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The Economics of Central Clearing

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Abstract

Central clearing counterparties (CCPs) have a variety of economic rationales. The Great Recession of 2007-2009 led regulators to mandate CCPs for most interest-rate and credit derivatives, markets in which large amounts of risks are transferred across agents. This change led to a large increase in CCP studies which, along with classical studies, are surveyed in this article. Discussed are, for example, multilateral netting, the insurance against counterparty risk, the effect of CCPs on asset prices and fire sales, margins setting, the default waterfall, and CCP governance. We review both CCP theory and empirics, and conclude by discussing regulatory issues.

Contents

1. INTRODUCTION

Following the Great Recession of 2007-2009, a key part of the agenda for financial regulators worldwide was the requirement to use central clearing counterparties (CCPs) for standardized derivatives. These reforms have by now largely been implemented, so that the microstructure of derivatives markets has changed dramatically. Consequently, central clearing has attracted the interest of a growing number of researchers over the last decade, and significant progress has been made on both the theoretical and the empirical fronts. It is this novel part of financial research that we review here.

To set the stage, what do CCPs do? The key issue they address is counterparty risk in financial markets. Namely, whenever two investors agree on a financial contract, there is a probability that at least one of them will default on his promises (payment, delivery of a security, etc.). This risk exists in any market, but is more acute for derivatives, due to the long maturity of contracts.[1] Counterparty risk can be managed in two ways, which coexist in practice. One possibility is for counterparty risk to be managed bilaterally, for example through the direct exchange of collateral between investors, hence the name *bilateral clearing*. In this case, the default of one investor can cause losses to its counterparties, as illustrated in the left chart of Figure 1(a).

Alternatively, counterparty risk can be managed via *central clearing*. After a trade is bilaterally agreed by two investors, a CCP steps in and becomes a buyer to the seller and

[1] While most papers in this survey study derivatives markets, CCPs exist in other markets (e.g., equities, repurchase agreements). Furthermore, clearinghouse mechanisms also exist for payments, and gave rise to a separate literature (see, for example, Börner & Hatfield 2017; Gorton 1985; Gorton & Mullineaux 1987). We do not cover payment, check and bank clearinghouses in this survey, since they are primarily dealing with netting of payments, not with the management of counterparty risk.

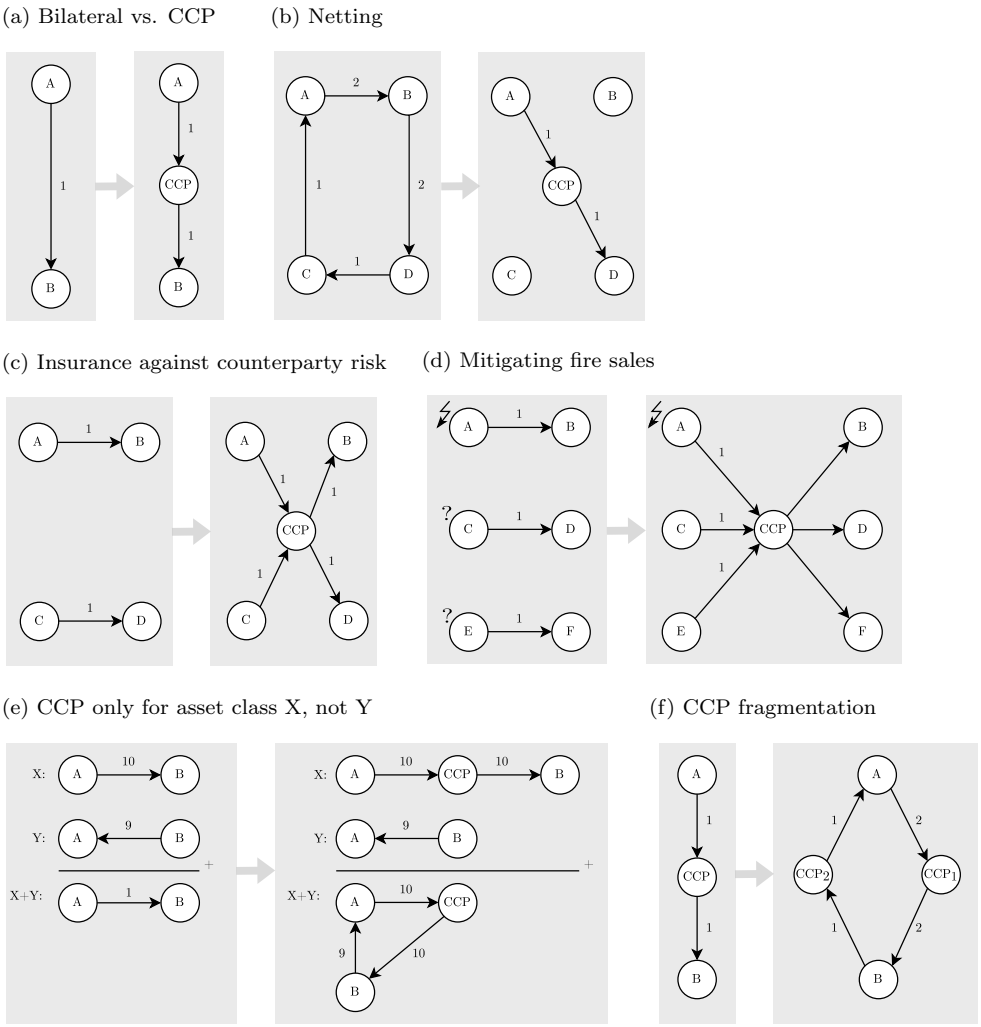

Figure 1

Panels (a) through (f) illustrate various channels by which the introduction of CCPs affect counterparty exposures.

a seller to the buyer. This process is called novation. The CCP subsequently bears all counterparty risk, and guarantees to each investor the execution of the terms of the initial contract. As illustrated in the right chart of Figure 1(a), investors are no longer directly exposed to each other, and become exposed only to the CCP. Provided the CCP does not itself default, investors should not be concerned any more about counterparty risk. To provide insulation against investors' default, CCPs use a variety of instruments, notably the collection of collateral. Relatedly, CCPs raise new challenges. Most importantly, when a large enough fraction of transactions is centrally cleared – as is currently the case – CCPs become extremely large, so that a CCP failure could lead to dramatic market disruptions.

The risks associated with CCPs are not just theoretical. For example, in September

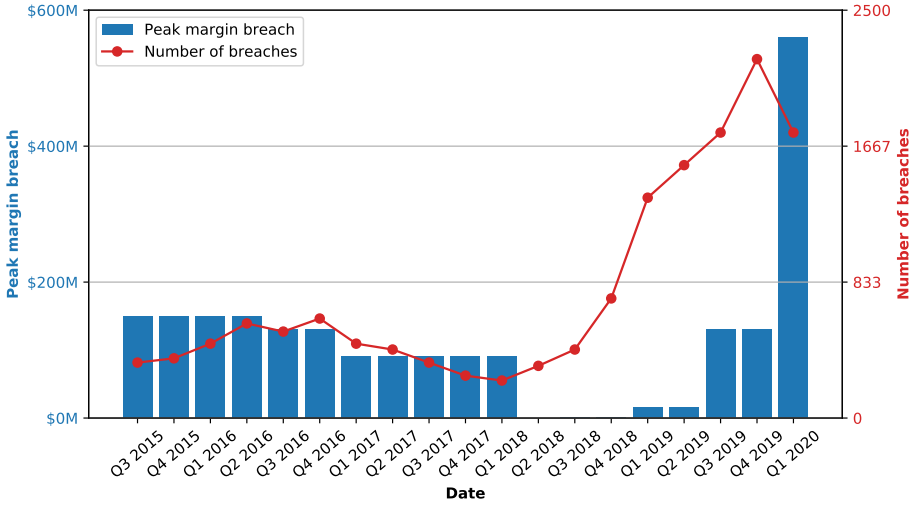

Figure 2

Time series of largest margin breaches and number of margin breaches at one of the world's largest CCPs, SwapClear, which mostly insures counterparty exposures in interest-rate derivatives. Source: Woodall (2020b).

