The Effects of Imposing a Central Counterparty in a Network*

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1 Introduction

A recent regulatory change involves the use of clearing in financial transactions. Under the new Dodd-Frank mandatory clearing regime, the ultimate counterparty of several transactions (swaps, futures, derivatives, etc) will no longer be the entity at the other side of the transaction. Instead the transaction will be submitted to a Central Clearinghouse (CCP) for clearing. Once cleared, the Clearinghouse is the counterparty to all trades, and the regulatory bodies (CFTC and SEC) will impose constraints that mitigate risks. Similar steps have been recently followed by the European Union's new regulations.[1]

The rationale of forcing the use of CCPs is to reduce counterparty risk and to mitigate network effects. What is the effect of these impositions on the way banks interact with each other? Why banks were not exploiting clearing in absence of regulations? We construct a model to understand how the network may change with and without clearinghouses and how those changes can translate in a stronger potential for contagion and endogenously higher financial fragility, and also what is its impact on the efficiency of the banking sector.

*The views expressed in this paper do not necessarily reflect those of the Federal Reserve Bank of Philadelphia or the Federal Reserve System.

[1]For details about the use of CCPs see Duffie et al. (2015) and for historical analysis of their role and performance Bignon and Vuillemey (2018) and Vuillemey (2018).

The model highlights a trade-off between the benefit of CCPs improving coordination and the costs in making transactions too transparent, opening the doors for new sources of contagion and fragility. We have access to confidential data on Capital Assessments and Stress Testing Reports (FR Y-14Q report) allows us to study how the network has changed upon the new regulations.

2 Opaque Market Without Multilateral Netting

2.1 Static benchmark

Banks and agents Consider n banks $Y = \{y_1, ..., y_n\}$, called the core. Each bank y_i has access to an outside lender (or *investor*) z_i that provides liquidity to y_i and has a counterparty bank x_i, with access to productive investment opportunities (or *projects*). The set of these counterparty banks $X = \{x_1, ..., x_n\}$ is called the periphery. Core serves the purpose of intermediating funds from outside lenders to the periphery, who then use those funds for projects as they do not have direct access to those investors.

At most one outside lender receives liquidity. z_i has probability γ_i of having 1 unit of liquidity. Moreover, z_i has an outside option of obtaining net return $r_i > 0$ on its liquidity, where r_i is drawn randomly from some distribution with CDF F. The outside lender z_i can lend to y_i at a rate r_z. Core banks can lend to each other at rate $r_y > r_z$. Core bank y_i can lend to periphery bank x_i at rate $r_x > r_y$. For the moment, all these interest rates are assumed exogenous.

Core Banks - Legacy Assets and Managers. Core banks have *legacy assets* and *managers*. There is $1 - \alpha/\alpha$ probability that a core bank has a good/bad manager. We simply call a core bank with a good/bad manager a good/bad core bank. Good core banks get return $a > 0$ from their legacy assets whereas bad core banks get 0 from their legacy assets.

Periphery Banks - Projects. Periphery banks have access to a safe project and a risky project. The safe project has a net rate of return $\underline{r} > 0$ with probability $\overline{p}$ and 0 net rate of return with probability $1 - \overline{p}$. The risky project has $\overline{r} > \underline{r}$ net rate of return with probability $\underline{p} \in (0, \overline{p})$ and 0 net rate of return with probability $1 - \underline{p}$. We assume $\overline{p}\underline{r} > \underline{p}\overline{r}$ so that safe projects are the efficient investments.

Lending and Collateral. Periphery banks have no collateral and interbank loans from core to periphery are not backed by anything besides the return from the projects, which we assume pledgeable. Both legacy assets and interbank loans can be used to collateralize the loan of outside lenders, but only interbank loans can be used to collateralize loans across core banks (for instance, because only core banks can understand and evaluate legacy assets).

Monitoring. We assume that $\underline{p}\,(\overline{r} - r_x) > \overline{p}\,(\underline{r} - r_x)$ and so the banks in the periphery prefer the risky project (this is just a standard *risk-shifting problem* from limited liability). If y_i lends to x_i, y_i prefers that x_i uses the safe project because $\overline{p} > \underline{p}$. If y_i is a good core bank, it can monitor x_i effectively to make sure that x_i uses the safe project.

