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ABSTRACT

We use an extensive data set of bilateral exposures on credit default swap (CDS) to estimate the impact on collateral demand of new margin and clearing practices and regulations. We decompose collateral demand for both customers and dealers into several key components, including the "velocity drag" associated with variation margin movements. We demonstrate the impact on collateral demand of more widespread initial margin requirements, increased novation of CDS to central clearing parties (CCPs), an increase in the number of clearing members, the proliferation of CCPs of both specialized and non-specialized types, and client clearing. Among other results, we show that system-wide collateral demand is increased significantly by the application of initial margin requirements for dealers, whether or not the CDS are cleared. Given these dealer-to-dealer initial margin requirements, however, mandatory central clearing is shown to lower, not raise, system-wide collateral demand, provided there is no significant proliferation of CCPs. Central clearing does, however, have significant distributional consequences for collateral requirements across various types of market participants.

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Introduction

The recent G20 reform of the over-the-counter (OTC) derivatives market, launched in the aftermath of Lehman's collapse (FSB, 2013), mandates the clearing of standardized derivative contracts by central clearing parties (CCPs). Central clearing aims to reduce the likelihood and severity of contagion effects in the OTC derivatives market. A CCP steps into bilateral trades by means of novation, becoming the buyer to every seller, and vice versa. By taking on and subsequently mitigating counterparty credit risk, CCPs insulate their members from default losses. CCPs lower counterparty exposures in part through margin requirements.

We provide an empirical analysis of the collateral requirements induced by broader application of margin requirements and central clearing, for an actual network of bilateral CDS exposures as of 2011. We demonstrate the impact on collateral demand of more widespread initial margin requirements, increased novation of CDS to CCPs, an increase in the number of clearing members, the proliferation of CCPs of both specialized and non-specialized types, and client clearing. Among other results, we show that system-wide collateral demand is increased significantly by the application of initial margin requirements for dealers, whether or not CDS are cleared. Given the new requirement for dealer-to-dealer initial margins, mandatory central clearing is shown to *lower* system-wide collateral demand, provided there is no significant proliferation of CCPs. Central clearing does, however, have significant distributional consequences for collateral requirements across various types of market participants.

The increasing use of central clearing raises the importance of CCPs as points of risk concentration. The US Financial Stability Oversight Council has designated three CCPs as systemically important under Title VIII of the Dodd-Frank Act.[5] Although CCPs may provide financial stability benefits (IMF, 2010), some, for example Singh (2010b), have questioned the extent to which CCPs tie up large amounts of valuable collateral.

A number of authors have assessed changes in collateral demand due to mandatory central clearing, arriving at a broad range of estimates, recently compiled by Sidanius and Zikes (2012). We contribute to this literature in three ways.

First, we use a novel and comprehensive dataset of CDS bilateral exposures to assess the impact of various margining and clearing schemes on collateral demand and its decomposition. Our sample, obtained from the Depository Trust & Clearing Corporation (DTCC), covers virtually all CDS bilateral exposures on 184 reference entities representing 31.5% of the global single-name CDS market as of the end of 2011. For each referenced name, the data base comprises counterparties at a global level. This is in contrast

5. See FSOC.

to the existing literature, which used aggregate bank data releases (Heller and Vause, 2012) or market-wide data (Sidanius and Zikes, 2012) at a product-level (CDS and interest rate swaps), without capturing the effect of the network structure of OTC markets and the heterogeneity of counterparty portfolios. CDS are of particular interest because of their jump-to-default risk and the correlation of credit risk with systemic risk.

Second, we study a variety of clearing schemes and market structures. Previous work had studied only simplified market structures. As opposed to prior research, our data enable us to model both dealers and their customers. We are also able to capture the impact on collateral demand of the new regulatory requirement for dealer-to-dealer (D2D) initial margins. From two base cases, with and without D2D margins, we analyse four effects : an increase in novation to existing CCPs, an increase in the number of clearing members, an increase in the number of CCPs, and client clearing. (With "client clearing," dealers clear the derivatives portfolio of their client end-users.) The second and the fourth of these effects had not been examined in the literature. Although the effect on collateral demand of increasing the number of CCPs had been investigated by Duffie and Zhu (2011), that study was severely limited by lack of access to bilateral exposure data. We distinguish between the impact of adding "specialized" CCPs, as opposed to "non-specialized" CCPs, which are shown to be substantially less efficient in collateral use because of lost netting and diversification opportunities.

Third, we provide a fully elaborated margin model that enables us to decompose margin demand both by trader type (customer or dealer) and by margin type. Specifically, our margin model features portfolio-specific initial margins, a contract-specific short charge for net CDS sellers, the impact of maintaining unencumbered assets in order to face daily variation margin calls, and the velocity drag of collateral movement within the financial system. The last two of these components had not been examined. Velocity drag is shown to have a significant impact on collateral demand. Our model captures how these components of margin demand incorporate the effects of cross-counterparty netting and diversification, which change with the clearing scheme.

Overall, we find that clearing more CDS leads to a much smaller change in system-wide collateral demand than suggested by previous studies. Indeed, assuming that initial margin is required for dealers whether or not their positions are cleared, we find empirically that central clearing actually *lowers* collateral demand through the effect of multilateral netting, provided there is no significant proliferation of CCPs.

We show that client clearing reduces system-wide collateral demand provided that dealers are able to re-use a large enough share of the collateral that they receive from their clients. The drop in collateral demand is driven by cross-counterparty netting and by diversification benefits, both for customers and dealers, and depends on the size of each investor's portfolio. Netting and diversification benefits outweigh increased initial margin requirements for investors whose portfolios are large enough.

