the risk-neutral lender values collateral (she considers the entrepreneur's investment opportunity to have a negative NPV), while the entrepreneur is still willing to undertake his project.

As the lender is risk-neutral, her utility is separable by individual entrepreneurs in the OTC market, while the whole CCP market is treated as a single borrower. The lender's expected profit from trading with an OTC borrower is

$$U_{OTC}(r_i, M_i) = (1 - P_i) \times (1 + r_i)M_i + P_i \times \mathbb{E}[min(R, (1 + r_i)M_i)] - (1 + r_f)M_i. \quad \text{(B-1)}$$

Notice that the second component in equation (B-1) stands for the excess amount of collateral value (when positive) being transferred back to the borrower if he does not repay. According to the assumption, the borrower is unable to benefit from this sum due to the default costs. Therefore, borrower i's expected profit in the OTC market is

$$W_{OTC}(r_i, M_i) = (\rho - r_i)M_i + (1 + \rho)m + \mathbb{E}[R]. \quad \text{(B-2)}$$

When the lender trades in the CCP market, the CCP novates all deals and becomes the ultimate borrower to the lender. Denoting by ξ the fraction of failed entrepreneurs in the CCP market, one can write the lender's expected profit from lending through the CCP market as

$$U_{CCP}(r_C, M_C) = (1-\xi) \times (1+r_C)M_C + \mathbb{E}[min(R\xi + g(1+r_f), (1+r_C)M_C\xi)] - (1+r_f)M_C. \quad \text{(B-3)}$$

[51] Alternatively, one can consider an extremely overconfident borrower, who considers his own failure to be impossible (as in Chebotarev (2020)). Intuitively, if the borrower and the lender agree about the NPV of the borrower's project, then, if NPV> 0, collateral is unnecessary, and if NPV< 0 the borrower does not undertake the project.

Notice the difference between the second terms of equations (B-1) and (B-3). While in the OTC market only the individual collateral is used, the CCP requires two types of collateral. When proportion ξ of CCP borrowers default, the lender gets individual collateral only from the defaulters (hence $R\xi$) but can use up to the entire guarantee fund $g(1+r_f)$ to cover the shortfall $(1+r_C)M_C\xi$ of the amount due.

The risk-management parameters are set by the CCP, and the only variable that the lender can affect is the interest rate $\hat{r}$ subject to the participation constraint $U_{CCP}(r_C, M_C) \geq 0$, which holds as equality in equilibrium.

The entrepreneur's utility when borrowing in the centralized market is

$$W_{CCP}(r_C, M_C) = (\rho - r_C)M_C + (1+r_f)g + b \times M_C - \mathbb{E}\left[min\left\{g(1+r_f), \frac{\xi}{1-\xi} \times max\{(1+r_C)M_C - R - g(1+r_f), 0\}\right\}\right] + \mathbb{E}[R], \quad \text{(B-4)}$$

where the term under the expectation operator corresponds to the expected loss from the guarantee fund contribution. When a borrower defaults, first, his collateral gets liquidated. If the proceeds are not enough to cover the loss (i.e., the collateral price is low), then the defaulter's contribution to the guarantee fund is used. The uncovered part of the loss is spread further to the guarantee fund contributions of the solvent clearing members. Finally, if the entire guarantee fund is insufficient, the CCP defaults, and the loss is allocated to the lender.[52]

B-2 Preliminaries

The following definitions will simplify the forthcoming derivations. First, I define the haircut of the deal as a measure of collateral sufficiency.

[52] In the reality, the "default waterfall" of a typical CCP will also contain the CCP's capital, also referred to as the "skin in the game." It is usually separated into two tranches, the first being used before the guarantee fund contributions of the solvent clearing members, the second immediately after. In the model, the CCP capital is neglected as the smallest component of the CCP waterfall.

Definition 1. *The haircut h of the repo deal is the overcollateralization of the contract $(1-M)$ normalized by the amount of money borrowed: $h \triangleq 1/M - 1$.*[53]

Second, I introduce the comfort return.