A good core bank has high probability of return $\overline{p} > \underline{p}$ due to monitoring and high collateral value $a > 0$ from its legacy asset. Accordingly, outside lenders would rather lend to good core banks. For simplicity we assume $a > r_z$ so that an outside lender's interest from lending to a good core bank is secured. Given that good core banks have enough skin in the game, we further assume $\overline{p}r_x > r_z$ so that they are willing to lend to periphery banks.

Information. Outside lenders cannot observe the details of the banking system: quality of managers, quality of projects chosen, and realized interbank lending. Banks, among themselves, know all details of the interbank system and the outside options of the outside lenders.

Liquidity provision and welfare. We assume $\overline{p}\left(r_y - r_z\right) > \underline{p}\left(r_x - r_z\right)$ so that a bad core bank would prefer to lend to a good core bank instead of directly lending to the periphery. This is because a good core bank is superior in implementing a better investment, then bad core banks would like to use that superior technology by transferring funds via the interbank network.

Now consider z_i that has 1 unit to lend. If z_i lends to y_i, and y_i has a good manager, then z_i's expected profit is $\overline{p}r_z + (1-\overline{p})\, min\left\{a, r_z\right\} = r_z$. If y_i has a bad manager and y_i lends to x_i, then z_i's expected profit is $\underline{p}r_z$. However, if there is a bank with a good manager, say y_j, y_i lends to y_j. Then z_i's expected profit is $\overline{p}r_z$. Accordingly, z_i's expected profit from lending to y_i is

$$\pi = \left(1 - \alpha + \alpha\overline{p} - \alpha^n\left(\overline{p} - \underline{p}\right)\right) r_z.$$

Therefore, z_i provides liquidity only if its outside options r_i is less than π, which has probability $F\left[\pi\right]$. Denote $\Gamma = \Sigma_{i\leq n}\gamma_i$, the probability that an outsider has liquidity. Then expected liquidity in the system is

$$l = F\left[\pi\right]\Gamma.$$

All liquidity is channeled through good banks to be used for safe projects, except when there are no good banks. Then expected welfare is

$$w = \left(\overline{p}\underline{r} - \alpha^n\left(\overline{p}\underline{r} - \underline{p}\overline{r}\right)\right) F\left[\pi\right]\Gamma + G\left[\pi\right]\Gamma.$$

where $G\left[u\right] := \int_{u'>u} xdF(u')$.

2.2 Dynamics and the steady state

Lending inside the core creates exposures between the core members. Nevertheless, in a static model, it is hard to imagine how such exposures can get tangled. Over time, such exposures can build up, in perhaps inefficient ways. Here we introduce a dynamic extension of the benchmark that leads to such exposures and study its steady state.

Time is indexed by t. Within a period t, the benchmark model applies. Manager qualities are drawn, banks obtain new legacy assets, outside lenders may receive liquidity and interbank lending channels funds toward safe projects. If there are multiple good banks, we assume that bad banks divide their loans equally between all good core banks.[2] Finally, before the period ends, all earlier projects, including the outside options of outside lenders, pay dividends.

Based on this timing, lending between banks also entails service payments over time in order to share the surplus from dividends. To make things tractable, we assume that goods are perishable (no savings from dividend retentions). At the end of each period, all remaining resources are consumed. Also, all projects have β probability of failing every period after their first period. Failed project stops yielding dividends and all associated future payments are voided.

Formally, before period t ends, earlier projects of period $t' < t$ pay dividends if they did not fail between periods t' and t. We assume those projects pay a fraction s to their initial returns. That is, if there has been at least one good core bank project in t', then all projects that have received investment in t' return an amount $s\overline{r}$ per unit invested. If all core bank at t' were bad, then projects of t' return $s\underline{r}$ at t. All lenders that contributed to intermediation in t' get an s fraction of the net payment they had received in time t', contingent on the project of t' still paying dividends.

Bank i pays bank j an amount sr_{ij} where r_{ij} is the corresponding rate between i and j in t'. Essentially, an s fraction of all new repayments due to lending within period t' are replicated every period after t'. This set of assumptions means that period incentives in the dynamic version mimic those of the static version, scaled by $1 + \frac{s}{1-\beta}$. Accordingly, decision within each period replicate those in the static model. Per period welfare in the steady state is, accordingly, $w\left(1 + \frac{s}{1-\beta}\right)$.