2018, the Sweden-based CCP Nasdaq Clearing AB, active in the electricity futures markets, was on the verge of failure after a large trader, Einar Aas, failed to respond to margin calls. Contributions from non-defaulted members had to be tapped to a significant extent (107 million out of a default fund of 166 million euros).

The risks are further evident from the recent Covid-19 crisis. We call a *margin breach* the situation in which a clearing member's mark-to-market loss exceeds the collateral he posted. Figure 2 shows that one of the largest CCPs, SwapClear, suffered serious breaches, with the largest breach amounting to half a billion US dollar. Figure 3 shows that such breaches were not idiosyncratic to SwapClear. Many CCPs experienced a substantial jump in their relative breach level. In itself, this is not that surprising during a crisis period, but it is worrisome that about half a dozen CCPs experienced breach levels in excess of one percent, which is the industry standard. Such events show that an appropriate understanding of the trade-offs involved when setting up CCPs is essential.

With this basic description in mind, the survey is structured as follows.[2] In Section 2, we discuss the theoretical rationales for central clearing. In Section 3, we review empirical studies on the effects of central clearing on the functioning of markets. Section 4 studies the design of CCPs and their resilience, both theoretically and empirically. Finally, Section 5 discusses policy issues related to central clearing. Throughout the paper, we highlight research questions that remain open for future work.

[2]Our survey has benefited from the industry-focused reviews by Pirrong (2011), Gregory (2015), Spatt (2020), and from the book by Murphy (2013).

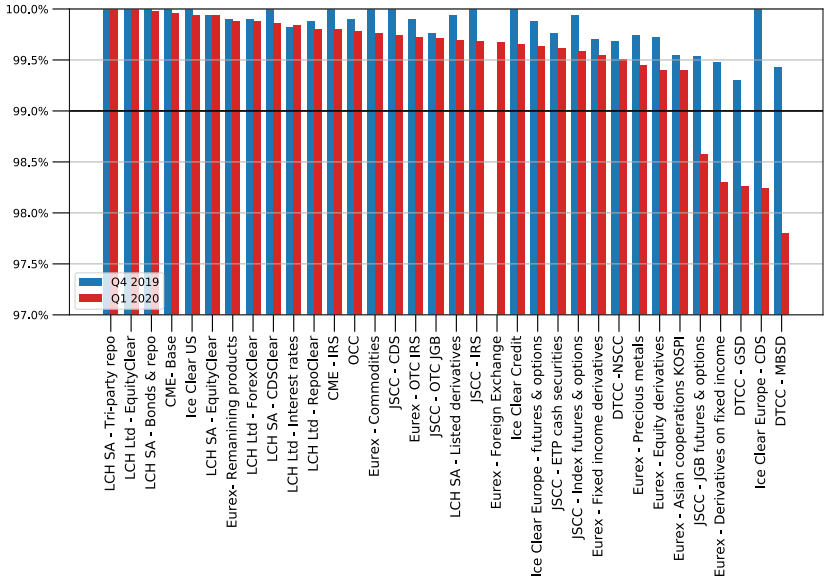

Figure 3

Margin breaches for the world's largest CCPs in the first quarter of 2019. A value of 100% means that the CCP had collected sufficient margins to cover for day-to-day variation in prices. A value below 100% indicates a shortfall. Source: Woodall (2020a).

2. THEORIES OF CENTRAL CLEARING

We start by reviewing the theories of central clearing. The key message is that there is no role for CCPs in *perfect* financial markets. Financial frictions are thus needed to justify the existence of CCPs. We group theoretical studies by the friction they have in focus and discuss them in the various subsections.

2.1. Central clearing in perfect financial markets

The idea that there is no economic role for central clearing in perfect financial markets follows from the Modigliani & Miller (1958) theorem (see also Stiglitz 1969). If markets are perfect – that is, if information is symmetric, there are no taxes or other transaction costs, no arbitrage opportunities, and financing does not affect cash flows from assets – then any choice of firms' capital structure is irrelevant for firm value. This is because capital structure becomes a way to split cash flows across investors. Since cash flows are perfectly priced, no particular split creates extra value.

The same logic implies that any financial intermediary interposing itself between firms and investors cannot create value (Freixas & Rochet 2008, Chap. 1): these intermediaries are simply implementing a different split of cash flows (for example between depositors and equity holders in the case of banks). The same holds true for CCPs. Simple intuition can be gained from Figure 1(a) where any payment that the CCP makes to investor B has to come either from investor A, or from a CCP's own resources. The CCP is thus simply

splitting cash flows in a particular way. To the extent cash flows are perfectly priced, this cannot create value.

Another intuition for why CCPs have no value in perfect markets can be gained from a replicating argument. Indeed, whatever CCPs do can be replicated by investors themselves. For example, if CCPs provide risk insulation by collecting margins, investors could equally well collect margins bilaterally. An important implication follows, namely, that any theory assigning an economic function to CCPs must be based on an explicit deviation from any of the assumptions that, collectively, define perfect markets.

2.2. Efficient posting of costly collateral

A first economic rationale for CCPs relates to their role in collecting collateral or in reducing the cost of posting collateral. In economic theory, collateral can be used to mitigate a number of frictions, including moral hazard and adverse selection. Moral hazard hampers trading when the ability of an agent to make good on contractual commitments depends on unobservable effort decisions. In this case, by posting collateral, the agent increases its resources at stake, and can credibly commit to exert effort, since collateral will be lost in case he defaults (Holmström & Tirole 1997).

Then, trade can also be hampered by adverse selection, i.e., the fact that an investor is not able to distinguish between "good" and "bad" counterparties, that is, those with high or low probabilities of default (Akerlof 1970). Requesting collateral can be used to screen counterparties. Indeed, all else equal, posting a given amount of collateral is more costly for riskier counterparties, since they are more likely to lose these resources. Therefore, if enough collateral is required, only high-quality counterparties will remain in the market (Bester 1987). Relatedly, in the absence of adverse selection but with limited ability to enforce contractual promises, Rampini & Viswanathan (2010) show that the amount of future promises an agent can make is limited by his current net worth, that is, his pledgeable collateral. In this context, it is also the case that posting collateral is more costly for more financially constrained agents, due to a higher opportunity cost of collateral.

What is the role of CCPs in this context? In principle, if collateral is valuable to support trading in the presence of frictions, agents should be able to post it bilaterally. Thus, it is not clear that requesting collateral to be posted centrally would further improve outcomes. However, a first possibility is that investors are imperfectly able to raise bilateral margins. This can arise if investors are concerned that counterparties will re-invest the collateral they receive, so that there is a risk that collateral will never be returned. A CCP, who does not play any active investment role, may be more credible at segregating margins.[3]

A second possibility is that central clearing reduces the cost of posting collateral, due to multilateral netting, that is, the ability to net positions and collateral calls across multiple counterparties. With multilateral netting – which can hardly be achieved in a bilateral market – a given quantity of collateral can support a greater number of positions.[4] The ability to conduct multilateral netting is the key comparative advantage of CCPs in the

[3]In practice, CCPs do reinvest margins received in cash, but only in safe assets. They can also lend securities received as collateral.

[4]In a bilateral market, multilateral netting can only be achieved through trade compression, by which a third party collects data about the positions of a set of traders and advises them on how to reduce bilateral net exposures. Trade compression shares features with the historical practice of "ring clearing" (Emery 1896; Moser 1998).

model by Duffie & Zhu (2011). This role is illustrated by Figure 1(b). The left chart illustrates the no-CCP case, where arrows indicate exposures. The right chart shows how exposures are reduced when a CCP is introduced. In this context, whatever friction is impairing financial markets, be it moral hazard, adverse selection, or limited enforcement, CCPs can improve outcomes by reducing the cost of posting collateral.[5] One example is the model by Carapella & Mills (2014): In their setup, the true benefit of CCPs is to make traded contracts information-insensitive (in the sense of Gorton & Pennacchi (1990)), that is, to eliminate adverse selection. This is achieved by collecting costly collateral, and reducing this cost through multilateral netting. The more information-insensitive securities become, the more liquid they will be.