Definition 2. *The comfort return is*

$$K \triangleq \frac{1+r}{1+h}.$$

K is the minimal value of the collateral return, such that if $R \geq K$, the lender does not suffer any loss when the borrower does not pay back, since the collateral is sufficient. Intuitively, the lender's payoff structure resembles the payoff of a short put option with the collateral value serving as an underlying asset. The lender benefits from an increase in the collateral value up to the strike K, but when $R \geq K$, she transfers the excess amount to the borrower.

Using definitions 1 and 2, one can rewrite equations (B-1)–(B-4) in the following way:

$$U_{OTC}(K_i, h_i) = K_i + P_i \times \mathbb{E}[min(R - K_i, 0)] - \frac{(1+r_f)}{(1+h_i)}. \tag{B-5}$$

$$W_{OTC}(K_i, h_i) = \frac{(1+\rho)}{(1+\hat{h})} - K_i + (1+\rho)m + \mathbb{E}[R]. \tag{B-6}$$

$$U_{CCP}(K_C, h_C) = K_C + \mathbb{E}[min(\xi(R - K_C) + g(1+r_f), 0)] - \frac{(1+r_f)}{(1+h_C)}. \tag{B-7}$$

$$W_{CCP}(K_C, h_C) = \frac{(1+\rho)+b}{(1+h_C)} - K_C + (1+r_f)g + \mathbb{E}\left[min\left\{g(1+r_f), \frac{\xi}{1-\xi} \times max\{K_C - R - g(1+r_f), 0\}\right\}\right] + \mathbb{E}[R]. \tag{B-8}$$

[53] In practice, this measure is usually called "margin," while a haircut is defined with normalization of $(1-M)$ by the collateral value at $t=0$. Note that the two metrics have a one-to-one correspondence, which allows to use the two terms interchangeably.

B-3 Equilibrium

Each entrepreneur decides where to trade comparing the utility from trading in the OTC and the CCP repo markets. Below, I first consider the individual equilibrium in the OTC market, followed by the equilibrium contract in the CCP market. Finally, I discuss the selection of borrowers between the two markets and define the overall equilibrium of the model.

B-3.1 Equilibrium in the OTC market

Each entrepreneur negotiates the haircut and the repo rate of his debt contract with the lender. Since the lender is risk-neutral, she faces each entrepreneur separately, independent of the rest. Furthermore, since the lender is competitive, she receives zero expected profit in equilibrium.[54] The lender's zero-profit indifference curve, that is, a set of all points in the $(1+r, 1+h)$ space that give her zero profit, represents the lender's participation constraint in the OTC market. In equilibrium, the individual OTC contract for a borrower i is defined as follows.

Definition 3. *The individual OTC repo market equilibrium contract is a combination of the repo rate and the haircut (r_i, h_i) such that the borrower's utility (B-6) is maximized subject to the lender's break-even condition $U_{OTC}(r_i, h_i) = 0$.*

Theorem 1. *If $(1+\rho) \times (1-P_i) > (1+r_f)$, the borrower's equilibrium OTC repo contract is $(r_f, 1/\bar{M} - 1)$. If $(1+\rho) \times (1-P_i) < (1+r_f)$, the borrower's OTC repo contract is determined by equations (B-9) and (B-10), as follows:*

$$1 + r_{eq} = (1+r_f) \times \left(1 + P_L \times \alpha \times \left[\frac{\mathbb{E}\left(R | R < F^{-1}(\alpha)\right)}{F^{-1}(\alpha)} - 1\right]\right)^{-1} \tag{B-9}$$

and

$$1 + h_{eq} = [F^{-1}(\alpha)]^{-1} \times (1+r_f) \times \left(1 + P_L \times \alpha \times \left[\frac{\mathbb{E}\left(R | R < F^{-1}(\alpha)\right)}{F^{-1}(\alpha)} - 1\right]\right)^{-1}, \tag{B-10}$$

[54] See Section B-5 for a discussion.

where

$$\alpha \triangleq \frac{(\rho - r_f)}{(1+\rho)P_i}. \tag{B-11}$$

Proof: Theorem 1 is a special case of Proposition 1 in Chebotarev (2020), where $P_L = P_i$ and $P_B = 0$. If $(1+\rho) \times (1-P_i) > (1+r_f)$, the lender does not need collateral and is willing to lend the entrepreneur the maximum amount ($\bar{M}$), at the funding rate r_f. Otherwise, an interior solution defined by equations (B-9)–(B-11) exists, where the lender requires collateral.

