A systemic risk assessment of OTC derivatives reforms and skin-in-the-game for CCPs

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The G20 OTC (over-the-counter) derivatives reforms impose large collateral/liquidity demands on clearing members of Central Counterparty (CCP) clearing platforms in the form of initial margins, variation margins and contributions to the default fund. In Heath et al. (2016), it was shown how this introduces a trade-off between liquidity risk and solvency risk with the system manifesting considerable systemic risk from these two sources of risk while CCP penetration is at current levels. We extend this analysis to include the European Market Infrastructure Regulation (EMIR) skin-in-the-game requirements for CCPs, which aim to ameliorate the contributions to the default fund by clearing members and also to prevent moral hazard problems associated with the too-interconnected-to-fail (TITF) status of CCPs as more and more derivatives are centrally cleared. We provide a systemic risk assessment of these features of the OTC derivatives reforms using network analysis based on 2015-end data on the derivatives positions for 40 globally systemically important banks (G-SIBs).

1I G20 over-the-counter derivatives (OTC-D) markets reform in perspective

One of the key manifestations of the 2007 Great Financial Crisis (GFC) arose from the activities of large financial institutions (FIs) in derivatives markets, with credit default swaps being strongly implicated in the crisis. There was a threat of financial contagion when the American Insurance Group (AIG) suffered escalating margin calls on derivatives positions, and as the value of underlying assets plummeted, it simultaneously faced failure from solvency and liquidity problems. This led to an unprecedented bailout package for AIG by the US Treasury of over USD 85 billion, which included USD 35 billion in collateral payments to its counterparties and USD 30 billion for the remaining market value of credit default swaps protection sold to global banks by AIG FP division.[1] The SIGTARP audit of November 2009 of AIG-FP, observed that the secrecy surrounding counterparties in AIG's OTC positions and the lack of ex ante close-out valuation and loss allocation rules that authorities could apply, made it difficult for the US authorities to negotiate haircuts on the counterparties of AIG.

In this context, much has been made of the orderly and speedy settlement of the central counterparty (CCP) cleared segments of Lehman Brothers' derivatives positions.[2] Indeed, some salutary insights can be gained from the Fleming and Sarkar (2014) study on the Lehman Brothers failure resolution process, which in the case of its derivatives positions included both OTC and CCP components. Firstly, it should be noted that CCP settled derivatives positions for Lehman Brothers were a minuscule part of the USD 35 trillion in notional value of its OTC derivatives which accounted for 96% of the net worth of its derivatives. The latter suffered an arduous and lengthy settlement process, taking over five years. Fleming and Sarkar *(Ibid)* conclude that "customers of centrally cleared securities were generally made whole .... In contrast, many counterparties of Lehman Brothers' OTC derivatives suffered substantial losses." The losses that Lehman Brothers itself suffered on derivatives, as mainly big bank counterparties shielded themselves by not making payments on their out-of-the-money positions and also by sequestering collateral posted by Lehman Brothers, were spread widely to other creditors. Creditors on average received a historically low recovery rate of 28% on the USD 1 trillion claims on Lehman Brothers.

Thus, in no small measure, the administrative efficiency behind CCP clearing of Lehman Brothers' derivatives relates to the small size of such claims and the scope for the bulk of the risk from losses to spill over elsewhere. This signals the need to assess systemic risk consequences of derivatives markets *in toto*, namely the inclusion of both OTC and CCP segments which co-mingle CCPs with many globally systemically important banks (G-SIBs) and other financial institutions (G-SIFIs).

The GFC gave clear evidence that the large value of derivatives positions and the potential for extreme losses in their underlying asset values exceeded the liquid and capital resources of G-SIFIs. This has brought to the forefront the regulatory challenge of determining and managing adequate liquid and capital buffers for major participants of these markets not only to mitigate their own failure, but to mitigate their contribution to system failure. In addition to vulnerability to exposures to falling assets values, the threat of counterparty risk from potential cascade failures of counterparties (see Haldane, 2009, Yellen, 2013) is increasingly seen as the hallmark of interconnected financial systems. There is a further dimension, which is compounded under conditions of stress, of having to grapple with the opacity of the bilaterally negotiated OTC positions (see Acharya and Bisin, 2013) that generate under the radar interconnectedness between the participants which involve derivatives positions and other components of their balance sheets. With CCPs novating positions with clearing members, by becoming a buyer to the seller and vice versa to the buyer, they start with a balanced book

1 See, the US Special Inspector General for Troubled Asset Relief Program (SIGTARP) audit of November 2009 of the AIG Financial Product division – *http://pogoarchives.org/m/er/sigtarp-audit-20091117.pdf*

2 Specifically, LCH.Clearnet resolved USD 9 trillion in notional value of Lehman's OTC derivatives positions, within three weeks, well within the margin held and without loss to other market participants. See "Managing the Lehman Brothers' Default", LCH.Clearnet, *http://www.lchclearnet.com/swaps/swapclear_for_ clearing_members/managing_the_lehman_brothers_default.asp* Likewise, DTCC and CME had similar successes. See "DTCC successfully closes out Lehman Brothers bankruptcy," *http:// www.bloomberg.com/apps/news?pid=newsarchive&sid=aojt5wVkz_EM*

(Tucker, 2011; Heath et al., 2015) and can reduce interconnections in the system. In OTC markets, balanced positions come at the price of complex bilateral offsetting trades which add to the density of links between the G-SIB dealers.

Hence, with the view to gaining the administrative efficiency of CCP settlement and to reduce the complexity of financial links and their lack of transparency, the main thrust of the G20 financial reforms mooted at the Pittsburgh Summit in 2009 has been to make it mandatory for all standardised OTC derivatives (OTC-D) contracts to be cleared through CCPs along with an extensive collateralisation programme for both CCP and bilaterally cleared OTC derivatives.

As the reliance on CCP clearing increases with the G20 reforms, Cœuré (2014, 2015) has famously called CCPs "super systemic" players. CCPs have begun to dominate an already crowded centrally clustered network structure of the global derivatives markets with 16 or so G-SIBs which currently account for over 85% of derivatives positions[3] in the OTC domain and as clearing members of CCPs. The question here is can CCPs cope with an increased burden of clearing derivatives as this migrates from the OTC domain? Have CCPs become *too interconnected to fail* (TITF)? TITF is a euphemism relating to the moral hazard problem that the economic repercussions from failure of CCPs could be so wide ranging that they could become prime candidates to receive tax payer bailouts (see Wendt, 2015; Blackrock, 2014; Markose et al., 2012).