Exposures and netting. Unlike the static setup, the dynamic setup can lead to two banks lending to each other, and so owing to each other. Yet, such two sided exposures can be eliminated by bilateral netting. If y_i owes y_j D, and y_j owes y_i D, the netted exposure is 0. Bilateral coordination is very natural since the pair that is netting out their debt is already the pair that has engaged in lending. However, when there are more banks in the core, netting multilateral exposures may not be as easy just by virtue of bilateral coordination. For example, if y_1 owes y_2 an amount D, y_2 owes y_3 an amount D, the net exposure is that y_1 owes y_3 an amount D. y_2 could be taken out of the picture thereby mitigating the exposure of y_3 from being exposed to y_1 and y_2 to only being exposed to y_1. We call such situations *chain exposures*, as illustrated in Figure 1. In what follows, we study the implementations and extent of netting in our framework.

Evolution and the steady state of the system. There is a probability γ_i that z_i receives liquidity. With probability $F[\pi]$, z_i lends to y_i. If y_i is a good core bank, or there are no good

[2]Selecting one good bank or diversifying across all good banks in inconsequential for the steady state of the model.

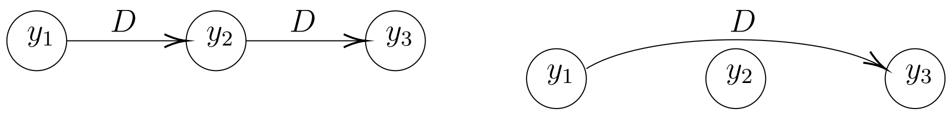

Figure 1: Chain exposures

core banks in the system at t, then y_i lends the funds to x_i. This does not add to the exposures inside the core. If y_i is a bad core bank, and there are good core banks, y_i will lend to a good core bank.

Take two core banks y_i and y_j. There is $\gamma_i F[\pi]\,\alpha(1-\alpha)$ probability that y_i will lend to y_j. In this case, if there are k more good banks, the loan from y_i to y_j will be $\frac{1}{k+1}$. Then the expected loan from y_i to y_j is

$$\gamma_i F[\pi]\,\alpha(1-\alpha)\,\mathbb{E}\left[\frac{1}{k+1}\right] = \gamma_i F[\pi]\,\frac{\alpha(1-\alpha-\alpha^{n-1})}{(n-1)}.$$

This implies that in steady state, the total amount of gross exposures of y_i to y_j is given by $D_{y_i y_j} = \gamma_i \zeta$ where

$$\zeta = F[\pi]\,\frac{\alpha(1-\alpha-\alpha^{n-1})}{(n-1)}\frac{s}{1-\beta}r_y.$$

The sum of all steady state gross exposures of y_i to other core banks is $E_{i+} = (n-1)\,\gamma_i\zeta$. The sum of all exposures of core banks to y_i is $E_{i-} := \zeta\sum_{j\neq i}\gamma_j$. The sum of all gross exposures is $\mathcal{E} = \zeta(n-1)\sum_i \gamma_i$.

Bilateral netting. We assume that gross exposures within the core are netted out by bilateral coordination. Given that i and j net out their outstanding debt to each other every period, the steady state net exposures are given by

$$D'_{y_i y_j} = (D_{y_i y_j} - D_{y_j y_i})^+ = (\gamma_i - \gamma_j)^+\,\zeta.$$

Note that at least one of $D'_{y_i y_j}$ and $D'_{y_j y_i}$ is zero. Without loss of generality, suppose that $\gamma_1 \leq \gamma_2 \leq ... \leq \gamma_n$. After bilateral netting, there is a hierarchy of exposures. All banks are exposed to y_1. All but y_1 are exposed to y_2. All but y_1 and y_2 are exposed to y_3... The total number of exposures in the bilaterally netted system is $n(n-1)/2$ because there is an exposure between every pair. The sum of y_i's bilaterally netted exposures to core banks are