□

According to Theorem 1, if the entrepreneur's project has a positive NPV (from the lender's point of view), there is no need for collateral, and the lender is willing to lend as much as possible at the lowest rate. However, if the NPV is negative, to break even she requires collateral as insurance. Thus, in this model, only entrepreneurs with negative NPV will need collateral to finance their projects. This follows from the assumption of the lender's risk-neutrality; by contrast, a risk-averse lender may require collateral even for positive NPV projects.[55]

B-3.2 Equilibrium in the CCP market

Assume that some subset $J \subseteq I$ of entrepreneurs decides to borrow in the CCP market. In equilibrium, when ξ is the proportion of CCP borrowers whose projects have failed, and the haircut h_C and the guarantee fund contribution g are determined by the CCP, the lender chooses the interest rate, at which she is ready to lend to CCP borrowers.

Definition 4. *The CCP equilibrium repo rate r_C is a repo rate that satisfies the competitive lender's participation constraint ($U_{CCP} = 0$) conditional on a given set of entrepreneurs J in the CCP market, and the CCP's risk-management parameters (h_C, g).*

Equation (B-7) implicitly defines the equilibrium CCP repo rate r_C.

[55] Later, this assumption is discussed in greater detail.

B-3.3 Selection between repo markets

In definition 4, the subset J of borrowers who choose the CCP market is treated as exogenous. In reality, however, J is determined as a result of borrowers' market choice. Assume that each entrepreneur is admitted in each of the two repo markets but can only choose one market to trade in. Below I characterize J when $J \subset I$ and $J \neq \varnothing$.

The first observation is that the borrower's utility in the CCP market does not depend on his success probability since all CCP borrowers get the same contract. Lemma 1 describes the dependence of the borrower's utility on his probability of failure P_i.

Lemma 1. *For two borrowers $i, j \in I$ such that $P_i < P_j$, $W_{OTC}(r_i, h_i) > W_{OTC}(r_j, h_j)$.*

Proof: Consider the lender's zero profit indifference curves C_i and C_j for borrowers i and j. Since the borrower j is riskier, for the two contracts $(r_1, h_1) \in C_i$ and $(r_2, h_2) \in C_j$ such that $r_1 = r_2$ one can show that $h_i < h_j$. To see this, take the total differential the lender's indifference curve (B-12), holding the repo rate fixed ($r = \bar{r}$)

$$0 = \frac{(1+r)}{(1+h)} + P \times \mathbb{E}\left[min\left(R - \frac{(1+r)}{(1+h)}, 0\right)\right] - \frac{(1+r_f)}{(1+h)}, \tag{B-12}$$

to obtain

$$\frac{dh}{dP} = \frac{-\mathbb{E}\left[min\left(R - \frac{(1+\bar{r})}{(1+h)}, 0\right)\right]}{(1+r_f) - \left(1 - P \times F\left(\frac{1+\bar{r}}{1+h}\right)\right)(1+\bar{r})}.$$

Since the numerator is positive, the sign of dh/dP depends on the denominator. One can rewrite the lender's break-even condition from equation (B-5) to get

$$(1+r_f) - (1+\bar{r})(1 - P \times F(K)) = P \times F(K) \times \mathbb{E}[R|R < K](1+h) > 0.$$

Therefore, $\frac{dh}{dP} > 0$. This can be seen in Figure B-1: When trading with borrower j, the lender offers higher haircuts for the same rate than when trading with borrower i. Since both have the same return on the investment opportunity when successful, the two borrowers have the same set of indifference curves, straight lines rotating around the point $(1+\rho, 0)$. Since the