The purpose of this note is to examine frameworks for assessing the systemic risk from CCPs in derivatives markets. Specifically in view of the TITF status of CCPs, in Section 2, we will discuss the problem of determining the adequacy of CCP capital in the context of what is now called skin-in-the-game (SIG) funds that are put at risk in the first tranche of losses to mitigate incentives for the CCP to free ride on the resources of clearing members or on those of the tax payer.

One of the highlights we provide is an assessment of the extant hybrid system of OTC-D and CCPs using the network approach in Heath, Kelly et al. (2016) which is based on the BIS MAGD[4] report (2013) data on the 2012 derivatives positions for the 40 G-SIBs and using a reasonable OTC-D and CCP clearing spilt with five CCPs clearing each of the main derivatives products.[5] Retaining the VaR method in Heath, Kelly et al. (2016), widely used for the calculation of initial margin and default fund contributions, the systemic risk analysis is updated to cover the 2015 end derivatives product level data for the 40 MAGD G-SIBs. Comparisons that can be made at these two points of time provide interesting ballpark figures for the extent to which progress has been made in the direction of mitigating systemic risk in global derivatives markets. Further, the empirically calibrated hybrid network model for CCP and OTC-D positions of 40 G-SIBs gives a good basis to include the skin-in-the-game capital funding of CCPs in addition to clearing member initial margin and default fund contributions to assess improvements in the stability properties of the network system. Following Alter et al. (2015), Markose (2012) and Heath, Kelly et al. (2016), we recommend the application of network centrality measures for CCPs to estimate the skin-in-the-game surcharges that have the best potential to mitigate contagion losses from clearing member defaults that can be transmitted by CCPs. Sections 4 and 5 give some empirical evidence for the size of the SIG funds and their effectiveness in dealing with TITF for CCPs clearing each of the five main derivatives products using the Heath, Kelly et al. (2016) CCP-OTC clearing split involving the 40 MAGD G-SIBs (see footnote 5).

Finally, we conclude by reiterating the call to arms (see Haldane, 2009; Markose, 2013) for a granular data driven approach of digital maps for the contractual obligations of G-SIFIs, especially in global derivatives markets, at regular intervals of time.[6] Only this can vitiate the unacceptable levels of model risk that prove a stumbling block to managing systemic risk in financial markets. This case was also

3 For the 2012 data, Markose (2012) showed that this accounted for 97% of global derivatives in terms of gross notional. Brunnermeier et al. (2013) study the CDS market on EU reference entities and note that the network of bilateral CDS exposures among counterparties resembles a "core-periphery" structure with the CDS market centred around 13 or 14 G-SIFIs. Likewise, Duffie et al. (2015) who have bilateral CDS exposure data for all participants in the single name global CDS market, confirm a similar structure of high concentration of links around 13 G-SIBs who dominate the CDS market.

4 This stands for the Bank for International Settlements Macroeconomic Assessment Group on Derivatives (MAGD) Report.

5 In Heath, Kelly et al. (2016), the hybrid OTC-CCP split in derivatives clearing network model is called Scenario 1: CCP1 clears 75% of all interest rate derivatives; CCP2 clears 15% Forex derivatives; CCP3 clears 15 % equity derivatives; CCP4 clears 50% credit derivatives and CCP5 clears 20% commodity derivatives.

6 Our view is that systemic risk does not happen overnight but builds up and hence digital maps of extant who-to-whom obligations at reasonably regular intervals can alert authorities. The current practice of calibration and simulation exercises undertaken to provide reasonable replicas of the real world interconnections, due to a lack of data, can be avoided.

made by Brunnermeier et al. (2013) on why models based on limited segments of G-SIFI activities can be misleading and "hence from an ESRB perspective, a holistic view of the exposures map is required."

2| Skin-in-the-game: CCPs as "super systemic" or "super vulnerable" in a hybrid system of clearing

The regulatory reform process has set out extensive institutional mechanisms that ensure that CCPs have: (i) sufficient resources in the form of stable and conservative initial margins that avoid procyclicality by being precalibrated to meet stressed market conditions, (ii) higher capital charges and margin requirements for non-standardisable OTC instruments, drawn up by BCBS and IOSCO (2013), and (iii) other risk management systems to deal with failure of clearing members (see CPSS-IOSCO, 2012, EMIR, 2012).

With regard to (iii) the current practice is for the CCP to rely on the default fund contributions from clearing members where the fund is calibrated to withstand failure of the two clearing members with the largest liabilities under extreme but plausible conditions. This goes by the name of *Cover 2* (CPSS-IOSCO, 2012). There are rules pertaining to how CCPs can mutualise losses of defaulting members to surviving members after exhausting the former's initial margin and contribution to the default fund. This schedule of loss settlement is called the default waterfall structure. Rule books of CCPs include close out valuation process and novation procedures for outstanding positions of defaulting members to surviving members. CCPs also have so called assessment powers over surviving members to specify the replenishment of the funds used in the mutualised loses of the defaulting members.

As CCPs are not public utilities (Lubben, 2014) but private firms competing for custom, there could be a race to the bottom in terms of less costly margining requirements and default fund contributions for clearing members,[7] and also undercapitalisation. In order to mitigate free riding by CCPs and moral hazard due to their TITF status, authorities such as those implementing the EMIR have included skin-in-the-game (SIG) requirements for CCPs. CCP SIG is given precedence in the waterfall structure ahead of the loss mutualisation based on the prefunded default fund contributions of surviving CCP members. The implementation of formal capital requirements for CCPs will bring them in line with banks which are subject to regulatory capital requirements.[8]

It is customary in such regulations that some formulaic and absolute minimum standards are stipulated. European Union CCPs are required to hold a minimum capital buffer of EUR 7.5 million or, a larger sum sufficient to provide adequate cover against a number of risks which include credit, counterparty, business and operational risks. The latter can involve the cost of orderly winding down. The SIG is viewed as a surcharge on top of the minimum CCP capital requirement. The EMIR SIG rule (Reg. 153/2013 Article 35, §2) specifies a 25% surcharge on top of the minimum CCP capital requirement.