2.3. Insurance against counterparty risk

Another stream of research, mostly represented by Biais et al. (2012, 2016) essentially considers CCPs as insurance companies. When investors are exposed to the risk that counterparties may fail on their commitments, value can be created by pooling resources across investors in order to insure each of them against counterparty defaults.[6] In any insurance company, agents contribute resources that are pooled in a common fund, and that are used to cover idiosyncratic risks. In a CCP, this pooling of resources occurs via default funds, i.e., mutualized resources that are used to cover the cost associated with member defaults, after the resources of the defaulted members themselves are depleted. Therefore, while theories explaining CCPs based on multilateral netting cannot explain the existence of default funds, it is a key element in Biais et al. (2012, 2016). Figure 1(c) illustrates how the introduction of a CCP leads to the pooling of exposures and therefore diversifies idiosyncratic risk across members.

This theory explains another important feature of central clearing. In the presence of moral hazard, arising from unobservable effort or risk management decisions, the provision of insurance by a third party (the CCP) can weaken the incentives of investors to prevent or reduce risks. For example, it can make investors less careful about the choice of their counterparties.[7] Thus, in the presence of moral hazard, the amount of risk is endogenous to the level of insurance provision: more insurance can increase risk-taking, potentially threatening the mere possibility of providing insurance. This outcome can be avoided by limiting the provision of insurance, that is, by assigning part of the losses to the parties that cause them. In standard insurance contracts, this role is played by deductibles: the insured agent supports part of the damages below some threshold. In the context of CCPs, this role is played by requiring initial margins to be paid: these are resources that will be lost by any investor in case he defaults. It therefore creates incentives to avoid defaults. Thus, the theory in Biais et al. (2012, 2016) also explains why margins are paid to CCPs. Finally, this theory points to an important limitation of CCPs: as any insurance contract based

[5] Amini & Minca (2020) note that, during the multilateral netting process, the priority structure in the network of transactions is also changed. End-users that are not part of multilateral clearing arrangements may become de facto junior.

[6] If markets are complete, investors should be able to hedge the risk that their counterparties default directly by buying or selling securities, such as credit default swaps (CDS). The existence of a centralized intermediary such as the CCP thus amounts to assuming that hedging markets are incomplete or costly to use.

[7] While not a full study on moral hazard in CCPs, Mayordomo & Posch (2016) show results consistent with this prediction.

on the mutualization of resources, it can only cover idiosyncratic risks, not systematic risk. Thus, the role of CCPs in mitigating the effect of aggregate shocks remains very limited.

The insurance role of CCPs has also been studied in a variety of related models. In Antinolfi et al. (2019), CCPs act as an insurance company, but give rise to a trade-off between bilateral clearing and central clearing. When some information about the credit risk of a counterparty (here, its pledgeable income) is soft, in the sense that it cannot be verified by a third party, then bilateral clearing may dominate central clearing. In particular, while providing insurance, central clearing reduces traders' incentives to acquire soft information, and may worsen outcomes. Koeppl & Monnet (2013) further discuss the trade-off between standardized and customized financial contracts. A CCP can only achieve the novation of trades, and pool risk exposures, if contracts are sufficiently fungible, that is, standardized. To the extent that customized contracts are valuable, they should be traded bilaterally. One important lesson is that the degree of standardization of contracts should not be taken as exogenous, but is endogenous to clearing arrangements. Empirically, Kroszner (1999) indeed links the emergence of CCPs to progresses in the standardization of contracts. Finally, Kuong & Maurin (2020) provide a model in which loss mutualization requires collateral for preventing moral hazard. Central clearing is thus optimal only when the collateral cost is intermediate. If the cost is low, full collateralization is optimal. If the cost is high, supporting loss mutualization with collateral is too expensive. They then use this basic structure to study a number of important elements of the structure of CCPs, including their default waterfall.

2.4. Mitigating fire sales

A last potential economic rationale for central clearing relates to the role of CCPs in mitigating fire sales. This mechanism aims to explain one feature of CCPs. Specifically, when a member defaults on its margin calls, the CCP does not liquidate this member's position in the open market. Instead, it organizes an auction, in which surviving members have incentives to bid at high prices.[8] These auctions can be understood as a mechanism to mitigate the inefficiencies associated with fire sales, such as deviations of prices from fundamentals, inefficient liquidations when margin constraints binds (Brunnermeier & Pedersen 2009), or predatory trading and short-selling (Brunnermeier & Pedersen 2005). This rationale for CCPs is modeled in Vuillemey (2020a), and a related intuition is developed in Kuong (2020).[9]

Theoretically, the existence of capital or margin constraints can give rise to multiple equilibria in financial markets. If investors expect other investors to sell assets and prices to decrease, they know that they will face margin calls and may be forced to sell when prices are already low. Expecting this, they may preemptively sell, pushing down prices earlier, and amplifying price drops. This equilibrium is inefficient: collectively, all investors would be better off not selling; but individually, it may be rational for each of them to sell. This inefficient equilibrium coexists with another equilibrium in which investors do not expect other investors to sell in the future, and thus have no incentives to preemptively

[8]These incentives take the form of juniorization of default fund contributions (i.e., resources mutualized across members) or of outright fines.

[9]Other related work is Biais et al. (2020). Their main message is that fire sales need not create inefficiencies, provided that agents can write contracts on them. In the context of theories discussed in this section, CCPs can be understood as one such contract.

sell. In this context, a CCP can be seen as an equilibrium selection mechanism. If agents can pre-commit to buy assets at high prices in states which would otherwise be associated with forced liquidations, then all incentives to preemptively sell can be eliminated.

The auction mechanism operated by CCPs achieves exactly this, in states where one investor defaults and his position has to be liquidated. This eliminates the inefficiencies associated with multiple equilibria in these circumstances. How the introduction of a CCP mitigates fire-sale risk is illustrated in Figure 1(d). If member A fails, those on the same side of the market could stay on their position or unwind it causing fire sales. The question marks illustrate these two options and the associated multiple equilibria. The situation is resolved in the right chart after the introduction of a CCP. That said, the optimal design of CCP auctions remains an open question. One of the only papers studying this topic is Ferrara et al. (2019), who show that CCP auctions with penalties do not increase the CCPs' expected revenue, and can also have unintended effects by fragilizing the surviving members.

3. EMPIRICS OF CENTRAL CLEARING

In this section, we review the empirical literature that studies the effect of central clearing on the functioning of markets.

3.1. Central clearing and asset prices

When thinking about how central clearing affects markets, a first natural outcome to study are prices of the cleared assets. Specifically, is counterparty risk priced differently before and after the introduction of central clearing? Several hypotheses can be tested. Most naturally, if CCPs are successful at eliminating counterparty risk at limited cost, then prices of cleared assets should *increase*: investors are willing to pay more because default probabilities are lower. On the contrary, a badly designed CCP, by providing insurance against idiosyncratic risk, may actually increase systematic risk (Biais, Heider & Hoerova 2012). This is the case if investors, subject to moral hazard, no longer have incentives to monitor the credit quality of their counterparties. In this case, asset prices are expected to *decrease*. Alternatively, if the cost of central clearing, in terms of collateral requirements, is too large, then funding and market liquidity may deteriorate, also negatively impacting asset prices (Garleanu & Pedersen 2011).