In sum, most of the increase in collateral demand associated with the new regulatory environment for CDS is caused by an increase in the set of market participants required to provide margin at standardized safe levels. Central clearing does not itself cause a major incremental increase in collateral usage, unless there is a further proliferation of central clearing parties. For a given level of protection against counterparty failure risk, the key determinant of collateral demand is netting. Combining offsetting and diversifying swaps in the same netting set causes a significant lowering of collateral demand. Central clearing can either improve or reduce netting opportunities, depending on how much is cleared, how many CCPs are used, and the degree to which the same swaps are cleared in different CCPs. Although every euro of variation margin paid by some market participant is received by its counterparty, the need to retain buffer stocks of funds suitable for variation margin payments and the frictional drag associated with the "velocity of circulation" of margin funds between participants are important components of the total demand for collateral.

Other Related Work

There is a growing literature on counterparty credit risk in OTC markets. Acharya and Bisin (2013) investigate theoretically the existence of a counterparty risk externality on opaque OTC markets, which is shown to be absent when a centralized clearing mechanism is implemented. Zawadowski (2013) models an OTC market in which unhedged counterparty risk may lead to a systemic run of lenders in case of idiosyncratic bank failure. Thompson (2010) studies the signaling incentives induced by counterparty risk. Empirical evidence on the pricing of counterparty risk on the CDS market have been provided by Arora et al. (2012).

Central clearing parties as a counterparty risk mitigation institution have recently been studied theoretically and empirically. Biais et al. (2013) and Koeppl et al. (2011) analyse theoretically the optimal design of incentive-compatible clearing arrangements. The working of clearing institutions during the October 1987 crash has been documented by Bernanke (1990). More recently, clearing in derivative markets has been described by Pirrong (2009) and Singh (2010a). Hull (2010) discusses the issue whether all OTC derivative transactions can be centrally cleared.

Duffie and Zhu (2011) focussed on the netting efficiency of bilateral versus centrally cleared derivatives, and showed that reducing the proliferation of CCPs also reduces counterparty exposure and collateral demand. Their work has been extended by Cont and Kokholm (2012), who focus on assets that are heterogeneous with respect to their risk characteristics, and by Anderson et al. (2013), who analyse netting efficiency with linked and unlinked

CCP configurations.

Our paper is most closely related to Heller and Vause (2012) and Sidanius and Zikes (2012), who estimate the system-wide increase in collateral demand due to mandatory central clearing. We extend their work in several respects. Rather that using simulated exposure data, we use actual bilateral pre-reform exposure data. This enables us to distinguish between customers and dealers and to account for actual netting and diversification benefits at the level of bilateral portfolios. Because of the granularity of these data, we are able to considerably refine the impacts of clearing schemes and market structure. For instance, emerging client clearing practices had not before been modeled, nor had the impact of the number of client clearing members on collateral demand. Finally, from contract-level exposure data, our margining model enables us to document the netting and diversification benefits of increased clearing, as well as the sizes of each component of collateral demand. Among these, the velocity drag on collateral arising from variation margin had not been formulated or estimated.

The remainder of the paper is structured as follows. The exposure data are first described (section 1). Then the baseline model for collateral demand is presented (section 2), and its results are described (section 3). Finally, the impacts of four alternative clearing models are analyzed (section 4).

1 The CDS exposure data

This section describes our data.

1.1 The bilateral exposure dataset

Our CDS bilateral exposure data are provided by the DTCC, as extracted from the Trade Information Warehouse (TIW). The snapshot of the world CDS market is as of 30 December 2011 for a large number of major reference entities. The TIW is a global trade repository covering the vast majority of CDS trades worldwide, and virtually all recent CDS trades. This data set is a legal record of party-to-party transactions, as the Warehouse Trust Company (a subsidiary of DTCC which operates the TIW) is supervised by US regulatory authorities. In addition to capturing the reports of dealers and banks, our dataset encompasses non-bank market participants such as hedge funds, insurance companies, central counterparties and potentially some industrial corporations. The dataset is unique as it is truly global. Whereas most regulators obtain exposure data from DTCC related to their *domestic* reference entities or institutions only, the dataset used in this paper has a *global* coverage.

Our sample covers 184 reference entities, including 9 G20 sovereigns, 20 European sovereign and 155 global financial entities. Overall, 885 counterparties have been active in at least one of these reference entities. Our dataset contains the names of the reference entities, but the identity of the counterparties is anonymised. A total gross notional of USD 4.91 trillion of CDS is covered by our sample. At the same date (30 December 2011) the total gross notional of the global CDS market was USD 25.9 trillion (ISDA, 2012). Our sample thus represents about 31.5% of the global single-name CDS market and 18.9% of the total CDS market (including multi-name instruments). We have deliberately excluded Asian names, so as to have a partition of the set of reference entities into two subsets (European and American names), which is useful when analysing the effect of separated central clearing. As our empirical analysis relies on the use of CDS price data, all CDS for which there is no available price time series on Bloomberg have been excluded.