The discussions, to date, on whether the EMIR SIG rule of a 25% top up on minimum CCP capital is adequate for the job at hand have mostly taken a qualitative perspective or used rule of thumb. The size of the SIG, it has been argued, should be large enough as the first loss tranche in order to prevent the CCP from free riding on the prefunded margin and default fund contributions of its clearing members. In the case of non-existent or low CCP SIG along with low initial margin and default fund contributions from clearing members to attract custom, both the CCP and its clearing members have or potentially can have highly leveraged uncollateralised positions that signal moral hazard problems that may require taxpayer bailout. Also, the CCP SIG should not be so large that the threat of mutualised losses becomes remote and can lose its power to discipline clearing members to control the size of their open interest.[9]

7 Zhu (2011) in his survey of a sample of CCPs does not find evidence of an obvious dropping of standards in regard to this. However, initial margin calculations differ on details such as length of the close out period for which initial margin is calculated. Hence, UK CCPs prescribe seven days as opposed to the five day norm and the former needs more initial margin than the latter.

8 See, BCBS 227 (DFCCP).

9 Cœuré (2015) notes that "the purpose of CCPs is to mutualise counterparty risk, not to remove it from clearing members altogether and bear it themselves. CCPs are risk poolers, not insurance providers". The International Swaps and Derivatives Association (ISDA), has weighed in on the suitable size of CCP SIG fund. In response to the European Banking Authority (EBA) consultation paper, ISDA stated "that having a 50% skin-in-the-game requirement may not strike the right balance between protecting non-defaulting members and ensuring that they have incentives to bid competitively in an auction of a defaulting clearing member's portfolio at a time when resources need to be replenished."

As in principle, the CCP operates a balanced book and can become a source of financial contagion only if the residual losses (in excess of the prefunded initial margin) of its defaulting clearing members are passed on in substantial amounts to non-defaulting clearing members, we will argue that the role of SIG should be viewed as a Pigou surcharge for the TITF status of CCPs, namely the negative externality that they pose to others from their systemic vulnerability to the exposures of their clearing members that can arise from inadequate CCP capital.

3| Frameworks for assessing the systemic risk from CCPs in derivatives markets

Clearly, there has to be empirical analysis to provide evidence for the efficacy or not for the CCP SIG in conjunction with the other CCP resources such as the prefunded initial margin and default fund. There have been a number of studies that have attempted to provide calibration and simulation stress test exercises to quantify and assess the risk management capabilities of CCPs mostly in the context of the prefunded initial margin and the default fund rather than for CCP capital and SIG buffers. Typically, formulaic calculations are made for initial margin and default fund contributions and it is conceivable that CCP SIG can be made in a similar vein and then the stress tests are conducted to see, under different scenarios, how CCPs fare under extreme but plausible conditions. The latter include simultaneous defaults of several large clearing members (CMs). The main difference in the methodology of these studies lies in whether these stress tests are conducted with a model limited to a single CCP and its clearing members or one that can include G-SIB positions in both bilateral OTC clearing and with multiple CCPs.

Table 1 summarises the key steps in such exercises.

In Step 1, after having calibrated open interest positions of clearing members at the CCP in question or within a hybrid OTC-CCP split clearing model,[10] the first order of business is to determine the initial margin requirements. **Step 2** involves *Cover 2* default fund estimates. For both these steps, the best practice (see Lin and Surti, 2015) is the conventional VaR type metrics that are calibrated to satisfy stress period

10 Exceptionally, Duffie et al. (2015) have bilateral exposure data for some 30% of the global market of single name CDS. This data obtained from the DTCC gives a snapshot of this fragment of the financial network for 30 December 2011.

T1 Steps in systemic risk assessment in stress test models for CCP and OTC-D clearing

Note: At each ***step***, the light blue box highlights the wider liquidity stress, while the darker blue boxes indicate solvency risks.

Step 1 Based on bilateral open interest positions of derivatives market participants, determine initial margin collateral of OTC-D banks and as clearing members based on VaR type metrics precalibrated typically at 99% confidence level (C_{ij} is the collateral for initial margin from *i* to *j*, see Box 1).

Reduces solvency risk: initial margin reduces uncollateralised derivatives exposures for both OTC G-SIBs and CCPs.	Heath, Kelly et al. (2016): initial margins add to liquidity encumbrance ratio of G-SIBs in both OTC and CCP positions vis-à-vis their available high quality liquid assets.	Current levels of CCP clearing at 35%-45% on average across all derivatives products with CCP fragmentation implies high levels of collateral demands, Duffie and Zhu (2011). Heath, Kelly et al. (2016) show this can trigger liquidity contagion.

Step 2 Determine Cover 2 Default Fund (DF) contributions of clearing members (CMs) for CCP.

Reduces Solvency Risk: DF provides CCPs buffers against exposures to clearing members.	Heath, Kelly et al. (2016) adds CM default fund contributions to Liquidity Encumbrance Ratio of CMs; New EMIR 2014 rule permits CM to reduce capital of clearing members.

Step 3 Stress test with extreme mark-to-market variation margin conditions (this is done pairwise between participants *i* and *j* as in V_{ij}, see Box 1: $V_{ij} - C_{ij}$ = Uncollateralised residual liabilties from *i* to *j* is a source of counterparty risk.
Interject CCP skin-in-game ahead of waterfall feature for mutualisation of defaulted losses on non-defaulting clearing member default funds.