$$E'_{i+} := \zeta\sum_{j<i}\gamma_i - \gamma_j.$$

The sum of bilaterally netted exposures of other core banks to y_i is

$$E'_{i-} := \zeta \sum_{j>i} \gamma_j - \gamma_i.$$

The sum of all bilaterally netted exposures in the core is

$$\mathcal{E}' = \zeta \sum_i (2i - n - 1)\, \gamma_i.$$

Effectiveness of bilateral netting. Clearly, $(n-1)\sum_i \gamma_i \geq \sum_i (2i - n - 1)\, \gamma_i$. So the total exposures decreases with bilateral netting. Moreover, $(n-1)\,\gamma_i \geq \sum_{j<i} \gamma_i - \gamma_j$ so exposures *of each bank* i decreases and $\sum_{j \neq i} \gamma_j \geq \sum_{j>i} \gamma_j - \gamma_i$ so exposures *to each bank* i also decreases. What is the extent of this change? For example, if $\gamma_n = \gamma_{n-1} = ... = \gamma_1 > 0$, exposures go down to 0 with bilateral netting. If $\gamma_n > 0 = \gamma_{n-1} = ... = \gamma_1$ there is nothing to net, and exposures do not change with bilateral netting. In general, $\mathcal{E}'/\mathcal{E} \in [0,1]$ and these bounds are tight. Nevertheless, this is the only case wherein there is no reduction. The following proposition summarizes these cases.

Proposition 1. *Fix* $\delta \in (0,1]$. *Suppose that* $\gamma_1/\gamma_n \geq \delta$. *Then*

$$\frac{\mathcal{E}'}{\mathcal{E}} = \frac{\sum_i (2i - n - 1)\, \gamma_i}{(n-1)\sum_i \gamma_i} \in \left[0, \frac{1}{2}\frac{1-\delta}{1+\delta} + o(n)\right].$$

Accordingly, bilateral netting reduces sum of exposures -across banks that receive liquidity- by about at least 50%. Let's further illustrate over a leading example, which we will use repetitively.

Example. (Lead example) Suppose that $\gamma_i = \gamma + i\epsilon$ for some $\gamma \geq 0$ and $\epsilon > 0$. Note that $\Gamma = \Sigma\gamma_i = n\gamma + n\,(n+1)\,\epsilon$. In this case, $D_{y_i y_j} = \zeta\,(\gamma + i\epsilon)$ whereas for $j < i$, $D'_{y_i y_j} = (i - j)\,\epsilon\zeta$. Also,

$$\frac{\mathcal{E}'}{\mathcal{E}} = \frac{\sum_i (2i - n - 1)\,(\gamma + i\epsilon)}{(n-1)\sum_i (\gamma + i\epsilon)} = \frac{(n+1)\,\epsilon}{6\gamma + 3\,(n+1)\,\epsilon} = \frac{\Gamma - n\gamma}{3\Gamma + 3\gamma} \leq \frac{1}{3}.$$

The exposures are reduced by at least 66% using bilateral netting. If ϵ is sufficiently small compared to γ, meaning that banks have similar lender pools, then the exposures are significantly mitigated by bilateral netting, down to near 0 compared to the gross exposures.

Excess exposures within the core. Bilateral netting reduces exposure, potentially by a large magnitude depending on parameters, but not completely. Consider the exposure of y_3 to y_2 and y_2 to y_1. y_2 is exposed y_1 an amount $(\gamma_2 - \gamma_1)\,\zeta$, y_3 is exposed to y_2 an amount $(\gamma_3 - \gamma_2)\,\zeta$. There is a chain exposure from y_3 to y_2 to y_1. If $\gamma_2 - \gamma_1 > \gamma_3 - \gamma_2$. In this case, the exposure of y_3 to y_2 could be entirely eliminated with trilateral netting. The exposure of y_2 to y_1 would be reduced and y_3 would be exposed only to y_1. This would mitigate any unforeseen risk that

y_2 might fail and y_3 does not get paid by y_2, which would have consequences for all banks down the line: $y_4, y_5, \ldots$. In the next section we explore how multilateral coordination could reduce further such excess exposures that bilateral netting cannot eliminate.

3 Opaque Market with Multilateral Netting

Multilateral netting and reduced system of exposures. How to mitigate these excessive exposures in the core? For every $i < j < k$, there is a chain exposure between banks y_i, y_j, y_k. Initially, there are $\binom{n}{3}$ such chains. Trilateral netting can be useful in doing so. For any triplet, there is a unique way to net its exposure. Then pick an arbitrary $3-$chain and net out the exposure. Keep doing this iteratively choosing a different $3-$chain every time as long as there are chain exposures in the system. At each step of the trilateral netting sequence, the number of such $3-$chains decrease strictly. Inductively, at the end of the iteration, there will be no chain exposure left anymore. We call the resulting system of exposures a *reduced system.*

Here, trilateral netting is not critical; any sequence of multilateral netting ends up with a reduced system. Nevertheless, the reduced system is path dependent and there are potentially multiple reduced systems. Let's illustrate this insight with our lead example.