To estimate the effect of central clearing on asset prices, the main identification challenge is the fact that the introduction of central clearing often is not exogenous. It can indeed be correlated with macroeconomic conditions, such as the occurrence of financial crises. The paper that most convincingly addresses this challenge is Bernstein, Hughson & Weidenmier (2019), who use the fact that, at the end of the 19th century, there were two competing stock markets in New York: the New York Stock Exchange (NYSE) and, across the street, the Consolidated Stock Exchange (CSE). The CSE had a clearinghouse starting from 1886, which was imitated by the NYSE only in 1892. Bernstein, Hughson & Weidenmier (2019) compare prices of the same securities on the sames dates, traded in either of the two exchanges, after the introduction of the NYSE clearinghouse. This setup allows for ruling out any impact of macroeconomic conditions. In a difference-in-differences specification, they find that the value of NYSE stocks, relative to CSE stocks, increased by 24 basis points after the introduction of the clearinghouse. This is consistent with the view that the

dominant force associated with CCP introduction is to ensure that the posting of collateral is done efficiently (see Section 2.2). Relatedly, McSherry, Wilson & McAndrews (2017) use the same historical setup to show that the NYSE clearinghouse reduced the failure rate of brokers. Even though the findings by Bernstein, Hughson & Weidenmier (2019) constitute the best identified evidence on asset prices so far, they are focused on one part of central clearing only. Indeed, the NYSE clearinghouse was only engaged in netting (allowing for multilateral netting instead of bilateral netting), but was not interposing itself between traders to assume counterparty risk, as modern CCPs do.

Therefore, a set of papers have looked at the introduction of CCPs in other contexts. Loon & Zhong (2014) study the pricing of credit default swaps (CDS), for which central clearing was voluntarily introduced by ICE between 2009 and 2011. They conduct event studies around the date at which central clearing starts. They show that, with central clearing, protection buyers are willing to pay 1.4% more on receiving the protection (i.e., CDS spreads go up by 1.4%). While this effect could theoretically be driven by changes in liquidity or in credit risk, they show that it is robust to the inclusion of liquidity proxies. Consistent with the idea that lower counterparty risk is a key driver of the effect, they also find that the sensitivity of CDS spreads to dealers' credit risk is reduced after central clearing. That said, the main concern is that the set of CDSs which are voluntarily cleared differ from CDSs for which no voluntary clearing starts during the period (for example, they could be more risky ex ante). While no exogenous source of variation can here be used for identification, Loon & Zhong (2014) show that their findings are robust when treated CDSs (i.e., those which start to be cleared) are matched with other CDSs with similar ex ante characteristics. Another paper, Menkveld, Pagnotta & Zoican (2015), focuses on volatility rather than on the level of prices. They study the introduction of a CCP in October 2009 in three equity markets: Denmark, Finland, and Sweden. This setup has the appealing feature that there was virtually no voluntary clearing of stocks before the event (less than 1% of the trading volume), and clearing then became mandatory. This alleviates concerns about the selection of trades that end up being centrally cleared or not. As a control group, Menkveld, Pagnotta & Zoican (2015) use a sample of matched European equities for which there is no change in clearing regime. In a difference-in-differences estimation, they find that the daily volatility of Nordic stocks declines by 20 basis points after the CCP is in place. This is economically large, as it represents a volatility decline by 8.77% compared to pre-clearing levels. Interestingly, insights into the mechanisms can be gained be exploiting specificities of the margining rules: the drop in volatility is even larger for higher levels of margins. This is consistent with the theory that higher margins dampen the effect of counterparty risk on prices.[10] That said, the paper also points to an interesting trade-off, namely, higher margins make it more costly for investors to trade. Consequently, they find that the introduction of the CCP causes a decline in trading volume by 9.8%. However, this decline in market liquidity does not seem to reduce market efficiency or the informativeness of prices.

While the above papers suggest that central clearing brings asset prices closer to their

[10]In contexts unrelated to central clearing, a few papers study the effect of margin requirements on market liquidity and price volatility (see Hardouvelis (1990); Hardouvelis & Peristiani (1992) and Hsieh & Miller (1990) for a critique). More generally, a large literature studies how margins can constrain the ability of investors or arbitrageurs to take positions, and in turn affect prices (see, for example, Gromb & Vayanos 2002). A related question is whether margins can be destabilizing, due to their procyclicality (Murphy et al. 2014).

fundamental value, one paper by Boissel et al. (2017) provides a more skeptical appraisal. They study rates on general collateral repurchase agreements ("repos") in Europe. This market is centrally cleared. Therefore, if the CCP is credible at eliminating counterparty risk, repo rates should not depend on the credit quality of the underlying collateral. Focusing on sovereign collateral, the paper indeed finds that, in times of moderate sovereign stress (2009-2010), repo rates are uncorrelated with CDS spreads in the underlying sovereigns. However, in 2011, during the European sovereign debt crisis, the two sets of rates become highly correlated. They interpret this finding as evidence that investors price the probability of CCP failure conditional on the failure of a sovereign entity. This finding is at odds with the one by Mancini et al. (2016), who also study the European CCP-based repo market, and confirm that CCPs act as shock-absorbers. In this last paper, higher market risk is associated with higher repo lending volumes, but not with higher spreads or haircuts. One reason why Boissel et al. (2017) obtain different findings may be because they look at a market where securities from specific governments are delivered, and not pools of sovereign bonds.

3.2. Central clearing and trade flows

Once the impact of central clearing on asset prices is established, a natural next step is to ask whether real variables are also affected. In the context of derivatives markets, does central clearing affect only the prices of derivative contracts, or also outcomes in the market for the underlying goods or securities? This question was tackled mostly by Vuillemey (2020b), who studies the introduction of the first derivatives CCP in history. This CCP, called *Caisse de liquidation des affaires en marchandises* (*CLAM*) was created in the market for coffee futures in the harbour of Le Havre (France) in 1882. At the time, the north western part of Europe was the most active trade area worldwide. The key innovation brought about by CLAM was to interpose itself between traders to fully insulate these traders against counterparty risk. The CLAM, in turn, protected itself against counterparty risk by imposing margins. Before 1882, earlier clearinghouses, for example in Liverpool or New York, only offered netting services to facilitate the settlement of transactions.[11]

Using archive data on trade flows in coffee and other commodities at a European scale, Vuillemey (2020b) estimates a triple difference-in-differences model, to show that central clearing had a significant effect on trade flows. After 1882, coffee (imported mostly from Brazil) entered Europe to a significantly larger extent through Le Havre, was warehoused there, and eventually exported again to other European countries for consumption. In sum, once they had access to a hedging technology that could remove counterparty risk, coffee dealers in Le Havre could hold significantly larger inventories than dealers in other European harbours. These other traders soon realized that they were losing business and, within 10 years, about 10 other European harbors also introduced CCPs.

This event can finally be used to shed light on the theories of Section 2, and explore the friction that was mitigated by central clearing in this market. Before the introduction of central clearing, futures trading was mostly based on reputation, which was a substitute for collateral. This system based on reputation collapsed during a major crisis in the coffee market in 1880-1881: several old and reputable trading houses in the US failed, casting doubts worldwide about the credit quality of counterparties. While reputation was mostly

[11] See also Schaede (1989).

a device to separate "good" from "bad" traders, the crisis pooled most of them together, creating adverse selection and slowing down trade. Evidence shows that central clearing was most valued for its credibility in calling margins at a relatively low cost (due to multilateral netting). In line with models that assign a screening role to collateral (Bester 1987), calling margins was a way to re-separate "good" from "bad" traders, because posting collateral is costlier for riskier investors, all else equal.[12] The shift from a system based on reputation to a system based on collateral also removed informational barriers to entry, and the number of new traders subsequently increased.