CCP skin-in-game can be a panacea for *Too Interconnected To Fail* moral hazard problem; SIG can forestall variation margin haircuts; latter are realised losses on derivatives assets and threaten insolvency.	Cover 2 default fund exhausted fully in Heath, Kelly et al. (2016) with 3.89 volatility stress at ***Step 3***.	**Step 3** stress of 2.67 and 3.89 volatility can cause added liquidity stress as G-SIBs which are clearing members of multiple CCPs have high liquidity encumbrance (Singh, 2010a and 2010b). Replenishment of default funds and VMHC can bring about solvency stress.

conditions rather than use point in time estimates which suffer from the "paradox of volatility" (Borio and Drehmann, 2011; Markose, 2013; Markose et al., 2017). The latter, in addition to being procyclical, will severely underestimate the risk buffers needed in the run up to a financial crisis. **Step 3** in Table 1 involves stress tests wherein more extreme market conditions, than for which prefunded buffers have been calibrated, to drive variation margins and hence the size of residual uncollateralised positions. The systemic risk consequences for CCPs and the liquidity and capital shortfalls are typically assessed by the classic Furfine (2003) style failure of clearing members. Different scenarios involving CCP infrastructure rules and OTC-D and CCP clearing splits have been investigated.

Lin and Surti (2015) and Armakola and Laurent (2015) conduct detailed analyses of US and/or European CCPs and their specific clearing members.[11] Armakola and Laurent (2015) analyse CCP resilience by conducting stress tests based on the capacity of clearing members, as determined by their ratings and default probabilities, to make good on their derivatives obligations. They conclude that in a *Cover 2* situation with a failure of two major clearing members, many CCPs in their sample may face serious liquidity problems.

In Table 1, the pale blue boxes and darker blue boxes, respectively, highlight the wider implications for liquidity and solvency systemic risks as a function of the size of the margin and default fund requirements on G-SIBs for derivatives clearing. The main findings here show that the key factor in the demand for collateral is the extent to which counterparty exposures can be compressed by netting. Duffie and Zhu (2011)[12] show that multilateral netting benefits from CCPs with few clearing members is limited. Hence, there has to be substantial migration from bilateral OTC to CCP and that too to a single CCP for all product clearing to achieve close to 40% counterparty exposure reduction when compared to the case of 100% bilateral clearing which benefits from multi-product netting efficiency germane to OTC markets. Along the lines of Duffie and Zhu (2011), for instance Heller and Vause (2011) show that margin requirements can be reduced by up to 15% if both credit default swaps and interest rate swaps are netted by one centralised CCP.

Current levels of CCP clearing of derivatives, with growing fragmentation of CCPs, are estimated to average between 35%-45%.[13] Interestingly, our so called Heath, Kelly et al. (2016) Scenario 1 OTC-D and CCP clearing with the latter being along single product lines resembles Duffie and Zhu (2011) Table 3 Column 8 case which signals 20% reduction in counterparty exposures (see footnote 12). However, with collateralisation of both OTC and CCP exposures, Heath, Kelly et al. (2016) make a careful audit of the high quality liquid assets of the 40 MAGD G-SIBs and find that some of them can suffer liquidity encumbrance of over 87% as a result of their collateral commitments given in **Steps 1** and **2** of Table 1. As pre-funding of collateral grows, clearly residual uncollateralised counterparty risk from extreme variation margin volatility can be mitigated, but only at the cost of triggering a liquidity contagion as G-SIBs become more and more encumbered as members of multiple CCPs (see Singh, 2010a, b). At 3.89 volatility[14] stress tests at **Step 3** of Table 1, Heath, Kelly et al. (2016) instigate a variation margin hair cut (VMHC) to the winning side non-defaulting clearing members of some CCPs as they become unbalanced from defaults of clearing members. They also assume that CCPs can in principle exhaust all the non-defaulting clearing member share of the default fund if the losses of defaulting members exceed their initial margin and default fund contributions. Clearly, this can be considered to be highly permissive of free riding on the part of CCPs and can result in both solvency and liquidity contagion effects.

To date, perhaps with the exception of Lin and Surti (2015), no paper has analysed the role of CCP capital and SIG funds within a model in which initial margin and the default funds have been

11 Lin and Surti (2015) study Swapclear for interest rates swaps and ICE for credit default swaps, while Armakola and Laurent (2015) cover eight European CCPs and five US CCPs. Their analysis can be compared to how CME conducts its stress tests: *https://www.cmegroup.com/clearing/risk-management/files/principles-for-ccp-stress-testing.pdf*

12 See Duffie and Zhu (2011) Table 3 column 9. Cont and Kokholm (2014) show that exposure reductions from CCP netting are greater than what Duffie and Zhu (2011) have estimated for high volatility underlying assets.

13 The 45% figure is given in EC Safer Financial Infrastructure #saferCCPs.

14 Based on daily data, this is only about a one in 8 year event.

quantified. Even more remarkably, despite the call to arms to model the interconnectedness of the extant financial exposures in complex derivatives markets (see Brunnermeier et al., 2013) virtually no network analytics has been brought to bear on the study of systemic risk or of adequacy of buffers in such systems. Cont (2015) succinctly notes how essential it is to model the links for G-SIBs who are common to multiple CCPs and also the OTC connections between G-SIBS to make realistic systemic risk assessments of these markets and infrastructure rules.

In the context of interconnected systems, we will follow Alter et al. (2015) and Markose (2012) who find that network centrality, i.e. eigenvector centrality, based capital allocation and bailout surcharges are best placed to "stabilise" the system. Alter et al. (2014) show that other capital allocation rules are less effective at preventing Furfine (2003) type contagion failures when the system is stress tested. Markose (2012) and Markose et al. (2017) give a more extensive rationale for the use of a recursively derived fixed point solution for the network centrality of financial participants in propagating contagion failures in the system. The principle of a Pigou or externalities tax that is proportionate to the network eigenvector centrality of the financial institution to mitigate its *TITF* was first mooted in Markose (2012).

4| Heath, Kelly et al. (2016) hybrid OTC and CCP global derivatives network

Table 2 gives the changes that have occurred in the balance sheet data for the 40 G-SIBs from 2012 to 2015-end with respect to their total derivatives positions, both OTC and CCP cleared. Firstly, note the compression in gross notional from about USD 755 trillion in 2012 to USD 628.24 trillion in 2015, which is about a 17 % fall. More impressive is the fair value of derivatives payables that fell by just over a third from USD 14.34 trillion to USD 9.75 trillion. Derivatives receivables at fair value have fallen even more by 37% from USD 14.48 trillion to USD 9.05 trillion.