Lead example. Going back to the example, figure 2 illustrates two reduced systems for $k = 4$. In the first one, the order of trilateral netting is $\{y_1, y_2, y_3\}$, then $\{y_1, y_3, y_4\}$. In the second one, the order of trilateral netting is $\{y_1, y_2, y_4\}$, then $\{y_1, y_3, y_4\}$.

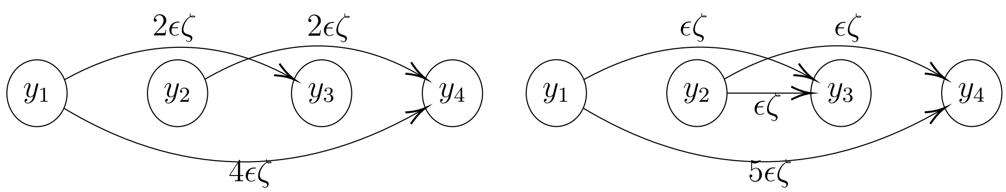

Figure 2: Path dependent reduced systems

The total exposure of any bank and the total exposures to any bank is invariant to the ordering of netting. Denote $E''_{i+} := \left(E'_{i+} - E'_{i-}\right)^+ = \left((2i-n)\,\gamma_i - \Gamma\right)^+$ and $E''_{i-} = \left(E'_{i-} - E'_{i+}\right)^+ = \left(\Gamma - (2i-n)\,\gamma_i\right)^+$.

Proposition. In any reduced system, y_i's netted total exposure is E''_{i+} and exposures to y_i is E''_{i-}. Banks get divided into two groups; one group is exposed to the other group. No bank has incoming and outgoing exposures at the same time. In other words, the dynamic structure generates a natural hierarchy that resembles a core-periphery structure inside the core itself.

The number exposures in the reduced system is at most $n^2/4$. That is at least 50% reduction compared to the bilaterally netted system wherein the number of exposures is generically

$n\left(n-1\right)/2$. The sum of all exposures gets reduced down to

$$\mathcal{E}'' := \sum E''_{i+} = \sum E''_{i-} = \sum_i \left(\left(2i-n\right)\gamma_i - \Gamma\right)^+ .$$

Exposures always get weakly reduced and so $\mathcal{E}'' \leq \mathcal{E}'$. What is magnitude of the exposure reduction due to multilateral netting? If the bilaterally netted exposures were cyclic, such as $D'_{12} = D'_{23} = D'_{31} > 0$ then multilateral netting would reduce the exposures down to 0. But the underlying economic structure entails a time-invariant arrival process for liquidity, and so does not lead to such cyclic exposures. There is an upper bound to the success of multilateral netting (i.e. lower bound to $\mathcal{E}''/\mathcal{E}'$).

Proposition 2. *Let k be given by $\left(2k-n\right)\gamma_k > \Gamma$. Then*

$$\frac{\mathcal{E}''}{\mathcal{E}'} = \frac{\sum_i \left(\left(2i-n\right)\gamma_i - \Gamma\right)^+}{\sum_i \left(2i-n-1\right)\gamma_i} = \frac{\sum_{k+1}^n \left(2i-n-\left(n-k\right)\right)\gamma_i - \left(n-k\right)\sum_1^k \gamma_i}{\sum_i \left(2i-n-1\right)\gamma_i} \in [\underline{??}, 1]$$

Example. Going back to the lead example, in the original bilaterally netted system, the total exposures of bank y_i is $E'_{i+} = \left(i-1\right)i\epsilon\zeta/2$. The sum of all exposures to bank y_i is $E'_{i-} = \left(n-i\right)\left(n-i+1\right)\epsilon\zeta/2$. The sum of the exposures of banks in the core is then given by $\mathcal{E}' = n\left(n+1\right)\left(n+2\right)\epsilon\zeta/6$. In the reduced system, y_i such that $i > n/2$ has exposures to y_j such that $j < n/2$. For $i > n/2$, the total exposure of y_i is $E''_{i+} = \left(\left(i-1\right)i - \left(n-i\right)\left(n-i+1\right)\right)\epsilon\zeta/2$ and $E''_{i-} = 0$. For $j < n/2$, the total exposures to y_j is $E''_{j-} = \left(\left(n-j\right)\left(n-j+1\right) - \left(j-1\right)j\right)\epsilon\zeta/2$ and $E''_{j+} = 0$. The sum of exposures in the system becomes

$$\mathcal{E}'' = \lfloor n/2 \rfloor \left(n+1\right)\left(n - \lfloor n/2 \rfloor - 1\right)\epsilon\zeta/2.$$