3.3. Central clearing and fire sales

The idea that central clearing can reduce inefficiencies associated with fire sales has received limited empirical attention, but a few studies point in this direction. To begin with historical settings, Vuillemey (2020a) studies the first event during which a CCP played an active role to avoid distressed sales: the crisis in wool futures in 1900 in Europe, during which a number of trading houses defaulted in Roubaix-Tourcoing (France), then a major center of the textile market. Instead of running an auction in a strict sense, the CCP coordinated surviving members. They collectively agreed to buy the defaulted position at a price above the one that would have otherwise prevailed, and which would have triggered additional rounds of margin calls. In difference-in-differences estimations, using local trade flows as a measure of local economic activity, there is no evidence that prices in the affected wool market remained depressed afterwards. Furthermore, the decision to collectively agree on liquidation prices (made easier due to strong family connections between the main firms) was unanimously praised, suggesting that it was indeed socially beneficial.

In more recent contexts, the liquidation of the derivatives position of Lehman Brothers, following its failure in 2008, has been the object of a few studies, primarily by lawyers. A detailed narrative is given by Norman (2011). Most of the legal research focuses on the treatment of derivatives in bankruptcy, and how a move towards central clearing would affect outcomes. The key feature that has attracted a lot of attention is the exemption of derivatives from automatic stays, which makes them effectively senior to all other claims (Duffie & Skeel 2012). Concretely, this means that, in bankruptcy, derivatives counterparties can repossess collateral and terminate positions immediately, without waiting for the insolvency procedure. In the case of Lehman Brothers, about 80% of the derivatives counterparties terminated their contracts within 5 weeks of the bankruptcy filing (Lubben 2017). Given the size of the Lehman Brothers derivatives portfolio (a notional value of 35 trillion USD), this was the largest-ever mass termination of derivatives. Although any counterfactual scenario remains unknown, anecdotal evidence suggests that massive, immediate, and uncoordinated sales caused prices to be depressed, and were associated with significant losses (Summe 2012).[13] Theoretically, the increasing use of central clearing could mitigate part of the inefficiencies: a CCP should indeed consider the entire value of a derivatives portfolio in bankruptcy, and not just specific positions. A number of studies, such as Summe (2012) and Roe & Adams (2015) express skepticism about the status quo: the exemption from automatic stays has essentially been left untouched by new regulations such as the

[12] Vuillemey (2020b) further shows that, for a subset of traders, the CCP was valuable as a tool to complete markets, consistent with the theoretical arguments in Biais et al. (2012, 2016).

[13] Other trade-offs associated with the effective seniority of derivatives are discussed by Bolton & Oehmke (2015).

Dodd-Frank Act.

4. DESIGN OF CENTRAL CLEARING

In this section, we discuss issues related to the design of CCPs. In short, the efficient functioning of CCPs relies on the collection of adequate amounts of margin, on a proper allocation of losses in case of member default, and on good governance. We also study issues related to the number of operating CCPs.

4.1. Design of margins

The first line of defense of CCPs against a potential default of their members is the collection of margins. Collecting the appropriate amount of margins is critically important, both to mitigate incentive problems arising from moral hazard or adverse selection (see Section 2.2) and to keep CCPs afloat, thus allowing them to make good on their commitments vis-à-vis surviving members. Consequently, a number of papers study, theoretically and empirically, the use of margins by CCPs.

A first strand of the literature studies how investors' net exposures, thus margin requirements, change under different clearing arrangements. The baseline theoretical framework has been laid out by Duffie & Zhu (2011).[14] This paper points out a simple but important trade-off at play when moving from bilateral clearing to central clearing. As discussed in Section 2.2, CCPs are valuable because of the multilateral netting benefits they offer. However, these benefits operate within a given asset class, but come at the cost of potentially lowering opportunities for bilateral netting across asset classes.[15] This is due to the fact that investors in a bilateral market can net margins (and reduce economic exposures) across all asset classes, while CCPs typically operate only within one asset class (and even CCPs operating in multiple asset classes typically segregate margins across classes).[16] Once this trade-off is accounted for, Duffie & Zhu (2011) conclude that it cannot be taken for granted that CCPs reduce economic exposures and margin requirements between investors.[17] For the same reason, they also point to the benefits of "interoperability" across CCPs, that is, links between CCPs that allow for multilateral netting across CCPs. Figure 1(e) illustrates how introducing a CCP in one asset class only can *increase* counterparty exposures.

The results by Duffie & Zhu (2011) have been extended along several dimensions. For example, Cont & Kokholm (2014) introduce heterogeneity along two key dimensions: the riskiness of each asset class, and the correlation of investors' exposures across asset classes. Intuitively, these two quantities critically determine how much cross-asset netting benefits

[14] An early contribution on this topic is Baer et al. (2004).

[15] Relatedly, Amini et al. (2016) show that partial multilateral netting may be worse (in terms of traders' surplus and asset prices) than no netting at all.

[16] To our knowledge, the theoretical rationale for segregating margins across asset classes has not been explicitly modeled in an optimal contracting framework. It can be that margin segregation is the efficient solution to mitigate agency or incentive problems. More mundane reasons for CCPs specialization in a single asset class is in-depth knowledge about risk profiles of the various securities and clearing members. Path dependence might also explain the status quo since if, historically, every asset class started out with their own CCP, integrating CCPs further down the road with more global, across-asset class trading becomes a non-trivial merger and/or acquisition endeavor.

[17] See Amini et al. (2020) for a related argument. A working paper version of that article (Amini et al. 2017) had a stylized model to study the capital structure of CCPs.

are lost when moving from bilateral to central clearing. Garratt & Zimmerman (2020) explore another dimension of heterogeneity. Indeed, while Duffie & Zhu (2011) assume that all bilateral exposures are non-degenerate random variables so that their financial network becomes fully-connected, Garratt & Zimmerman (2020) study the impact of centralized netting in a variety of network structures. A related contribution, by Glasserman et al. (2016) studies traders' incentives to split positions across CCPs when margins increase with position sizes, and study equilibrium in this context.

Furthermore, while the above papers rely on simulated networks to assess the impact of central clearing on net exposures, Duffie et al. (2015) use actual data to study the amount of collateral required to safely clear CDSs under various market structures (e.g., the status quo as baseline, an increase in CCP membership, an increase in the number of CCPs, client clearing, etc.).[18] They find that aggregate collateral demand is massively increased via the imposition of initial margins for inter-dealer trades. However, once these margins are accounted for, central clearing reduces aggregate collateral demand, provided there is no proliferation of CCPs.

A second strand of the literature asks whether margin levels used by CCPs are sufficient to allow them to make good on their commitments vis-à-vis members. Jones & Pérignon (2013) use data on the daily gains and losses that clearing members realized on their Chicago Mercantile Exchange (CME) positions to study the probability of margin breaches (that is, the probability that the change in the value of the cleared portfolio exceeds the amount of initial margin posted).[19] Over a three-year period (1999-2001), they find that margin breaches cluster in time – a finding that raises concerns about systematic risk. The recent CPMI-IOSCO Principles for Financial Market Infrastructures (CPMI-IOSCO 2012, 2015) require CCPs to publish margin breaches to increase transparency. Huang & Takáts (2020), for example, use such data to analyze model risk and conclude that CCPs with more skin-in-the-game are associated with more prudent initial-margin setting. Finally, Capponi et al. (2020) find that CCPs set margins more conservatively than standard value-at-risk measures would imply.

The study of positive correlation across member positions has been taken up theoretically by Menkveld (2015), who calls them "crowded positions".[20] Crowded positions arise when multiple investors take positions on the same side of the market, and thus end up with highly correlated portfolios. This can put the CCP at risk, since multiple members are likely to default at the same time.[21]

Crowded positions have then been showed to be empirically relevant by Menkveld (2017). This paper starts from a simple but important observation: current methodologies used by CCPs compute margins for each member based on the characteristics of the

[18] In a "client clearing" regime, large CCP members (typically dealers) clear the derivatives portfolio of their client end-users.

[19] In this literature, margin breaches are often interpreted as the probability of default of a member vis-à-vis the CCP. However, upon a margin breach, a CCP would call additional margin that the member may be able to pay using unencumbered resources. These resources are often left unmodeled, because they are hard to observe in practice. Also note that a member may default on its commitments vis-à-vis the CCP for reasons unrelated to changes in the price of cleared portfolios.