For each reference entity, our dataset contains gross and net bilateral exposures between any two counterparties. The overall network consists of 44,155 bilateral exposures on individual reference entities. Any bilateral exposure may result from several separate transactions, so that the number of transactions covered is 503,119. We do not have access to additional information at a transaction level. For example, we know neither the date at which a particular deal has been executed, nor the maturity (initial or remaining) of each position. The market value of open positions is not available. [6]

We have performed checks on data quality. We drop 328 bilateral exposures of a counterparty vis-à-vis itself. Such exposures involve 12 individual counterparties, and are barely relevant for our purposes as they reflect aggregation inconsistencies at a bank level (an internal trade between two accounts or two subsidiaries or other legal entities of the same firm).

We obtained daily CDS pricing from Bloomberg.

1.2 Empirical identification of CCPs

Our dataset includes a fraction of trades that are centrally cleared. Given our focus on netting efficiency and collateral demand induced by the design of clearing schemes, we devote careful attention to the identification of bilaterally and centrally cleared exposures in the dataset. We identify CCPs from their business model by identifying institutions which have large gross exposures but consistently zero multilateral net exposures on *all* reference

6. The dataset used in this paper is a sub-sample of the one used in Peltonen et al. (2013), and is restricted to reference entities which are liquid enough so that time series of prices or quotes exist at a daily frequency. A more thorough description of the data can be found in this paper.

entities they are trading [7]. Among the 50 largest counterparties [8] (ranked by gross notional amounts bought and sold), we identify two CCPs.

Descriptive statistics regarding these CCPs are provided in table 1. Out of 184 single-name reference entities in the sample, 39 are centrally cleared. CCP-cleared exposures represent 7.02% of the market gross notional amount (at the same date, year-end 2011, the ISDA estimated the percentage of CCP-cleared single-name CDS to be 8%, based on a broader sample - see ISDA (2012)). For reference names that have some CDS cleared by at least one CCP, on average 32% of the gross notional amounts are centrally cleared. No CDS is cleared by both CCPs. We also find that one CCP only clears European names whereas the other clears only North American and Latin American names, which we shall call "American."

Descriptive statistics	All sample
Number of CDS cleared	39 (out of 184)
Share of the gross market notional cleared through CCPs	7.02%
Share of the gross market notional cleared for each clearable CDS	
Min.	0.4%
Average	32%
Max.	47.9%
Market shares	
CCP 1	64,7%
CCP 2	35.3%
Cleared names	
CCP 1	American
CCP 2	European

TABLE 1 – Descriptive statistics on CCP-cleared exposures. This table describes the two CCPs identified in the dataset. No overlap in the names cleared by both of them is observed. Instead, an American/European breakdown is documented, with a larger market share for the CCP clearing American names. American names include Central and Latin America, Canada and the United States. European Names include Norway, Russia, Switzerland and the European Union. Source : DTCC.

7. Formally, in terms of the notations introduced below (section 2.1), an institution i is identified as a CCP if $\sum_j \left[G^k(i,j) + G^k(j,i)\right] \geq 5.8$ bn USD and $\sum_j \left[X^k(i,j) - X^k(j,i)\right] = 0$ for all k. The threshold of 5.8 bn USD corresponds to the gross buy and sell notional amount traded by the 50th largest institution.

8. The criteria for identifying CCPs are valid for institutions with an large activity only. Indeed, we do observe a handful of much less active institutions trading one or two CDS and having a zero multilateral net exposure. These institutions, however, are not likely to be central clearing parties. Institutions below the top-50 trade gross buy and sell notional below USD 3 bn.

As regards the characteristics of the clearable CDS, we observe 25 American names and 14 European names, which break down into 36 financial names and 3 sovereign names (all in the American area). The median gross notional amount of a cleared name is USD 13.5 bn, which is about 90% larger than the sample median, implying that clearable names are CDS with large gross notional amounts traded.

2 The baseline case : the observed network

In the baseline case studied in this section, we focus on modelling collateral demand given the network of exposures observed in the data. In later sections, we focus on the dynamics of collateral demand when the network of exposures is altered as a consequence of increased novation to CCPs, under a variety of alternative market structures.

2.1 Market participants, reference names, and exposures

Consider a set $\Omega = \{1, \ldots, n\}$ of market participants—also referred to as “investors", for simplicity—partitioned into two subsets based on their membership to one or several CCPs. Of these n investors, D institutions, called *dealers* or *clearing members*, are members of at least one CCP, whereas $n-D$ institutions, called *customers* or *end-users*, do not have direct membership to central clearing parties. In addition, there is a set of n^{CCP} central counterparties that do not belong to Ω and K reference entities indexed by k. The $n \times n$ bilateral exposure matrix for reference entity k is denoted G^k. The (i, j) element of G^k is the gross CDS exposure sold by bank i to bank j on k. It does not include exposures to or from CCPs. From G^k, a $n \times n$ net bilateral exposure matrix, denoted X^k is constructed. Each of its elements is given by $X^k(i,j) = \max\left\{0; G^k(i,j) - G^k(j,i)\right\}$. Therefore, $X^k(i,j) = 0$ whenever $X^k(j,i) > 0$ for all i and j.

2.2 Collateral posting

We now turn to collateral posting in the baseline case. Collateral requirements are defined for four types of bilateral exposures, namely customer-to-dealer, dealer-to-dealer, dealer-to-CCP and, for a small number of cases, customer-to-customer. Our model accounts for both initial and variation margins, and for collateral “drag” due to limits on the velocity of circulation of collateral. In addition, collateral posting on a bilateral basis differs from collateral posting to a CCP.