This is approximately a 25% reduction in total exposures compared to bilaterally netted exposures. It is true in general that coordination reduces the total amount of exposures quite significantly, but the exact magnitude of change is, naturally, case specific.

Regardless of the specific anatomy of exposure, the reduction of the system requires lengthy and complex coordination among many banks. Moreover, path dependence of the reduced system can be problematic to forecast for market participants and to regulate for policy makers. Perhaps the simplest way for banks to coordinate such multilateral netting is the so called clearinghouses. This has the added benefit of generating a unique outcome and removing path dependence. Clearinghouses have historically been an effective tool of netting out exposures and as such recently induced by regulatory changes. This section had the purpose to shed light on the benefits form such coordination on eliminating excessive exposure in the system.

4 Transparent Market Without Multilateral Netting

Now we go back to the benchmark with only bilateral netting and study the effect of opacity on the functioning and exposure in the system. Suppose that the interbank activity inside the core is public information. We start off with the static version to convey the main insights, then we move back to the dynamic model.

4.1 Static setting.

Upon observing the activity inside the core, outside lenders can withdraw their loans from core banks and use their outside option instead. We assume that managers are sufficiently likely to be good managers:

$$\alpha < \frac{1-\overline{p}}{1-\underline{p}}. \tag{1}$$

If z_i observes that y_i has lent to y_j, z_i infers that y_i is a bad core bank and so its legacy assets have low collateral value. In this case, the expected profit of z_i is $\overline{p}r_z$. If $r_i > \overline{p}r_z$, then z_i withdraws from y_i and uses the outside option. Therefore, y_i would lend to x_i instead of lending to y_j to mimic being a good bank. Ex-ante, z_i with $r_i > \overline{p}r_z$ knows that y_i lends to x_i regardless of the manager quality of y_i. Then z_i's expected profit is $\pi_T = \left(1-\alpha+\alpha\underline{p}\right)r_z$. Note that $\pi_T > \overline{p}r_z$ by (1). Then, if $r_i > \pi_T$, z_i does not lend to y_i in the first place. Liquidity withdrawal "unravels" into under-provision of liquidity.
All in all, if $r_i > \pi_T$, z_i does not lend. If $\pi_T > r_i > \overline{p}r_z$, z_i lends and y_i lends to x_i. If $\overline{p}r_z > r_i$, y_i lends to a good core bank y_j if there are any. Therefore, liquidity in the system is

$$l_T = F\left[\pi_T\right]\Gamma.$$

Note that $\pi_T < \pi$, so $l_T < l$. Market becomes less liquid.
$F\left[\overline{p}r_z\right]\Gamma$ is channeled within the core to good core banks. $\left(F\left[\pi_T\right]-F\left[\overline{p}r_z\right]\right)\Gamma$ is channeled directly to the periphery without being channeled inside the core by potentially bad core core banks. From an ex-ante point of view, $\left(F\left[\pi_T\right]-F\left[\overline{p}r_z\right]\right)\Gamma$ is channelled through random managers to be used for random projects. Welfare is then

$$w_T = \left(\overline{p}\underline{r}-\alpha^n\left(\overline{p}\underline{r}-\underline{p}\overline{r}\right)\right)F\left[\pi_T\right]\Gamma-\left(\alpha-\alpha^n\right)\left(\overline{p}\underline{r}-\underline{p}\overline{r}\right)\left(F\left[\pi_T\right]-F\left[\overline{p}r_z\right]\right)\Gamma+G\left[\pi_T\right]\Gamma.$$

Note that welfare changes more starkly than liquidity because project composition also gets distorted on top of the reduction in liquidity. For all reasonable parameters, welfare falls. If n is not too small so that composition of funded projects gets sufficiently distorted and $\underline{r}$ is not too close to r_z so that welfare gains and intermediation gains are not too misaligned, then welfare decreases.