T2 Balance Sheet Data *(for 40 G-SIBs)*

(USD trillions)

	2015 All banks	2012 All banks	2015 Top 16 core banks	2012 Top 16 core banks
Derivatives liabilities negative fair value	9.753	14.34	6.822	12.16
Derivatives assets positive fair value	9.035	14.48	7.541	12.35
Gross notional outstanding	628.249	755.08	534.731	633.49
Tier 1 capital	2.630	2.39	1.573	1.34

Source: 2012 financial reports data reported in Table 1 of Heath, Kelly et al. (2016); 2015-end data obtained from financial reports for each of 40 G-SIBs (from BIS MAGD).

The share of the top 16 G-SIBs recognised as global derivatives dealers was 83% in 2012 and this has increased to 85% in 2015. The share of the 16 top G-SIBs for fair value derivatives receivables has remained at around the 84%-85% mark while these G-SIBs seem to have reduced their liabilities considerably from 85% in 2012 to about 70% in 2015. Tier 1 capital of the 40 G-SIBs has increased from USD 2.39 trillion in 2012 to USD 2.63 trillion in 2015 which is about a 10% increase.

The 2015 initial margin and default fund contributions are pre-determined as in **Steps 1** and **2** given in Table 1. This is reported below for 2012 and 2015 in Table 3. The estimated total

T3 2012 and 2015 initial margin and default fund *(for 40 G-SIBs)*

(USD billions)

	Prefunded total initial margin				Default fund
	Total	Bank-bank	Bank-CCP	CCP-Bank	Total Bank-CCP
Scenario 1 2012 MAGD G-SIBs derivatives data (Heath, Kelly et al., 2016)	920.25	892.88	37.37	0	6.95
Scenario 1 2015 MAGD G-SIBs derivatives data	490.51	444.20	46.32	0	10.69

Notes: Estimates based on Heath, Kelly et al. (2016), Scenario 1, CCP-D and OTC clearing split for 40 G-SIBs (from BIS MAGD). 2012 data is reported in Table 5 (initial margin) and Table 6 (default fund) of Heath, Kelly et al. (2016).

initial margin has fallen from USD 920.25 billion in 2012 to USD 490.51 billion for all five CCPs. What is interesting is that while the initial margin for bank-bank OTC positions halves from USD 892.88 billion in 2012 to USD 444.2 billion in 2015, the initial margin from bank-CCP rises from USD 37.37 billion to USD 46.32 billon. The total default fund from banks to CCPs in 2012 is smaller than the USD 10.69 billion in 2015. This follows the trend in initial margins as well. The break downs for the default fund for each of the five CCPs will be reported in the next section.

Following **Step 3** of Table 1, the so-called stability matrix based on the residual uncollateralised variation margins (see Box 1) is derived for stresses modelled at 2.6 volatility in the underlying. The stability matrix and the systemic risk analytics for the global derivatives network are given Box 1.

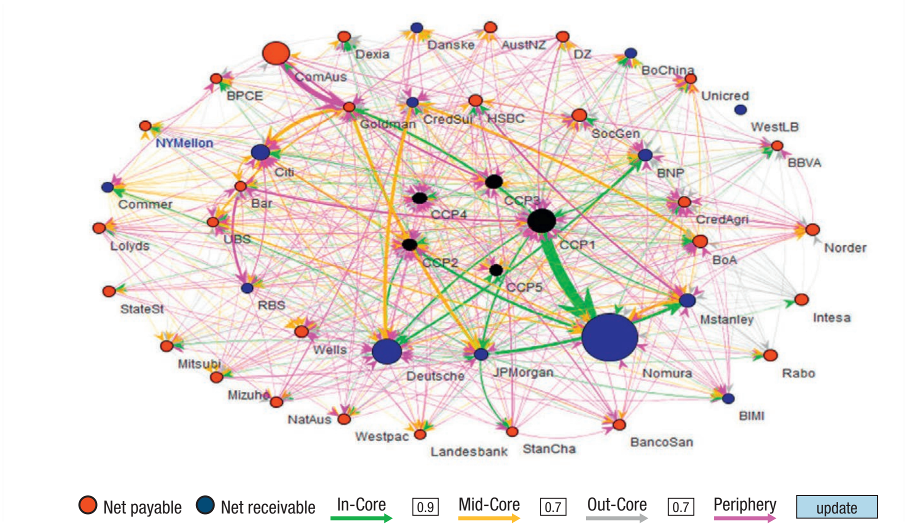
Chart 1 characterises the hybrid elements of the extant global derivatives markets with 16 G-SIBs dominating in both CCP derivatives clearing and also in the OTC markets, while the remaining 24 occupy the outermost tier of the network. The important feature of Scenario 1, as noted by Cont (2015) as being significant for realistic systemic risk assessments of CCPs, is the presence of common clearing members. Failure of a clearing member in one CCP will have implications for all others.[15]

The network analytics of systemic importance and vulnerability are based, respectively, on the right eigenvector centrality and left eigenvector centrality of the hybrid derivatives network described in **Box 1**. These resemble Google page rank statistics and are recursively obtained to establish a relationship between network participants in that a player is systemically important (vulnerable) not only because it has large liabilities (exposures) to counterparties but also because it is connected to other central players.

When comparing the 2012 MAGD-based derivatives network (see Heath; Kelly et al., 2016, Chart 5), with Chart 2 for 2015, there are considerable changes in the centrality positions. In 2015, European G-SIBs have

15 Cont (2015) states: "If one of these dealer banks defaults on its margin calls in one of the CCPs, it will simultaneously default on its positions in all CCPs of which it is a member, leading to possible draws on the default fund of one or more CCPs."