2.2.1 Margin requirements

Margin requirements for all types of institutions are summarized in table 2, and are designed in the baseline case so as to reproduce widespread market practices before mandatory central clearing is implemented. First, initial margins are posted by customers to all their counterparties, whether dealers or customers. In contrast, dealers do not post initial margins to customers. Dealer-to-dealer initial margins are treated parametrically, so as to consider both the case where they are zero (akin to the pre-reform case) and strictly positive (as on-going regulatory reforms are set to require such margins (BCBS, 2013)). In addition, dealers post initial margins to CCPs, whereas CCPs do not post initial margins to them.

Party	Counterparty	Initial Margins	Variation Margins
Customer	Dealer	Yes	Yes
Dealer	Customer	No	Yes
Dealer	Dealer	Yes/No	Yes
Customer	Customer	Yes	Yes
Dealer	CCP	Yes	Yes
CCP	Dealer	No	Yes

TABLE 2 – Initial and variation margin requirements. This table describes the margin requirements for all possible pairs of trader types. In the baseline case and for alternative specifications, results are presented both with and without dealer initial margins, thus enabling a reproduction of both the pre-reform and the post-reform cases.

Second, variation margins are posted for all bilateral exposures. They are decomposed into a buffer of unencumbered assets maintained to meet daily calls and a component accounting for the velocity of circulation drag within the financial system.

2.2.2 Initial margins

Initial margins between any two parties are computed at a bilateral portfolio level. They are calculated as the sum of a risk-based component and a short charge for net CDS sellers, in order to replicate current market practice (for example, LCH-Clearnet (2012)). We define the bilateral portfolio $\mathcal{P}_{ij}$ between any i and j as the $K \times 1$ vector

$$\mathcal{P}_{ij} = \left\{ X^1(i,j) - X^1(j,i), \ldots, X^K(i,j) - X^K(j,i) \right\}.$$

Component k of $\mathcal{P}_{ij}$ is positive whenever i is a net seller to j on reference entity k, and negative otherwise. Denote $\phi_T^t(\mathcal{P}_{ij})$ the change in the market value of $\mathcal{P}_{ij}$ over the period of T days spanning between $t - T + 1$ and t. We have :

$$\phi_T^t\left(\mathcal{P}_{ij}\right) = \left|\sum_k \left(X^k\left(i,j\right) - X^k\left(j,i\right)\right)\left(p_t^k - p_{t-T+1}^k\right)\right|, \tag{1}$$

where p_t^k is the price of CDS k at date t. The initial margin to be posted by i to j, denoted C_{ij}^{IM}, is the worst historical change in the value of $\mathcal{P}_{ij}$ over any T-day period, computed over the last $P \geq T$ days. Thus :

$$C_{ij}^{IM} = \phi_T^{t^*}\left(\mathcal{P}_{ij}\right), \text{ where } t^* \equiv \max_{t\in\{T+1,P\}}\phi_T^t\left(\mathcal{P}_{ij}\right). \tag{2}$$

This initial margin is computed from the time series of CDS price data. Our calculation ignores the impact of reference entity defaults, of which there are none in our sample period [9].

In addition to this portfolio-based initial margin (which is equal for both i and j), a *short charge* is added for bilateral net CDS sellers, in order to mitigate jump-to-default risk. Initial margins computation differs for customers and dealers, as customers do not have access to central clearing and post collateral bilaterally to all other institutions in Ω. Dealers post initial margin only to central clearing parties and, to a specified extent, to other dealers.

Regarding customers first, the total initial margins to be posted by any customer i, denoted C_i^{IM}, is

$$C_i^{IM} = \sum_j \left[\upsilon^C \phi_T^{t^*}\left(\mathcal{P}_{ij}\right) + \alpha^C \sum_k X^k\left(i,j\right)\right]. \tag{3}$$

The first term, in the sum over all counterparties, is the initial margin computed from the left tail of the portfolio historical value $\phi_T^{t^*}\left(\mathcal{P}_{ij}\right)$. The second component is a short charge computed on the basis of all net bilateral short exposures at a reference entity level, parameterized by α^C. Here, $\upsilon^C \in [0;1]$ is a parameter capturing the potential undercollateralization of bilaterally cleared trades compared to centrally cleared trades [10]. A trade is fully collateralized whenever $\upsilon^C = 1$.

For dealers, assuming no rehypothecation, we have :

9. Another source of potential minor under-estimation of collateral demand stems from the fact that, due to data limitations, each exposure $X^k\left(j,i\right)$ may aggregate CDS traded at different dates and with different maturities. Thus CDS exposures which we consider as fully offsetting may nevertheless give rise to collateral posting on actual markets, once heterogeneity with respect to these two characteristics is considered.

10. Levels of collateralization below 1 are documented for bilaterally cleared trades by ISDA (2011, p.14)

$$C_i^{IM} = \sum_{d=1}^{D} \left[\upsilon^D \phi_T^{t^*} (\mathcal{P}_{i,d}) + \alpha^D \sum_d X^k (i,d) \right] + \sum_{h=1}^{n^{CCP}} \left[\phi_T^{t^*} (\mathcal{P}_{i,CCP_h}) + \alpha^{CCP} \sum_h X^k (i, CCP_h) \right], \quad (4)$$

where $\mathcal{P}_{i,CCP_h}$ denotes the bilateral portfolio of a clearing member i vis-a-vis CCP h. The first term in equation 4 corresponds to dealer-to-dealer initial margins. The second term corresponds to margins posted to CCPs. Differences are twofold [11], reflecting the fact that risk-management practices by CCPs tend to be more conservative than those for investors. First, centrally cleared trades are fully collateralized. Second, the short charge is different for bilaterally and for centrally cleared trades, with typically $0 < \alpha^D < \alpha^{CCP}$. Furthermore, the introduction of different margin parameters for customers and dealers (υ^C and υ^D for the under-collateralization, α^C and α^D for the short charge) is justified on the grounds that a significant share of dealer activity (for example market making and prime brokerage) does not generate sizeable potential future exposure in a medium-term perspective and is thus subject to lower collateralization standards.