[20] Crowding in financial markets has also been studied by Pedersen (2009).

[21] Menkveld (2015) also shows that, while crowding may be excessive, the optimal level of crowding is not zero. Also note that, in a CCP context, crowding can only be a concern for a subset of members, since CCPs operate, by definition, with matched books (that is, with a long position for every short position, and vice versa).

member's own portfolio (volatility, size, diversification, etc.). As such, margin methodologies overlook the risk associated with correlated exposures across members. Menkveld (2017) proposes measures of CCP exposure (inspired by Duffie & Zhu 2011) that account for crowded positions, as well as measures of crowding per se. This method can potentially be used to collect more resources from members that contribute more to crowding – a method which is akin to a polluter-pay principle.[22] The paper also empirically documents that measures of crowding spike when aggregate or idiosyncratic volatility rises – which further confirms the relevance of crowded positions for systemic risk. A similar intuition is explored by Cruz Lopez et al. (2017), who build on the *CoVaR* methodology of Adrian & Brunnermeier (2016) (albeit with some differences) to propose a methodology called *CoMargin*. Using copulas, they estimate the multivariate profit-and-loss distribution of the clearing members in a CCP. The CoMargin of a clearing member is then computed based on its probability of margin breach conditional on one or several other clearing members also facing margin breaches. Furthermore, building on Menkveld (2017), Huang et al. (2020) propose a methodology to decompose intraday changes in CCP exposure, after accounting for crowded positions. The exposure of CCPs is decomposed at high frequency into price components (changes in the level, the volatility, or the correlation of price changes) and trade components (changes due to new trades and to crowding).

Finally, the literature on margins gives rise to an emerging literature on stress-testing of CCPs. The early attempts in this respect were heavily inspired by the large literature on the stress-testing of banks (Benoit et al. 2017), and thus failed to account for the specificities of CCPs (as pointed out by Cox & Steigerwald 2018). These specificities include obviously the key role of margins and of other resources originating from the default waterfall (see next section), as well as specificities associated with the treatment of derivatives in bankruptcy (Bliss & Kaufman 2006). One recent study by Paddrik et al. (2020a), focusing on variation margin calls following a shock, finds that CCPs limit rather than amplify the propagation of shocks in networks.

4.2. Default waterfall and CCP resolution

In addition to margins, CCPs can use a variety of other resources to protect themselves against the potential default of members. These resources, described by Duffie (2015), are known as the CCP's "default waterfall:" Typically, after a defaulting member's margins and default fund contributions have been used, a first tranche of the CCP's equity is impaired, then resources mutualized across members (default fund) are used. If this is not enough, then a second layer of CCP equity is impaired, before exceptional end-of-waterfall procedures are used, such as variation margin gains haircutting or contractual tear-ups.[23] Whenever losses fall deep into the default waterfall, the CCP itself may experience financial distress. In the current context, where central clearing is mandatory and CCPs are *de facto* key financial market utilities, the failure of CCPs is expected to be disastrous. This topic

[22]Whether these resources should be collected in the form of margins or via other forms of contributions (default fund, CCP equity) remains an open question. Another open question is how alternative margining rules would change the sets of members and portfolios.

[23]Theoretically, the main attempts to model the default waterfall of CCPs is by Kuong & Maurin (2020). The distinction between resources that are mutualized and resources designed to alleviate moral hazard is modeled by Biais et al. (2012), while Wang et al. (2018) model explicitly the distinction between default funds and initial margins at the end of default waterfalls.

also gives rise to growing policy discussions.[24]

So far, the study of CCP failures has been limited to a few historical cases. A first merit of these studies is to show that CCP failures or near-failures are not impossible. Three cases of CCP failures are most often cited: the failure of the *Caisse de liquidation* in Paris in 1974, that of the Kuala Lumpur Commodity Clearing House in 1983, and that of the Hong Kong Futures Guarantee Corporation in 1987.[25] There are also a few examples of near failures, for example in the US during the October 1987 crash (Bernanke 1990), or in 2018 in the Nordic energy market, when the failure of the Norwegian investor Einar Aas put the CCP at risk (Bell & Holden 2018).[26] So far, the most detailed study of a CCP failure, based on archival data, is Bignon & Vuillemey (2020), who study the failure of *Caisse de liquidation*, a CCP mostly active in the market for sugar futures, which failed in 1974 following the failure of its largest member when sugar prices collapsed (following a boom).

Bignon & Vuillemey (2020) first discuss the factors that led to large losses for the CCP. Among them is the existence of crowded exposures, in the sense of Menkveld (2017), as well as of a single position of extremely large size. In this context, while average margin levels were arguably appropriately set, no mechanism was used to contain the growth of large positions, which are arguably more costly to liquidate (and should thus be accompanied by higher initial margins). However, the most novel part of the analysis concerns the existence of severe agency problems around distress. First, there is evidence of risk-shifting incentives (Jensen & Meckling 1976). Specifically, when the largest member defaulted on margin calls amidst falling sugar prices, the CCP realized that this would impair its equity, and took the decision to delay the liquidation of the defaulted position. This decision is interpreted as a bet on a price reversal: if sugar prices fall further, the loss for the CCP becomes larger, but its equity value is bounded from below by zero (due to limited liability); instead, if sugar prices revert, the member does not default anymore, and CCP equity is not impaired. Unfortunately for the CCP, this "gamble for resurrection" did not succeed. Second, Bignon & Vuillemey (2020) show that the CCP had incentives to misreport relevant information to the regulator (akin to a resolution authority) in order to obtain a write-down of its debt vis-à-vis surviving members, to the benefit of the defaulted member. In plain terms, the CCP, which usually operates a matched book and thus has no incentives to favor a particular member, can have – in extreme stress scenarios – interests that become aligned with those of defaulting members.[27]

4.3. The governance of CCPs

Besides financial resources, the governance of CCPs is also essential to their stability, as the historical example of *Caisse de liquidation*, discussed in the previous section, illustrates.

[24] On the policy side, guidelines about risk management in CCPs are part of the Principles for Financial Market Infrastructures (PFMI), issued by the Committee on Payments and Market Infrastructures (CPMI) and by the International Organization of Securities Commissions (IOSCO). See, for example, CPMI-IOSCO (2017). As pointed out by Braithwaite & Murphy (2016), legal certainty will arguably be critical to handle CCPs defaults in the future.

[25] See Hills et al. (1999) for a brief overview of these three events. The events in Hong Kong gave rise to a public report by Davison (1988), whose findings are summarized by Cox (2015).

[26] Another example of near-failure, the New Zealand Futures and Options Exchange, is studied by Budding et al. (2016).

[27] Bignon & Vuillemey (2020) show that this further led the CCP to reject value-improving renegotiation plans, which is another form of risk-shifting.

Specifically, CCPs can be organized as for-profit or as member-owned institutions.[28] In a member-owned structure, clearing members are also equity holders and play an active role in the management of the CCP. In a for-profit structure, equity holders are external investors pursuing profit maximization. The advantages of for-profit structures are well-known; for example, the interests of equity holders and of other creditors are generally aligned, except when close to distress.[29]

However, it is doubtful whether the for-profit model is optimal for CCPs, for at least two reasons. First, the market for central clearing is unlikely to be perfectly competitive because of the benefits obtained from multilateral netting. Therefore, the management of a CCP is unlikely to be disciplined by competition. For example, it could charge excessively high clearing fees to members. Second, managers of a for-profit CCP are unlikely to internalize the costs that the default of the CCP may impose on financial markets. We are thus in a situation where equity holders of a CCP may benefit from risky strategies when they work, while externalizing its costs to financial markets at large when they fail. This intuition is modeled by Huang (2019), who provides a rationale for the "skin-in-the-game" that CCP equity holders have (that is, the first tranche of equity in the default waterfall): It provides better incentives to manage risk, and avoids too much of the cost of defaults to be shifted to surviving members. This paper also shows, perhaps surprisingly, that a CCP with higher equity also chooses higher margin requirements – a correlation that Huang (2019) observes in the data.