C1 2015 40 MAGD G-SIBS and hybrid derivatives clearing by CCPs and OTC (Scenario 1)

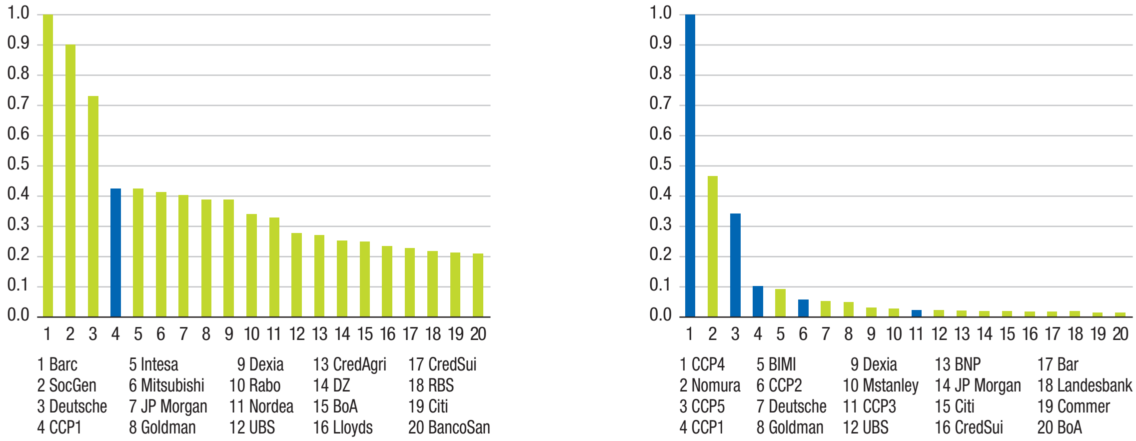


Note: CCP1 (clears 75% interest rate); CCP2 (clears 15% Forex); CCP3 (clears 15 % equity); CCP4 (clears 50% credit); CCP5 (clears 20% commodity)
The arrow starts from the FI making the net derivatives payables with the arrow head ending with the counterparty who is exposed to the former.

C2 Centrality measures for systemic importance and vulnerability of hybrid derivatives network for 40 MAGD global banks and CCPs (2015) (Top 20)

a) Right eigenvector centrality: measure of systemic importance

b) Left eigenvector centrality: measure of systemic vulnerability



Note: These have been normed by the largest centrality values.

taken the place that US G-SIBs held in the 2012 data for being most systemically important, see Chart 2a.

The systemic importance of CCP1 which clears interest rate derivatives is ranked 4th after 3 G-SIBs. A single net bilateral payable flow prominent in Chart 1 from CCP1 to Nomura is material here and this also shows up in the high ranking of Nomura in the vulnerability index. The greatest vulnerability in terms of the left eigenvector centrality is seen in CCP4 (credit) and CCP5 (commodity) in Chart 2b. The case of CCP5 reflects recent conditions regarding the high volatility in commodities markets.

5| Skin-in-the-game (SIG) fund calibration using spectral stability methods

A network system can be viewed as a dynamical system in which some network configurations or topologies determined by the distribution of links and weights of links between nodes give the potential for the network to be prone to cascade failures from arbitrary sized shocks. When systems fall into some regions of network configurations, they can become unstable and tip over. Box 1 shows how classical spectral methods given by the maximum eigenvalue (λ_{max}) of an appropriately constructed matrix representing snap shots for the network configuration of extant financial obligations of major financial institutions to counterparties relative to their buffers, can give the tipping point. Given the size of derivatives payables and the bilateral exposures faced by counterparties, regulators are concerned about the adequacy of the buffers that can be used. The point up to which these buffers can be eroded by losses is the so called regulatory loss threshold (denoted by ρ) when financial institutions are deemed to be in a state of distress. The question is how can network systems be constrained to stay in the stable region determined by the maximum eigenvalue of the stability matrix in Box 1 and loose no more capital than the given (%) regulatory loss threshold?

In Heath, Kelly et al. (2016) it is assumed that a G-SIB should be limited to using only 10% of its Tier 1 capital as a buffer against exposures

Box 1

Network based spectral systemic risk analytics for 40 G-SIB and CCP based global derivatives markets

In the hybrid case, derivatives are cleared both bilaterally by banks in an OTC setting and also centrally with separate CCPs, one for each of the derivatives products. We assume that there are $B+c$ financial institutions, where B is the number of banks (40 in the MAGD G-SIB data) and $c = 1, 2, ..,5$ are the number of CCPs, in Scenarios 1 of Heath, Kelly et al. (2016). The "stability matrix" Θ in (1) is instrumental for giving the Spectral Systemic Risk analytics derived below and it is based on the representation of the extant contractual obligations of the major participants and also of their relevant resources is a $(B+c)\times(B+c)$ matrix[1] as follows:

$$\Theta = \begin{bmatrix} 0 & \frac{V_{12}-C_{12}}{K_2} & \cdots & 0 & 0 & \cdots & \frac{V_{1CCP_5}-C_{1CCP_5}}{K_{CCP_5}} \\ 0 & 0 & \cdots & \frac{V_{2B}-C_{2B}}{K_B} & \frac{V_{2CCP_1}-C_{2CCP_1}}{K_{CCP_1}} & \cdots & \frac{V_{2CCP_5}-C_{2CCP_5}}{K_{CCP_5}} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{V_{B1}-C_{B1}}{K_1} & \frac{V_{B2}-C_{B2}}{K_2} & \cdots & 0 & \frac{V_{BCCP_1}-C_{BCCP_1}}{K_{CCP_1}} & \cdots & 0 \\ \frac{V_{CCP_1 1}}{K_1} & \frac{V_{CCP_1 2}}{K_2} & \cdots & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \frac{V_{CCP_5 2}}{K_2} & \cdots & \frac{V_{CCP_5 B}}{K_B} & 0 & \cdots & 0 \end{bmatrix} \quad (1)$$

Here $V_{ij} > 0$ is the variation margin (as determined in ***Step 3*** of Table 1) to be paid from i to j as i is out-of-the-money and $C_{ij} > 0$ is the collateral posted by i to j as the initial margin (in the prefunding ***Step 1*** in Table 1). Thus, pair wise between banks, only the positive residual obligations such as $(V_{12} - C_{1B}) > 0$ are included in the matrix Θ. The same is the case for bank to CCP elements with $V_{1CCP_5} - C_{1CCP_5} > 0$. In the case of CCPs, if for example, CCP_1 is out of the money vis-à-vis clearing member 1, as no initial margin is assumed to be paid by CCPs to clearing members, we have $V_{CCP_1 1} > 0$, as shown in the matrix Θ. Each bilateral uncollateralised exposure of a participant is expressed as a ratio of the resources of the participant. The latter is Tier 1 capital for each of the banks, denoted by K_i.[2] The CCP resources will typically be denoted as K_{CCP_1}. In Section 5 , we will consider two cases for K_{CCP_1}: ***pre skin-in-the-game*** and ***post skin-in-the-game***.