In later sections, we consider $\upsilon^D < \upsilon^C$ and $\alpha^D < \alpha^C$. We also later consider a base case in which $\upsilon^D = 0$ and $\alpha^D = 0$, that is, an absence of dealer-to-dealer initial margins. Finally, one important feature of margins computed according to equations 1 and 2 is that portfolio diversification reduces initial margin requirements.

2.2.3 Variation margin

In order to be prepared to pay variation margins, a bank must have a precautionary stock C_i^{VM} of unencumbered assets ready to be transferred. Let us denote $\sigma \left(X^k (i,j) \right)$ the daily standard deviation of $X^k (i,j)$. For investor i, this precautionary stock is computed on the basis of its whole portfolio, regardless of its counterparties, and is given by :

$$C_i^{VM} = \kappa^{VM} \sigma \left(\sum_k \sum_j \left| X^k (i,j) - X^k (j,i) \right| \right), \quad (5)$$

where $\kappa^{VM} > 0$ is a multiplier on the daily standard deviation of the portfolio of investor i. Equation 5 captures the benefits of portfolio diversification.

11. Other requirements for centrally cleared trades—such as a contribution for the maintenance of a default fund—are ignored.

2.2.4 Margin velocity drag

In addition to initial and variation margins, we model the collateral "drag" caused by limits on the velocity of circulation. From the time that it is committed to be transferred, and until it becomes unencumbered and ready to deploy for the counterparty to whom it is transferred, variation margin payments are assumed to be unavailable, and thus augment the collateral demand by a "velocity drag" of amount

$$C_i^D = \sum_j \kappa^D \sigma \left(\sum_k \left| X^k(i,j) - X^k(j,i) \right| \right), \tag{6}$$

where κ^D is a multiplier on the daily standard deviation of the portfolio of investor i. Whereas variation margins are computed on the basis of an institution's entire portfolio (regardless of the particular counterparties), velocity drag depends on the structure of bilateral exposures. The magnitude of velocity drag therefore changes when a CCP interposes between dealers' exposures.

2.2.5 Total collateral demand

The total collateral demand C at a system level is given by the sum of the three components :

$$C = \sum_i \left[\hat{C}_i^{IM} + C_i^{VM} + C_i^D \right]. \tag{7}$$

3 Results for the baseline case

In the baseline case, we focus on collateral demand given the network of exposures observed in the dataset. Only 7.02% of these exposures are cleared through one of the two existing CCPs. The set of dealers is the set of clearing members observed in the dataset. We find that $D = 14$, in line with anecdotal evidence according to which the CDS market is centered around 14 dealers (Brunnermeier et al., 2013). Comparative descriptive statistics for dealers and customers are presented in table 3. Furthermore, in the baseline case, the set of cleared exposures is left unchanged, as is the clearing scheme.

3.1 Calibration

Parameter values are calibrated to replicate actual market practices. Initial margins are designed to cover the potential future exposure of a party

	Dealers	Customers
Number of institutions	14	871
Number of CDS traded		
Min.	179	1
Median	184	5
Max.	184	177
Gross notional traded (USD bn)		
Min.	104.1	0.0002
Median	286.3	0.07
Max.	503.7	120.5
Number of counterparties		
Min.	102	1
Median	310	3
Max.	460	50

Table 3 – Descriptive statistics for dealers and customers. This table presents comparative descriptive statistics for dealers and customers. The D dealers are identified by the fact that they belong to the existing central clearing parties. Dealers consistently trade a larger number of CDS than customers and with a larger number of counterparties. With one exception, this is also true for the gross notional amount traded. Group differences in median values are highly significant. Source : DTCC.

(including the CCP), which exists during the few days needed to liquidate and replace exposures with a defaulted counterparty. We thus consider $T = 5$ days in the calculation of initial margins. Variation margins cover current exposure arising between two margin calls, which usually occur at a daily frequency. We calibrate the multiple on the daily standard deviation as $\kappa^{VM} = 2$. Even if variation margins are called on a daily basis, a lag exists between the time at which a party commits to pay and the counterparty receives the variation margin payment. The velocity drag parameter (a multiple on the daily standard deviation of each bilateral portfolio) is set at $\kappa^D = 1.5$.

The calculation of short charges on the market relies on the estimation of wrong-way risk (credit event and counterparty default occurring simultaneously, see LCH-Clearnet (2012)). We adopt a simplified approach. Short charges α^C and α^D for both customers and dealers are assumed to be equal to 1% of their net bilateral notional exposure. CCPs are assumed to take a more conservative stance and require $\alpha^{CCP} = 0.02$.

The level of under-collateralization for customers is set to $\upsilon^C = 0.75$, in line with the figure provided by ISDA (2011) for the whole OTC derivatives market. We assume a lower collateralization level of $\upsilon^D = 0.5$ for dealers, based on the view that a sizeable share of dealer activity, including market making and their role as intermediaries, does not generate genuine medium-term bilateral exposure. Finally, we assume no rehypothecation ($\rho = 0$) in the base case. These baseline parameters, and alternative specifications, are summarized in table 4.