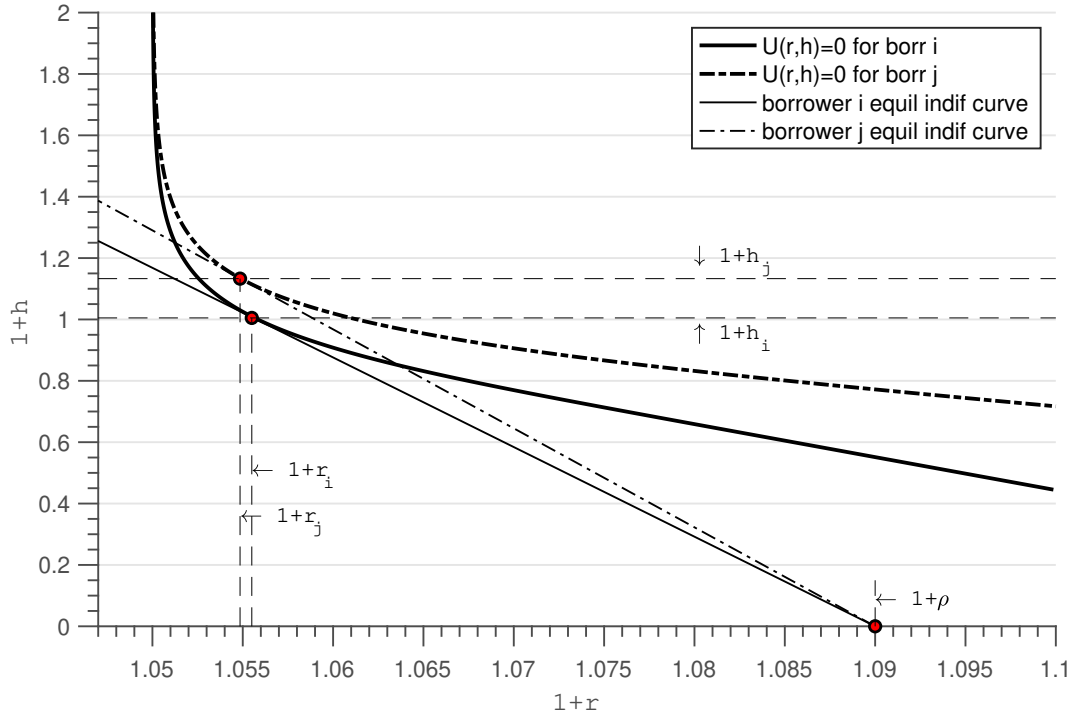

Figure B-1: The equilibrium in the OTC market for borrowers i and j, when $P_i = 8\%$ and $P_j = 15\%$.

lender's indifference curve is higher for borrower j, her equilibrium indifference curve will be steeper than for borrower i.[56] In terms of the slopes,

$$\frac{1+h_i}{(r_i-\rho)} > \frac{1+h_j}{(r_j-\rho)},$$

or

$$\frac{(\rho-r_i)}{1+h_i} = W_{OTC}(r_i,h_i) > \frac{(\rho-r_j)}{1+h_j} = W_{OTC}(r_j,h_j).$$

□

Given the assumption about the distribution of entrepreneurs' probabilities of failure on the interval $[P_{min}, P_{max}]$, it follows from Lemma 1 that the borrower with P_{min} has the highest utility from his equilibrium OTC contract, while the borrower with P_{max} has the

[56]Notice that in equilibrium on the graph $r_j < r_i$. As shown by Chebotarev (2020), the exact sign of the inequality depends on the elasticity of the cdf of the collateral returns distribution in the equilibrium point. By contrast, the relation of equilibrium haircuts ($h_j > h_i$) is robust to changing the distribution parameters.

lowest utility. Since all entrepreneurs face the same contract when borrowing through the CCP repo market, the sets J and J^C can be characterized in Lemma 2.

Lemma 2. *If the set of borrowers J such that $W_{OTC}(r_j, h_j) < W_{CCP}(r_C, h_C)$ for $j \in J$ is not empty, and $J^C \neq \varnothing$, there exists $k \in I$, such that each entrepreneur i with $P_i < P_k$ prefers the OTC market, and each entrepreneur i with $P_i > P_k$ borrows in the centrally cleared market.*

The proof of Lemma 2 follows directly from Lemma 1. Given the description of the borrowers' market selection provided in Lemma 2, one can define the equilibrium.

Definition 5. *The equilibrium is a set $\{\tilde{h}_{OTC}, \tilde{r}_{OTC}, P_k, r_C\}$, such that:*
i) $\tilde{h}_{OTC}$ and $\tilde{r}_{OTC}$: $I \to \mathbb{R}$ are individual OTC repo market equilibrium contract functions (in terms of definition 3);
ii) for each borrower i, if $P_i < P_k$, $W_{OTC}(r_j, h_j) > W_{CCP}(r_C, h_C)$, otherwise $W_{OTC}(r_j, h_j) < W_{CCP}(r_C, h_C)$;
iii) r_C is the CCP equilibrium interest rate.