The significance of the formulation of the matrix Θ in (1) for driving the rates of failure denoted as u_i^L for each of the participants i in the network is that it can be defined as a dynamical system. Using matrix notation:

$$\boldsymbol{U}_{q+1} = [(1-\rho)I + \Theta']\boldsymbol{U}_q = \boldsymbol{Q}\boldsymbol{U}_q \quad (2)$$

1 Note, the lower right hand bloc has no connectivity as the CCPs do not have direct links to one another.

2 In Heath, Kelly et al. (2016), bank *i*'s resources, Ki, *i*'s Tier 1 capital is adjusted for bank *i*'s contributions to any CCP default funds. Thus, this framework allows for the new EMIR (2014) rule for this.

In (2) rates of failure for each participant in vector U_{q+1} is given by the matrix of counterparty exposures relative to buffers and the $(1 - \rho)$ is the extent to which i's buffers are constrained from being used.

The system stability of (2) that can evaluated by the power iteration algorithm in (3), implies that the maximum eigenvalue of Θ denoted by λ_{max} (Θ) is less than ρ. If not the system will become unstable and participants can fail from an arbitrary size shock and with no outside interventions.

$$U_q = Q^q U_0 \rightarrow \lambda_{max}(\Theta) < \rho. \quad (3)$$

Thus, (3) defines the tipping point and λ_{max} is the systemic risk index for system failure. In (2) and (3), ρ corresponds to the same cure rate or the regulatory loss threshold (%) of i's buffers that can be used to offset losses from exposures to counterparties given in matrix Θ'. Using the eigenvalue equation $\lambda_{max} v^R = \Theta\, v^R$, we have the recursive solution for the right eigenvector centrality of each node in the system, while $\lambda_{max} v^L = \Theta'\, v^L$ gives the left eigenvector centrality. Following, Newman (2010, p. 651), λ_{max} (Θ) gives the % loss of resources in system as a whole from cascade failure and the product of the ith right eigenvector and λ_{max} gives the % loss of resources that i can potentially cause in the near term and so is a measure of systemic importance. Likewise, the product of the ith left eigenvector centrality and λ_{max} gives the % loss of i's own resources and hence is the systemic vulnerability index. Thus, unlike averages based on simulated stress test losses, these indices are internally consistent. The same goes for the skin-in-the-game recursive solutions which targets the λ_{max} of the transformed networks to achieve no more than λ_{max}=10% of system wide losses by augmenting CCP resources, $K_{CCP_{c=1\ to\ 5}}$ in matrix Θ, by SIG funds proportionate to the respective eigenvector centralities of the CCPs. This is reported in Table 4 columns 2 and 4.

T4 Systemic Risk Index and CCP skin-in-the-game (SIG) fund to stabilise the system at 10% default fund loss threshold with 2.6 volatility stress for variation margin (2012 and 2015)

	2012		2015	
Systemic Risk Index: λ_{max} (See Box 1)	0.163*		0.148	
	Default Fund USD bns Precalibrated *Cover 2* **	SIG (USD bns)	Default Fund USD bns Precalibrated *Cover 2*	SIG (USD bns)
	1	2	3	4
CCP1 (Rates)	3.86	14.28	6.87	10.03
CCP2 (Forex)	0.45	1.19	1.75	2.15
CCP3 (Equity)	1.63	14.45	1.58	1.66
CCP4 (Credit)	0.84	2.11	0.29	1.74
CCP5 (Commodities)	0.17	0.43	0.21	0.57
Total	**6.95**	**32.46**	**10.7**	**16.15**

*For 2012 Scenario 1 case, see Heath, Kelly et al. (2016) Table 9 for the systemic risk index and Table 6 for default fund**.

to counterparties derivatives positions as the latter constitutes a subset, rather than the whole balance sheet. From Table 2, this corresponds to USD 263 billion in permissible losses in 2015. If a similar 10% loss threshold is used to proxy the maximum that a CCP can use of its pre-calibrated default fund under conditions of stress, then system stability requires that the systemic risk index given by λ_{max} of the stability matrix (see Box 1) cannot exceed 10% loss threshold.[16]

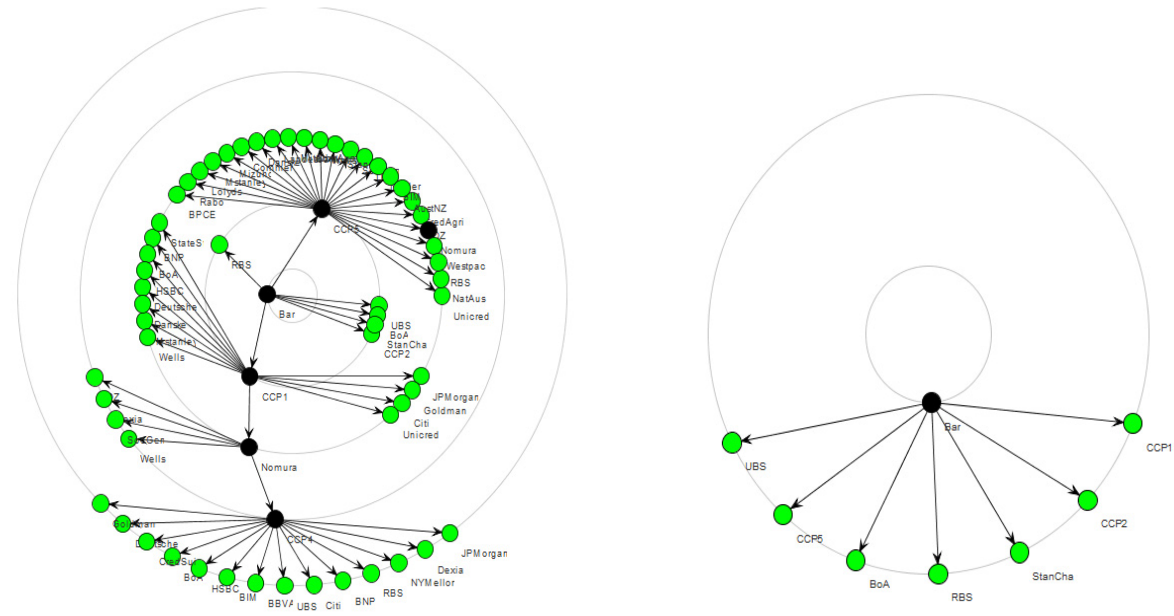
Table 4 shows that compared to 2012, the global derivatives markets in 2015-end is relatively more stable with lower systemic risk index,

16 The specification of loss thresholds are critical in the spectral stability analysis and also in Furfine (2003) simulated contagion stress tests. The following error is often commonplace: networks based on a subset of banks' balance sheets are calibrated and then an inappropriately large percentage of Tier 1 capital loss threshold is assumed when defining bank "*failure*" in the contagion stress test. A lack of direct contagion is reported when losses from counterparties arising from a subset of the balance sheet may not exceed all of Tier 1 capital or a large percentage of Tier 1 capital.