The main takeaway of this set of assumptions is that opacity about core interbank relations allows bad banks to channel funds more efficiently to good banks without a fear to be identified as a bad bank. Once information about core interbank relations become available, signaling considerations prevent this outcome and induce a misallocation of resources that reduce welfare.

Dynamic case. As before, the dynamic incentives replicate the static incentives and so steady state welfare is $w_T\left(1+\frac{s}{1-\beta}\right)$. As for exposures, less liquidity is being channeled inside the core, and so the exposures fall.

Take two core banks y_i and y_j. There is $\gamma_i F\left[\overline{p}r_z\right]\alpha\left(1-\alpha\right)$ probability that y_i will lend to y_j. Similar analysis to before shows that the total amount of gross exposures of y_i to y_j is given by $D_{y_iy_j,T}=\gamma_i\zeta_T$ where

$$\zeta_T=F\left[\overline{p}r_z\right]\frac{\alpha\left(1-\alpha-\alpha^{n-1}\right)}{(n-1)}\frac{s}{1-\beta}r_y.$$

All exposures get scaled down by ζ/ζ_T compared to the opaque case. All in all, transparency makes the market less liquid, reduces welfare, but reduces exposures.

5 CCP and the transparent market with multilateral netting

In our framework, exposures do not get triggered hence do not affect ex-ante incentives. Accordingly, we do not need to take a stance on the resolution of the CCP in case it fails. The fact that all exposures get accumulated at the CCP do not effect the market forces regarding lending by outside lenders. Only the transparency aspect of the CCPs have an impact. Accordingly, the market with a CCP generates the effects given in the two previous sections combined. This is described in Figure 3.

Welfare is given by w_T and exposures are given by the reduced systems scaled down by ζ/ζ_T. So exposures get reduced by both central clearing and transparency. Central clearing does not impact welfare and liquidity but transparency reduces welfare and liquidity.

In future work, we will study a framework in which exposures get triggered and discuss 1) diversification benefits and potential volatility via CCP and 2) optimal resolution mechanisms of the CCP.

6 Preliminary Empirical Analysis

In order to analyze empirically the role of CCPs on systemic risk in the financial network and the allocation of resources, we plan to use derivatives data from the Capital Assessments