Parameter	Definition	Calibration
Baseline case		
υ^C	Level of under-collateralization for customers	0.75
υ^D	Level of under-collateralization for dealers	0.5
T	Initial margins computation period	5
α^C	Bilateral short charge for customers	0.01
α^D	Bilateral short charge for dealers	0.01
α^{CCP}	Short charge to CCP	0.02
ρ	Rehypothecation ratio	0
κ^{VM}	Variation margin	2
κ^D	Velocity of collateral	1.5
Alternative specifications		
$\bar{t}$	Exposure-level CCP eligibility threshold	0
λ	Re-usable collateral for client clearing dealers	0.5

Table 4 – Calibration for the baseline model and alternative specifications. This table presents the calibration used both for the baseline model and for alternative specifications. The baseline model derives from the pattern of exposures observed in the data, without changes in the clearing scheme or in the clearable CDS.

3.2 Collateral demand decomposition, with and without dealer-to-dealer initial margins

We consider the magnitude and decomposition of collateral for two calibrations of the baseline case alternatively. First, when $\upsilon^D = 0$ and $\alpha^D = 0$, dealers do not post initial margin to each other. Second, when $\upsilon^D > 0$ and $\alpha^D > 0$, we focus on the dynamics of collateral demand once dealer-to-dealer initial margins become mandatory. The first scenario is akin to the pre-reform case ; the second resembles the post-reform case. Each of the baseline cases is designed to investigate the impact of gradual or outright changes in novation to CCPs and in clearing schemes, both pre-reform and post-reform.

The decomposition of collateral demand both with and without dealer-to-dealer initial margins is presented in the first two columns of figure 11. In the absence of dealer-to-dealer initial margins, 68.9% of total margin is posted by customers in the form of initial margins (including the short charge component). Margin posted by dealers to CCPs accounts for only 7.6% of the system-wide collateral demand. The variation margin component, including velocity drag, accounts for 23.4% of the system-wide demand for collateral.

The velocity-drag component is 2.2 times the component associated with the precautionary stock of unencumbered assets.

The introduction of dealer-to-dealer initial margins increases total collateral demand by 76%. The increase is purely due to dealers' collateral demand, which increases by a factor of 10.9, then representing 47.5% of system-wide collateral demand. As regards the decomposition, note that the short charge component of initial margins is relatively more important for dealers (48.6%) than for customers (30.0%). This is due to the fact that dealers manage larger CDS portfolios than customers, therefore enjoying larger diversification benefits on the part of their initial margin requirement computed at a bilateral portolio level (equation 2). The definition of the short charge, on the contrary, excludes diversification benefits, and thus represents a larger share of margins demand for dealers.

In terms of magnitude, without dealer-to-dealer initial margins, system-wide collateral demand is about 4.6% of the market-wide net notional positions and 0.35% of the market gross notional positions. With dealer-to-dealer initial margins, collateral demand rises to 8.1% of net notional and 0.62% of gross notional.

	D-to-D IM	No	Yes	No	Yes
	Client clearing	No	No	Yes	Yes
Δ demand by type of trader	Customers	0	0	-0.19	-0.19
	Dealers	1.34	-0.48	0.74	-0.68
Δ demand by type of exposure	C-to-C	0	0	-1	-1
	C-to-D	0	0	-0.25	-0.25
	D-to-D	-	-1	-1	-1
	D-to-CCP	4.42	4.42	6.87	6.87
Δ total demand		0.29	-0.27	0.01	-0.48

Table 5 – Change in collateral demand from baseline cases. This table contains estimates of changes in total collateral demand when shifting from two base cases (with and without dealer-to-dealer initial margins) and no central clearing to full central clearing with and without client clearing. Only exposures which are already cleared in the dataset are centrally cleared in the base cases. "IM" stands for "initial margins", "C" for customer, "D" for dealer. The computation of the change in collateral demand by type of exposures excludes variation margins, as such margins are not allocated counterparty by counterparty, but at a portfolio level.

3.3 Portfolio margin assumptions

In this subsection, we analyse the sensitivity of collateral demand to the initial margin model. The number of days T on which the worst historical change in portfolio value $\phi_T(\mathcal{P}_{ij})$ is computed (equation 2) is varied between

3 and 10 days. The appropriate choice of T for this purpose has been a matter of some disagreement between regulators and market participants in the United States.

Our results depend on the "clearing threshold," defined as the level of gross notional amount of CDS outstanding for a given reference name at or above which CDS for that reference name are assumed to be centrally cleared. Figure 1 plots total collateral demand, broken down between dealers and customers, for a given clearing threshold. From the baseline case ($T = 5$), an increase in the initial margin computation period to 10 days yields an increase in collateral demand by 27.7% for dealers and by 21.4% for customers. Therefore, without any change in the clearing requirements, a slight change in the initial margin model may have a sizeable impact on collateral demand. Moreover, the slope of the initial margin demand curve when T is varied is steeper for customers than for dealers. Such highest sensitivity is explained by the fact that customers typically manage smaller CDS portfolios (table 3) and therefore enjoy lower diversification benefits.