Theorem 2. *If the equilibrium exists, it is unique.*

The proof (by contradiction) of Theorem 2 follows directly from Lemma 2.

B-4 Default probability of the CCP

The main target of the model is to illustrate the effect of borrowers' selection on the CCP default probability. In the model, the CCP defaults when the individual collateral and the guarantee fund are insufficient to cover the losses due to the borrowers' insolvency. The fraction of insolvent borrowers (i.e., those who do not repay) in the CCP market is $\xi = (P_k + P_{max})/2$. The CCP defaults in the states when $\xi(K_C - R) > g(1 + r_f)$; that is, the guarantee fund is insufficient to cover the shortfall of the collateral.

To decrease the default probability, the CCP can change its risk-management policy, that is, the haircut or the guarantee fund requirement. Adjustment of the former (the main target

Parameter	Value
ρ	9%
r_f	5%
P_{min}	1%
P_{max}	20%
b	0.005
g	0.07
μ	1.07
σ	0.2
R_{min}	0.3
R_{max}	1.87

Table B-1: Parameters of the model, used in the numerical example.

of the model) has two effects. On the one hand, each borrower has to post more collateral, which decreases the CCP's default probability. On the other hand, as the haircut increases, it makes OTC borrowing more costly. In response to an increase in costs, some of the safest entrepreneurs borrowing through the CCP decide to switch to the OTC repo, decreasing the average credit quality in the CCP market. Although the individual collateral shortfall $(K_C - R)$ decreases when the haircut grows, the average borrower becomes riskier ($\xi \uparrow$); the overall change of the CCP default probability depends on the relative magnitude of these two effects. A numerical example below demonstrates that the relation of these effects can be non-monotonous in the haircut.

Using parameters in Table B-1, I calculate the equilibria for a range of exogenously set CCP haircuts (from 5% to 35%). I choose a normal distribution of collateral returns with mean μ and standard deviation σ, truncated on the support $[R_{min}, R_{max}]$. I start the calculations by conjecturing that the average entrepreneur from the sample is the threshold borrower and that the CCP repo rate is 5.03% in the initial point, that is, slightly higher than r_f. Taking a fine grid of borrowers with default probabilities $P_i \in [P_{min}, P_{max}]$, I calculate the optimal OTC haircut and interest rate for every borrower. The fraction of borrowers who choose to stay in the OTC market and the CCP repo rate are obtained by iterating the lender's break-even condition $U_{CCP} = 0$ (equation (B-7)), readjusting the values of P_k and

r_C at each step until the fixed point is achieved.