C3 2015 Before and after skin-in-the-game (SIG) fund cases for contagion "failure" of top systemically important G-SIB (loss threshold of 10% for G-SIB and CPP Buffers)

a) Before SIG fund system unstable

b) After SIG fund: stabilised at λ_{max} just below 0.10



Source: Hybrid OTC-CCP derivatives network based on 2015 MAGD G-SIB data.
Note: Distressed units in black when 10% loss threshold is breached; green units suffer some losses that are less than this threshold.

λ_{max}, at 0.148 when compared to 0.163 in 2012 for 2.67 volatility stress. In 2015, Table 4 shows the λ_{max}= 14.8% signals that some 14.8% of total capital and default fund resources could be lost while the loss threshold is 10%. The spectral approach shows there can be instability and contagion losses with respect to the failure of those participants which have right eigenvector centrality times λ_{max} that is greater than 10% (see Box 1) as shown in Chart 3a.

In the case of CCP buffers against clearing member exposures, we consider two cases. In the ***pre skin-in-the-game case***, CCPs only have the default fund to buffer exposures to the uncollateralised realised residual liabilities of their clearing members. In the ***post skin-in-the-game case***, the default fund for each of the CCPs will be augmented by a surcharge which is recursively estimated (see Markose, 2012 and Box 1) to be proportionate to the left eigenvector centrality of CCPs representing their vulnerability/exposure to clearing members. When modelled within a framework of failure rates for the financial institutions brought about by the erosion of their capital buffers, the left eigenvector centrality based capital surcharges targeting the CCPs will be internally consistent, as a fixed point result,[17] with the allocations being assigned to all CCPs given extant distribution of liabilities and buffers of other participants. Further, the CCP capital surcharges have to be made to satisfy a certain level of maximum eigenvalue for the network as whole, which is 10% to correspond to the loss threshold. Thus, we assume that the skin-in-the-game CCP buffers have to kick in with only a 10% hit on the CCP default fund being permissible. The latter can be regarded to be a proxy for the default

17 Gauthier et al. (2012) have underscored the importance of determining capital allocations that are fixed point solutions and are internally consistent. However, they did not use network analytics for this.

fund contributions of the two most systemically important clearing members. In other words, the SIG is modelled to precede any further use of the default fund beyond a 10% loss.

Table 4 columns 2 and 4 give the SIG funds needed for each of the CCPs to stabilise the pre-SIG networks for 2012 and 2015, respectively, to achieve λ_{max} below 0.10. As a result, as shown in Chart 3b for the after SIG case, there is no distress when the most systemically important bank (see Chart 2a) is subject to a Furfine (2003) type failure. Further, Table 4 shows that in 2015 a SIG fund of USD 16.15 billion will suffice to restore stability to the system while in 2012 a SIG fund of USD 32.46 billion is needed to do the same.

Finally, it must be clear as to what "failure" or distress (nodes in black in Chart 3a) means in the contagion analysis. The contagion/domino losses stemming from the default on the derivatives positions of the Furfine trigger bank exceeds the 10% loss threshold that has been assumed for all participants. Thus, the default of Barclays on its variation margin (net of its prefunded initial margins) clearly breaches 10% of the default funds of CCP1 and CCP 5 directly. Indirectly, in Chart 3a, each of these CCPs cause a Tier 1 capital loss of more than 10% for Nomura as the non-payment by the CCPs to the in-the-money positions of Nomura is booked as a loss in Nomura's derivatives assets. This leads to some distress in CCP4.

5I Concluding remarks

A case has been made for why it is essential to make systemic risk assessments for CCPs in a comprehensive network setting that reflects the hybrid structure of G-SIB dealers handling OTC positions as well as being clearing members of multiple CCPs.

In this note, we have updated the MAGD based G-SIB derivatives data from 2012 to 2015 in Table 2 and applied identical calculations (as in Heath, Kelly et al., 2016) for the prefunded initial margins and default fund contributions of clearing members for the five CCPs, reported in Table 3. This has provided interesting comparisons. The analysis shows considerable improvements in the stability of the hybrid derivatives network with the spectral systemic risk indexes in Table 4 showing smaller numbers for 2015 as compared to 2012. This is clearly the result of the USD 100 trillion compression of derivatives in terms of notional and an over 30 % reduction in their fair values. Nevertheless, the global derivatives network in 2015 still remains unstable even under 2.6 volatility stress. The proof of concept is given of how *skin-in-the-game* for each of the CCPs can be determined to mitigate potential contagion with the before and after SIG contagion results given in Charts 3a and 3b, respectively. The SIG has been designed to kick in after only 10% of CCPs' default funds have been eroded by the failure of most systemically important G-SIB to pay its residual uncollateralised variation margin. Chart 3a shows how this directly causes distress in two CCPs at once. The absence of such network based spectral systemic risk analytics is a major drawback for determining if a time series of snap shots based on bilateral contractual obligations relative to their prefunded resources are contagion prone or not. Further, we also need assessment of systemic importance and vulnerability of financial participants of these crucial markets.

While some progress has been made on data disclosures by CCPs (CPMI-IOSCO, 2015), G-SIBs and other participants in global derivatives market, it is our view that this falls far short of what is needed to create digital snap shots of holistic maps of financial interconnectedness (see also Brunnermeier et al., 2013) which can mitigate model risk from calibration of derivatives positions of G-SIBs.

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