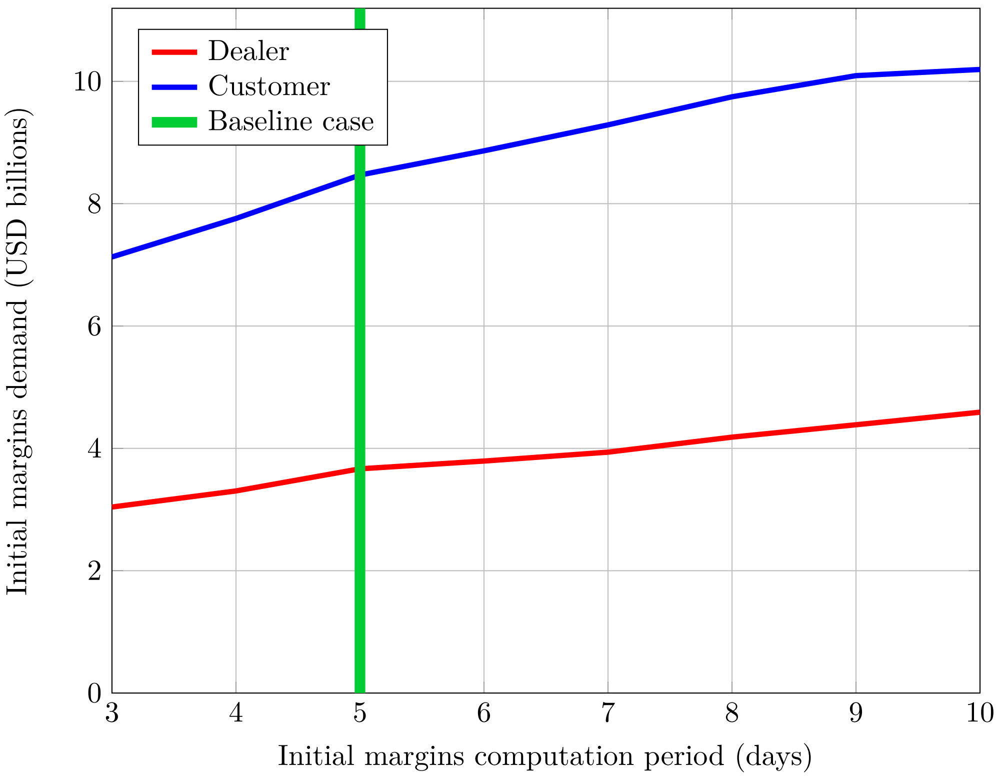


FIGURE 1 – Initial margins demand as a function of T. This chart plots the initial margins demand for dealers and customers when T is varied. The short charge is not included in the initial margin, as it does not change with T. This chart is for a given clearing threshold $\bar{T} = 1.4 \cdot 10^9$ (i.e. all CDS are centrally cleared).

3.4 Rehypothecation

In the market for bilaterally cleared derivatives, rehypothecation of received collateral is common (Singh, 2010b). In this section we analyse the effect of rehypothecation or other repledging practices on total collateral demand. We denote by $\rho \in [0;1]$ the "rehypothecation ratio," that is, the proportion of received collateral that a bank may re-use. We assume that only dealers can re-use initial margin received from others. For dealer i, the total initial margin requirement, net of rehypothecated collateral, $\hat{C}_i^{IM}$, is

$$\hat{C}_i^{IM} = \max \left\{ 0; C_i^{IM} - \rho \sum_{d=1}^{D} C_{di}^{IM} \right\}. \tag{8}$$

Here, the collateral drag arising from rehypothecation is ignored.

The impact of rehypothecation on collateral demand in the baseline case is illustrated in figure 2. In the presence of dealer-to-dealer initial margins for uncleared trades, the impact of rehypotecation on dealers' collateral demand is sizeable. Initial margins decrease linearly with ρ (up to the point where, for a bank i, $\rho \sum_{d=1}^{D} C_{di}^{IM} > C_i^{IM}$). When $\rho = 0$, dealers' collateral demand is 4.2 times higher than when $\rho = 1$. A detailed assessment of collateral needs implied by mandatory central clearing should therefore rely on an appropriate account of rehypothecation in the baseline case. The effect of increased central clearing on collateral demand, with varying levels of ρ, is investigated in the next section.

4 Alternative clearing schemes

In this section, we investigate alternative structural assumptions for central clearing. We focus on the impact on collateral demand of *(i)* increasing novation to CCPs, *(ii)* increasing the number of CCP members, *(iii)* increasing the number of CCPs, and *(iv)* introducing client clearing services.

4.1 Increased novation to CCPs

This section focuses on the impact on collateral demand of increased central clearing. The market composition of customers, dealers and CCPs, is kept at the baseline case. Ongoing reforms require central clearing for derivative contracts which are sufficiently standardized. [12] We assume two requirements for a CDS exposure to be novated to a CCP. First, a CDS contract must be sufficiently actively traded. We assume that a reference entity is eligible for central clearing when its global gross notional amount