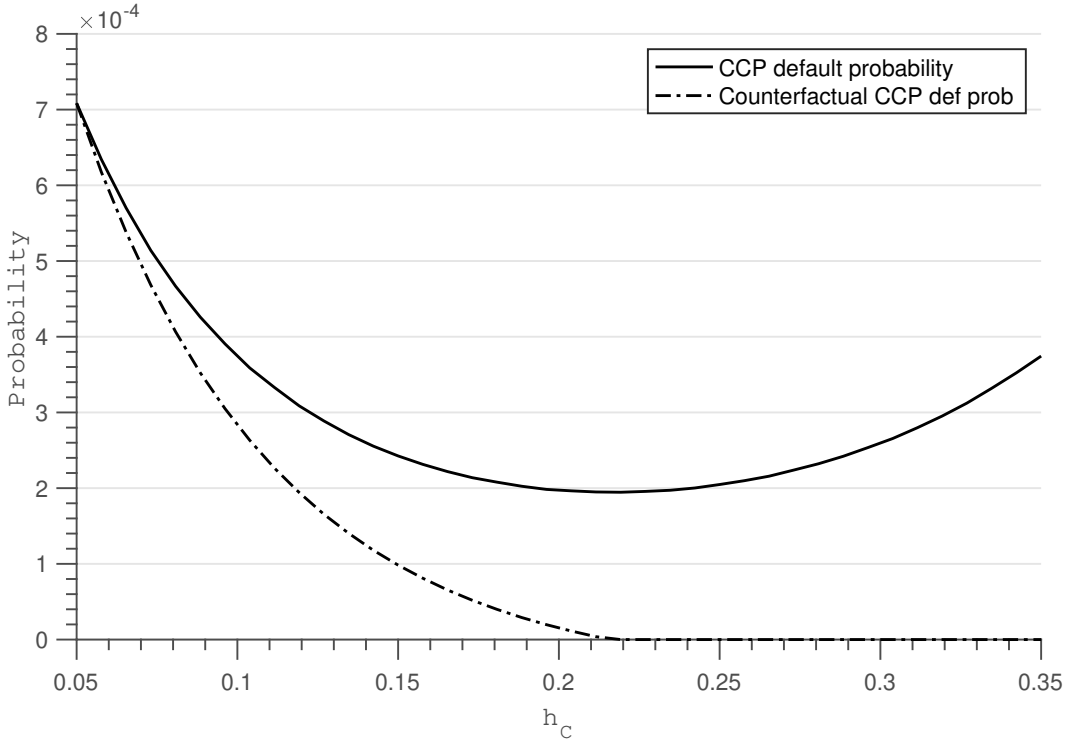

Figure B-2: The equilibrium CCP default probabilities for a range of exogenous CCP haircuts. Dotted line represents the counterfactual calculation, when ξ is kept fixed, i.e., when a haircut increase does not induce selection.

The result is presented in Figure B-2 (solid line). When the CCP starts to increase the haircut, the $(K_C - R)$ falls faster than the average borrower's credit risk ξ grows; as the haircut increases, the speed at which borrowers switch the market augments, reversing the dynamics. The intensity of the effect changes because in equilibrium W_{OTC} is convex in the default probability; that is, the same decrease in the utility of the outside option (i.e., W_{OTC}) affects the preferences of a larger set of CCP borrowers when applied to riskier entrepreneurs. This idea is illustrated in Figure B-3: A decrease in the CCP borrower's utility W_{CCP} from 1.182 to 1.18 (interval A) has a smaller effect compared to the same magnitude drop in utility from 1.178 to 1.176 (interval B).

Until now, I considered $g = m$. In reality, however, the CCP can pick a combination of the haircut and the guarantee fund contribution. As outlined by Wang et al. (2020),