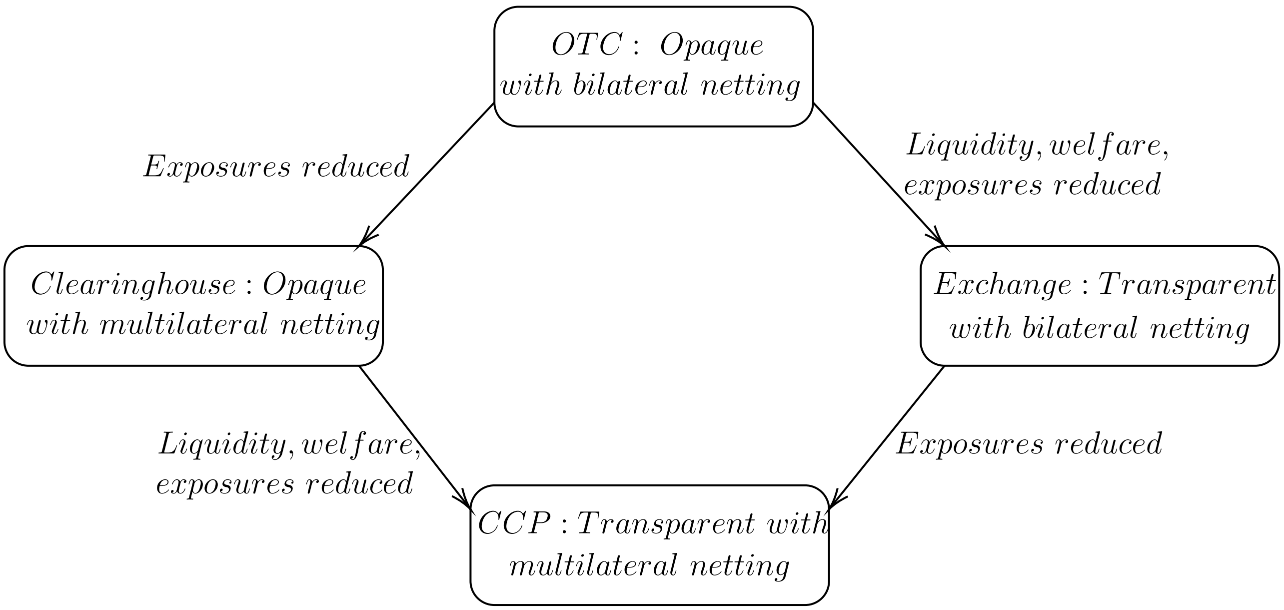

Figure 3: Description of the effects of CCPs

and Stress Testing Report (FR Y-14Q report) around the introduction of restrictions by Dodd-Frank (see BCBS and IOSCO (2015) "Margin requirements for non-centrally-cleared derivatives" Technical report, BIS and OICU-IOSCO, Basel, Switzerland for a discussion of this regulatory change). This report collects detailed confidential data on bank holding companies (BHCs) on a quarterly basis, which is used to support supervisory stress testing models and for continuous monitoring by the Federal Reserve. We already gained access to the "Trading and Counterparty" schedules that are submitted by BHCs subject to supervisory stress tests and that satisfy the following requirements: (1) have aggregate trading assets and liabilities of \$50 billion or more, or aggregate trading assets and liabilities equal to 10 percent or more of total consolidated assets, and (2) are not "large and noncomplex firms" under the Board's capital plan rule.[3]

We have obtain clearance for unique information about the derivative profile at the counterparty level and aggregate across all counterparties. Possible BHCs counterparties include (but are not limited to) other BHCs, financial institutions (domestic and foreign), sovereigns and central counterparties. Designated central clearing counterparty (CCP) exposures include both cleared over-the-counter (OTC) derivatives and exchange traded derivatives. All counterparties have a unique identifier which allows as to track relationships over time, with information on the industry code (six digit NAICS code), the country of domicile of the counterparty, an internal rating, and (when available) the external rating of the counterparty.

We plan to measure counterparty exposure using the following variables:

[3]A large and noncomplex firm is a BHC with total consolidated assets of at least \$50 billion but less than \$250 billion, total consolidated nonbank assets of less than \$75 billion, and is not a U.S. Globally systemically important bank (GSIB).

1. Gross Credit Exposure (Gross CE): pre-collateral exposure after bilateral counterparty netting. Sometimes referred to as the replacement cost or current credit exposure, Gross CE is the fair value of a derivative contract when that fair value is positive. Gross CE is zero when the fair value is negative or zero.

2. Net Credit Exposure (Net CE): Gross CE netting agreements for a given counterparty less the value of collateral posted by the counterparty to secure those trades

3. Total Notional: The gross notional amount of all derivatives positions associated with the reported amount in the item Gross CE.

4. Weighted Average Maturity: The average of time to maturity in years for all positions associated with the reported amount in the item Gross CE, as weighted by the gross notional amount associated with a given position.

5. Position Mark-to-Market (MtM): The net mark-to-market of all positions associated with the item Gross CE not including collateral. This amount could be positive or negative.

Using this information we plant to construct a detailed picture of counterparty exposures across the largest BHCs and CCPs. While data disclosure is not possible at this time, the Office of the Comptroller of the Currency (OCC) Quarterly Report on Bank Trading and Derivative Activities provide an overview of BHCs counterparty risk.[4] This report shows that derivative activity is concentrated in Interest Rate Swaps (76.02 percent of total amount, measured using the notional amount) and the next category Foreign Exchange derivative contracts. Importantly, four banks with the most derivative activity (JPMorgan Chase Bank, Bank of America, Citibank, and Goldman Sachs, which are included in our sample) hold 89.4 percent of all bank derivatives, while the largest 25 banks account for nearly 100 percent of all contracts. This is important since we have access to data at the counterparty level only for the largest BHCs. In addition, in the fourth quarter of 2017, 38 percent of banks' derivative holdings were centrally cleared (47.8 percent for interest rate derivative contracts). The fraction of centrally cleared derivative contracts shows an increasing path.

[4]The OCC Quarterly Report on Bank Trading and Derivative Activities is based on Call Report data (Y-9) that we also have access to. The latest report can be found here: https://www.occ.gov/topics/capital-markets/financial-markets/derivatives/dq318.pdf