While research on the governance of financial market utilities remains scarce, a few papers suggest that member-owned structures may be preferred.[30] This is the case in Huang (2019), in which a member-owned CCP is assumed to solve the social planner problem, rather than to maximize profit. In the presence of large externalities associated with misguided risk management decisions, member-owned structures have advantages: members should internalize the consequences of mismanagement (e.g., the fact that the market may freeze or dysfunction). Cox & Steigerwald (2016) also point to advantages of member-owned CCPs. They note that a for-profit model is associated with recurring conflits between CCPs and their members, about either risk management (too much risk being taken) or about the pricing of clearing services (CCPs extracting rents). A greater involvement of members in the governance of CCPs can mitigate these agency conflicts.[31] While the advantages of a member-owned model are clear, its costs can be discussed based on Hart & Moore (1996), one of the of the very few papers discussing the governance of cooperatives. In particular, if membership is more diverse, and a member-owned institution relies on majority voting, it is possible that inefficient decisions are taken. Another possibility is that current members restrict access to new members in order to limit competition.[32] Given that the market for

[28]In the case of for-profit CCPs, an open question relates to the effect of the identity of equity-holders. In some cases, the exchange can own the CCP, creating a "vertical silo." For example, in 2019, the Chicago Board Options Exchange (CBOE) acquired EuroCCP.

[29]See Shleifer & Vishny (1997) for a survey on the governance of for-profit corporations.

[30]An older but related literature looked at the trade-offs between member-owned and for-profit securities exchanges. See for example Pirrong (2000) and Aggarwal (2002).

[31]Even in for-profit CCPs, members typically have some role in CCP governance, for example, participating in risk committees.

[32]See, e.g., "A Secretive Banking Elite Rules Trading in Derivatives," *New York Times*, December 11, 2010.

clearing is unlikely to be competitive, such attempts may succeed.[33]

4.4. CCP fragmentation and CCP basis

Regarding the design of central clearing institutions, a last topic that has received attention is that of market fragmentation, that is, trade-offs arising from the existence of multiple CCPs for a given asset class. The study of this trade-off goes back to Duffie & Zhu (2011). While the use of multiple CCPs within a given asset class may bring benefits in terms of financial stability or regulation, it also breaks "netting sets," thus reducing opportunities for multilateral netting. Figure 1(f) illustrates this inefficiency. In the left chart, there is a single CCP between A and B and the arrows indicate *net* exposures. If an additional CCP is introduced, then if member A cleared his long position in some security through CCP_1, but his short position in a highly correlated security through CCP_2, then exposures in the system can be larger in the two-CCP case.

This form of fragmentation has been most carefully studied by Benos et al. (2019), and is shown to give rise to a "CCP basis," that is, an equilibrium difference between the prices of two identical contracts, depending on the CCP in which they are cleared. Theoretically, they build a model of inventory management with the following structure: clients are required to clear transactions with the local CCP, while dealers act as liquidity providers across jurisdictions. This market structure implies that dealers clear similar contracts at different CCPs. This increases their collateral requirements, and even more so if inventory imbalances exist across markets. Provided that collateral is costly, this leads dealers to quote higher or lower prices across markets characterized by different levels of local inventories and netting opportunities (as in Ho & Stoll 1981; Hendershott & Menkveld 2014). Therefore, this gives rise to a non-zero CCP basis.

From this model, Benos et al. (2019) derive a number of predictions which they test using data on dollar-denominated swaps cleared by two CCPs: London Clearing House (LCH) and CME. First, the CCP basis should allow dealers to recoup collateral costs, and thus increase when collateral is more costly to pledge. This should be the case either when more collateral has already been pledged, or when the credit risk of dealers rises.[34] Empirically, it is indeed the case that the CME-LCH basis correlates positively with these two quantities. Second, the CCP basis should be lower when there are more sophisticated clients who can choose where to clear. Third, the local quoting activity of dealers should depend on local inventories, and contribute to reduce the basis. In time-series specifications, these two other predictions are also confirmed. Finally, the magnitude of the CCP basis over the sample period (2014 to 2016) fluctuates between one and four basis points, which is economically significant given the large size of swap markets. Clearing fragmentation thus has meaningful asset pricing consequences.

[33]This mechanism helps explain the wave of stock exchange demutualizations that occurred in the 1990s (Aggarwal & Dahiya 2006).

[34]One reason why higher credit risk translates into a higher marginal cost of collateral for dealers is because it worsens debt overhang problems associated with entering new trades (Andersen et al. 2019).

5. POLICY INTERVENTION IN CENTRAL CLEARING

CCPs had remained lightly regulated until the global financial crisis of 2008-2009. Since central clearing became mandatory for a large set of transactions, a number of new issues arise. Many of them remain open and deserve further research.

5.1. Why mandate CCPs? The socially optimal level of central clearing

Central clearing became mandatory for a large set of "standardized" derivatives following the financial crisis of 2008-2009.[35] The clearing mandate was part of the Dodd-Frank Act in the United States and of the European Market Infrastructure Regulation (EMIR) directive in Europe.[36] Furthermore, regulation also aimed to penalize transactions that remain bilateral with high margin requirements. The regulators' goal is to move most of the trading volume to CCPs.[37] Given that central clearing arose as a private arrangement between investors (Vuillemey 2020b) and existed in a variety of markets long before any requirement came into place, a natural question is why central clearing needs to be mandated. In other words, one needs to explain why the level of central clearing that exists between private agents can be too low from a social perspective.

One first possibility is that central clearing is not adopted by private agents because of a coordination failure. This stems from the fact that central clearing features network externalities, like other technologies such as the telephone (Katz & Shapiro 1985, 1986). Indeed, the possibility to engage in multilateral netting implies that, if everyone is already part of a CCP, a marginal investor also wants to join the CCP. Instead, if no investor is part of a CCP, the incentives to join are non-existent: for an investor, being the first member of a CCP would imply losing bilateral netting opportunities while not enjoying any benefits from multilateral netting.[38] A CCP can thus be created only if sufficiently many investors coordinate to join a CCP. Historically, it is indeed the case that CCPs appeared primarily in markets where coordination costs are low (e.g., in the inter-dealer market for OTC derivatives).[39] Therefore, it is plausible that some value-enhancing CCPs are not created. If so, the role of the regulator is simply to force coordination on the efficient

[35]Besides Lehman Brothers, the failure of Bear Stearns also played a role in shaping the regulators' decisions (Brunnermeier 2009). Some papers, such as Cerezetti et al. (2019), challenge the view that CCPs are the best instrument to enhance financial stability. They argue that financial stability is a public good, while CCPs can only manage club goods. Others suggest amendements to existing rules (Murphy 2020).

[36]The Financial Stability Board regularly publishes progress reports on the implementation of OTC derivatives market reforms. See, for example, FSB (2019).

[37]Ghamami & Glasserman (2017) use simulations, calibrated to confidential data on the positions of large banks, to argue that the cost advantage imposed by regulators in favor of centrally cleared trades in not clear-cut, even after accounting for higher margins on bilateral transactions. This can explain why a significant share of derivative transactions remains uncleared as of 2020. Instead, comparing bilaterally and centrally cleared interest rate swaps using real data, Cenedese et al. (2020) provide empirical evidence that EMIR regulation made bilateral trades more costly.

[38]In their simulations for the CDS market, Duffie et al. (2015) confirm that the aggregate collateral demand is non-monotonic in the fraction of centrally cleared transactions. A low fraction of central clearing leads to higher collateral needs (since the loss of bilateral netting benefits dominates), while a high share of central clearing reduces aggregate collateral demand (since benefits from multilateral netting start to dominate).