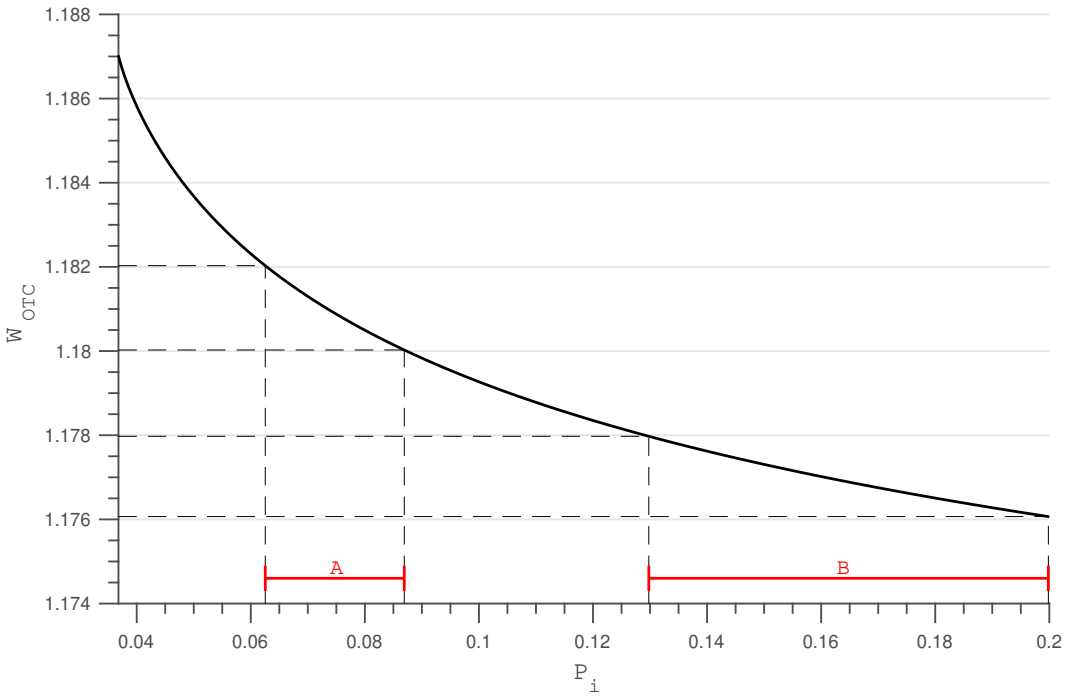

Figure B-3: Equilibrium utility $W_{OTC}(r_i, h_i)$ as a function of P_i.

the guarantee fund plays a role similar to that of the collateral requirement, which makes the two partially interchangeable. Calculating the default probability for different (g, h_{CCP}) combinations, I build a default probability surface for the CCP (see Figure B-4). To do so, I set the borrower's endowment to $m = 0.1$, while varying the guarantee fund contribution g from 0.05 to 0.08. As expected, the slope of the surface shows that the guarantee fund contribution and the haircut are interchangeable to some extent: For a fixed value of h_{CCP}, the default probability is monotonically decreasing in g. However, for each value of g on the chosen grid, the CCP default probability curve has a U-shape. The difference in the monotonicity of the effects of g and h_{CCP} on the CCP default probability limits the interchangeability of the two risk-management parameters and highlights the important difference between individual and mutual collateral types. Although similar in many aspects, the guarantee fund contribution of borrower i can be used by the CCP to cover the losses inflicted by borrower j. Therefore, when each borrower puts more money into the guarantee fund, the decrease in the CCP default probability is larger due to the joint effect of two distinct factors: an increase of individual collateral (since defaulter's contribution is used first)

and the growth of the potential transfers from solvent borrowers to the CCP. By contrast, the haircut increase only activates the individual collateral channel.

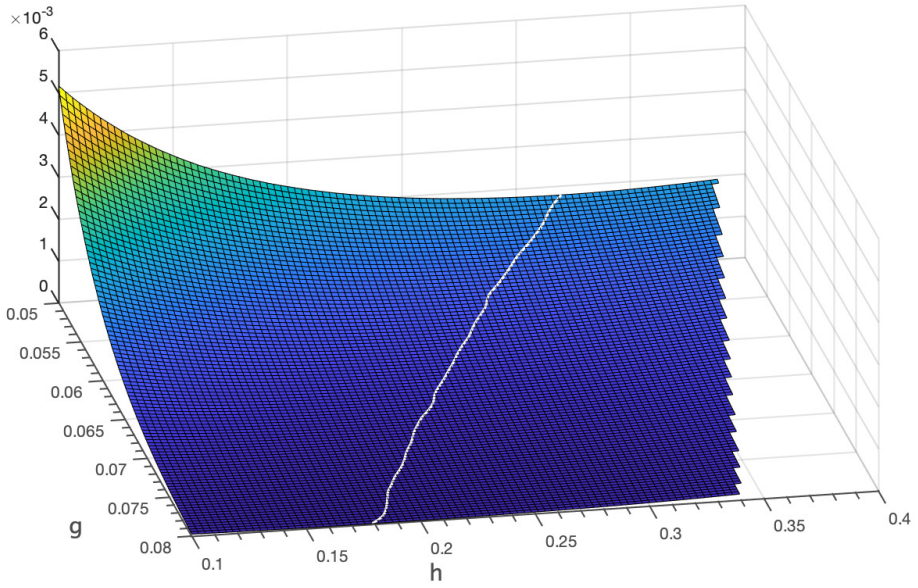

Figure B-4: CCP default probability surface for different combinations of h_C and g. The white line displays the haircuts that lead to the minimal default probability given specific guarantee fund requirements (smoothed by the moving average).

B-5 Discussion

This example presents a striking fact: Under a certain combination of parameters, an increase in the haircut does not lead to a lower CCP's default probability, but on the contrary, makes the default more probable. In a counterfactual example, when I switch off the selection channel, the effect of the haircut on the default probability is monotonic, as shown by the dotted line in Figure B-2. The results of this model contradict to the main premise of the regulatory and academic literature, which considers high collateral requirements to be unconditionally beneficial to CCPs' stability. This example supports the importance of the selection effect, which I identify in Section 4. Below I discuss the limitations of the model.