[39]At the end of the 19th century, CCPs appeared first in futures exchanges where traders knew each other well or had strong family ties (Depitre 1907).

outcome.

A second general reason why regulators may want to mandate central clearing is because they believe that the level of protection against counterparty risk that agents privately choose is too low. For example, while requiring collateral from each other, agents may still demand too little collateral, and thus default too often in equilibrium. This can be because they don't internalize the cost of their default onto other market participants (or on the government and the real economy). Such an argument can be made given any of the theoretical rationales for collateralization (see Section 2.2), particularly if the failure of trading institutions is costly, because of, for example, their large size.[40]

Another possible reason for a clearing mandate stems from the friction that an investor may not be able to observe a counterparty's positions with other investors.[41] Acharya & Bisin (2014) and Leitner (2012) show that in this case, the counterparty might leverage excessively, by promising the same amount of resources to various other parties. This gives rise to a "counterparty risk" externality. Acharya & Bisin (2014) and Leitner (2012) show that inefficiencies coming from this counterparty risk externality can be suppressed if trade occurs via a single counterparty, which is able to observe all transactions. This institution can be interpreted to be a CCP.[42]

5.2. Moral hazard and regulation of CCPs

While central clearing has benefits, mandatory central clearing also has costs. Therefore, it is an empirical question whether clearing mandates bring significant improvements to the functioning of financial markets – and research at this stage remains scarce.[43] Specifically, mandatory central clearing is likely to create novel agency problems, in the form of moral hazard. Moral hazard is of two types. First, it creates moral hazard for the CCP itself. Indeed, before the clearing mandate, CCPs had to attract investors in order to operate. Afterwards, CCPs have a captive clientele, since investors are required to clear and competition between CCPs is limited. This could potentially induce CCPs to relax risk management standards, for example to attract larger quantities of trades. This is even more the case now that CCPs are becoming an order of magnitude larger than before, and thus more systemic. In a context where they are mandatory, it is hard to believe that distressed CCPs could be resolved just as any other firm. In this context, implicit guarantees exist (France & Kahn 2016), and have sometimes become explicit in the form of commitments by central banks to lend to CCPs. These guarantees are known to create convexity in the equity value function, and thus to incentivize higher risk-taking (see, for example, Keeley 1990).

[40]There is a large literature studying the costs associated with bank failures (Ashcraft 2005), and more generally associated with shocks to banks (Chodorow-Reich 2014).

[41]Relatedly, Koeppl et al. (2012) study a case where agents are imperfectly able to write bilateral contracts in order to mitigate counterparty risk.

[42]Interestingly, Leitner (2012) shows that a clearing mandate may not be necessary. By setting position limits appropriately, the CCP can induce agents to clear all their bilateral trades via the CCP voluntarily, even if this involves some small cost.

[43]Other aspects of the post-crisis OTC derivatives market reform have been studied more carefully, including centralized trading (Benos et al. 2020; Collin-Dufresne et al. 2020; Loon & Zhong 2016) and the pricing of OTC derivatives (Cenedese et al. 2020). Ranaldo et al. (2020) show that the new regulatory framework induces CCPs to supply large amounts of cash in reverse repurchase agreements (repos) thus decreasing short-term rates.

Second, while CCP members in an unregulated market have incentives to monitor the CCP (since they bear the cost of its failure), these incentives are weakened when central clearing is mandatory. Instead, members may benefit from loose CCP risk management (lower clearing fees and lower margins) most of the time, also betting on high transfers from the government in stress periods. Thus, not only the CCP could choose risk to maximize the value of risk transfers to the government, but members as well.

Given these new agency problems, the regulation of CCPs seems warranted. Unfortunately, at this moment, there is very little work on the regulation of CCPs. Theoretically, the main goal should be to curb risk-taking incentives. Among the main topics being discussed in policy circles are, for example: standardization of initial margins, constraints on CCP leverage, and more explicit regulation of the recovery and resolution of CCPs. These topics are largely open for future research.

6. CONCLUSION

While the literature on central clearing has made significant progress over the past ten years, a number of important questions remain open. On the theoretical front, there is still no standard model of the capital structure of CCPs, of the structure of their default waterfall, of their governance, and of client clearing. This leaves room for important future contributions, given the centrality of policy debates on this question. That said, how to optimally structure CCPs and their resources must depend on the specific financial friction they are meant to mitigate. In this respect, empiricists should work increasingly on the economic function of CCPs. Whether CCPs are primarily valuable for collateral netting, for enforcement of margin calls, or to mitigate adverse selection or moral hazard problems, remains an open question. Relatedly, there is still very little theoretically motivated empirical assessments of the post-2008 reforms. A related topic is also that of the interaction between CCPs and other financial market infrastructures, such as trading platforms or swap execution facilities. Finally, CCPs potentially raise new risks, which are still poorly understood. For policymakers, an open issue is the design of stress testing exercises that account for the specificities of CCPs and are not just the same tests as those used for banks. More broadly, the potential recovery and resolution of CCPs remains a largely unexplored question.

SUMMARY POINTS

1. When markets are perfect, the Modigliani-Miller theorem applies and CCPs cannot create any value. The existence of CCPs presupposes financial frictions.
2. CCPs are counterparties to all traders and can thus set margins based on net positions. Such multilateral netting reduces collateral demand.
3. CCPs mutualize idiosyncratic default risk through default funds, and can thus act as insurance providers. Insurance comes at the cost of reduced incentives for members to monitor counterparties when trading.
4. CCPs can avoid socially costly fire-sale dynamics by coordinating traders on a socially preferred outcome after a member defaults (e.g., by applying penalties for low bids in a follow-up auction).
5. Empirical studies show that the introduction of CCPs affects the trading in secondary markets (e.g., a lower required return and less risk) and thereby affects the real economy (e.g., global coffee flows in 19th century).

6. Studies on the optimal design of CCPs focused on several issues: crowded positions that create exposure beyond what member-specific margins account for, the default waterfall, and the level of skin-in-the-game for non-member owned CCPs, CCP fragmentation, and, more generally, the corporate governance of CCPs.
7. The regulation of CCPs is non-trivial. Network externalities create a role for regulators to coordinate investors on a socially desirable equilibrium. However, CCPs are systemic in nature because they absorb all counterparty risk in securities markets. This creates a need for regulatory oversight and, potentially, for financial support, which in turn creates moral hazard.

FUTURE ISSUES

1. Theoretically, there is a need for a standard theoretical model of CCPs that allows studying capital structure, the default waterfall, and governance.
2. Empirically, more evidence is needed on the relative importance of the various channels through which CCPs could add or destroy value (e.g., multilateral netting, insurance, fire-sale prevention). A related question is how the importance of these channels might depends on the way securities are traded (i.e., secondary-market structure), on the risk profile of the securities, on the size and composition of the clearing members, on the state of the economy, or even on the legal framework in particular jurisdictions (e.g., priority rules in bankruptcy).
3. For policymakers, there is a need to design stress testing methods that account for the idiosyncrasies of CCPs (as opposed to banks). This concern is acknowledged by policymakers (CPMI-IOSCO 2016) and increasingly taken up by academics (Paddrik et al. 2020b).
4. The recovery and resolution of CCPs remains a largely unexplored topic.
5. How CCPs invest their collateral and how this is affected by regulation (liquidity ratios) is also an unexplored issue.
6. Investors who are not CCP members are required to clear via client accounts held with one of these members. The workings of the client clearing market is an open question. How do CCP members compete for this business? Can there be inefficiencies in this market? One choice clients have is to make accounts portable or pool them with other members. What are the consequences of these choices?
7. A policy question is whether central clearing should extend to new markets, e.g., repos or Treasuries (Duffie 2020).
8. More broadly, relationships with the literature on payment systems need to be explored. While a key benefit of CCPs is that they allow settling positions in net terms, payment systems in many jurisdictions have evolved towards gross settlement (via real-time gross systems, or RGTS). The reasons for this difference are worth exploring.

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