As on the Moscow Exchange, in the model, the borrower is free to decide whether to attract funding in the OTC or the CCP repo market. For simplicity, I ignore the differences

between the bilateral and limit-order book segments of the CCP repo market: In the model, the knowledge about the identities of CCP borrowers is useless since the CCP offers the same contract to all clearing members. The borrowers' freedom of market choice implicitly relies on an assumption of no information asymmetry, which excludes moral hazard and adverse selection.[57] In the model, the lenders do not explicitly ration the borrowers in the OTC market but offer them combinations of haircuts and rates that lead to a lower borrowers' utility than the CCP contract.

Consistent with the findings, when the haircut is higher, the average credit quality of the CCP borrowers deteriorates. However, since in the model the marginal borrower in the OTC market has a higher default probability than the average borrower, as the CCP haircut grows, in the model, the average OTC borrower becomes riskier, while the empirical results in Section 4 show the opposite dynamic. This is because in this simple framework all borrowers have the same clearing benefits and individual sensitivity to haircuts (i.e., have the same cost of collateral). By contrast, in Section 5, I show that the borrowers' difference in the tightness of collateral constraints matters for their preferences over repo contracts.

Following the vast academic literature on collateralized lending (e.g., Barro (1976), Chan and Kanatas (1985), Besanko and Thakor (1987a), Besanko and Thakor (1987b), and Boot et al. (1991)), I model the lender as a risk-neutral and competitive agent. Risk-neutrality greatly simplifies the model: It switches off the wealth effect, making the lender's problem separable by borrowers. By contrast, a risk-averse lender's utility depends on the contracts she offers in both the CCP and the OTC repo markets, while the contracts, in turn, depend on the utility level. Using risk-averse lenders would create another fixed point, adding complexity without qualitatively altering the results. Meanwhile, risk-neutral lenders in the model act as effectively risk-averse agents; for example, they are sensitive to the increase in

[57] Moral hazard models treat collateral as the borrower's "skin-in-the-game," making the borrower's insolvency determined by the collateral payoff (see, e.g., Geanakoplos (2003)). This feature is undesirable in a model where all borrowers are using the same (or perfectly correlated) collateral. On the other hand, the decision not to focus on adverse selection as the main driving mechanism is justified by the results in Section 3, where I demonstrate that the credit rating is a sufficiently good signal of the credit quality to affect the allocation of borrowers across the markets.

the collateral price volatility. Effective risk aversion is the result of the kink in the payoff function (Merton (1974)). This kink does not allow the lenders to gain more than the amount due, neither from the solvent borrower's payoff, nor from selling the collateral if the borrower defaults. As a result, a risk-neutral lender is sensitive to any variable that increases the payoff volatility. In the model, the lender's effective risk aversion depends on the borrower's success probability and on the volatility of the collateral price.

Unlike risk-neutrality, the lenders' competitiveness is important for the results, as it supports the interchangeability between the haircut and the repo rate for the lender.[58] While the free entry and the absence of search costs in the model lead to a zero profit for the lender, in reality lenders may receive a profit margin in equilibrium. This margin can be accounted for in the expected return: The lender will receive a premium over the funding rate r_f in (B-5) and (B-7). Then, a lender's return margin is limited, for example, by the borrower's search costs. This formulation is equivalent to giving some bargaining power to a return-maximizing lender in a Nash bargaining game. By contrast, the baseline version of the model assumes that the borrower has all the bargaining power.

[58]To see this, consider again the example in Figure B-1 for the borrower i with $P_i = 8\%$. Assume that the lender wants to receive \$0.02 from a deal with a lender who has the collateral worth \$1. If the haircut is small, for example, $h = 0$, the repo rate is 3.4%; that is, the combination $(h = 0, r = 3.4\%)$ satisfies $U(r_i, h_i) = 0.02\$$. If the haircut is very high, for example, $h = 100\%$, then, on the one hand, the deal is safer, and the lender may require a lower rate. But on the other hand, since the lender wants to get the same expected profit from a borrower while giving him a smaller loan, she needs to increase the interest rate to $r = 3.9\%$. This breaks the interchangeability between the haircut and the rate.