12. Standardization criteria still to be defined. In the case of Europe, see ESMA (2013).

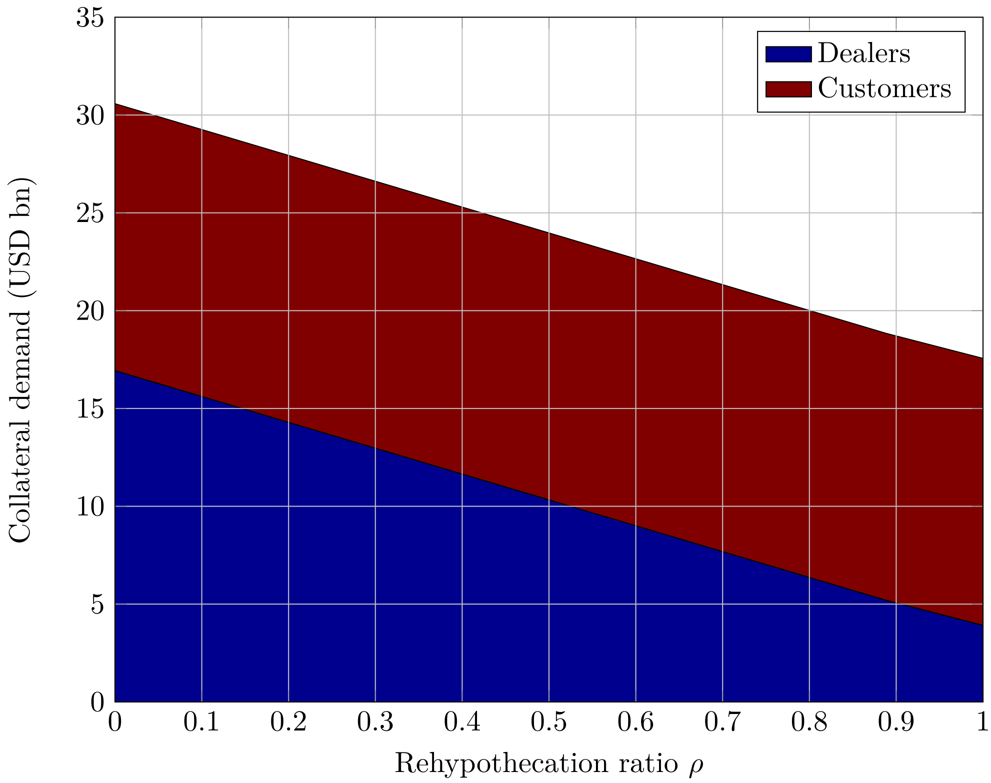


FIGURE 2 – Baseline collateral demand as a function of ρ. This chart plots a decomposition—between dealers and customers—of the system-wide collateral demand in the baseline case when the rehypothecation ratio is varied. The baseline case is with dealer-to-dealer initial margins, and with the network of exposures (including centrally cleared exposures) observed in the data. Only dealer-to-dealer collateral received can be rehypothecated. Other calibrations are those of the baseline case.

is above a threshold $\bar{T}$, which can thus be interpreted as a proxy for standardization. By dialing $\bar{T}$ down, the gradual shift from the pre-reform to the post-reform case is mimicked. Our dataset indeed (section 1.2) suggests that names with larger gross notional amounts traded have been cleared first by dealers, so that $\bar{T}$ is a reasonable proxy for "clearability." Second, whenever a reference entity is eligible for central clearing, only trades above a threshold $\bar{t}$ are cleared. A justification for $\bar{t} > 0$ is that there may exist exposure-specific fixed costs associated with central clearing (data processing, information requirements). Formally, whenever

$$\sum_i \sum_j G^k(i,j) \geq \bar{T},$$

and $G^k(i,j) \geq \bar{t}$, an exposure $G^k(i,j)$ is assumed to be cleared at a CCP. Only dealer-to-dealer exposures are eligible for central clearing in this subsection. Increased CCP membership and client clearing are explored in later subsections. The number of CDS cleared for several values of $\bar{T}$ is presented in table 6, while the breakdown of trade types as a function of $\bar{T}$ is shown in table 7.

CCP Threshold $\bar{T}$ (USD billion)	Number of cleared CDS	Percentage gross notional cleared
1	184	1
34	41	0.64
68	15	0.37
101	8	0.26
135	5	0.19
168	2	0.10
202	1	0.06
235	1	0.06
269	1	0.06
305	0	0

TABLE 6 – Distribution of cleared CDS, by CCP clearing threshold ($\bar{T}$). This table displays the number of CDS cleared and the percentage of the market gross notional they represent as a function of $\bar{T}$. CDS exposures which are already cleared in the dataset are not accounted for here. The set of values of $\bar{T}$ is the one used in all other tables and figures where $\bar{T}$ appears. A threshold $\bar{T} = 305$ bn USD corresponds to the baseline case. Source : DTCC.

We make additional assumptions on the assignment of particular exposures to CCPs. Consistent with the pattern observed in our dataset, we assign each CDS reference entity to one of the two existing CCPs, based on a European/American geographical breakdown (see section 1.2). All European (including European Union, Norway, Russia and Switzerland) CDS

	CCP Threshold (USD bn)	1	34	68	101	135	168	202	235	269	305
Customer-to-customer	% Number of trades	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	% Net notional	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Customer-to-dealer	% Number of trades	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
	% Net notional	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Dealer-to-dealer	% Number of trades	0	0.27	0.32	0.33	0.34	0.35	0.35	0.35	0.35	0.35
	% Net notional	0	0.22	0.34	0.39	0.42	0.46	0.47	0.47	0.47	0.49
Dealer-to-CCP	% Number of trades	0.36	0.10	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01
	% Net notional	0.49	0.27	0.15	0.10	0.07	0.04	0.03	0.03	0.03	0.00

TABLE 7 – Trade types and net notional as a function of $\bar{T}$. This table presents the share of trade types, and the share of net notional exposure they represent, for all pairs of party-to-counterparty exposures. Changes in the CCP clearing threshold $\bar{T}$ does not affect customer-to-customer or customer-to-dealer exposures. A decrease in $\bar{T}$ lowers the share of dealer-to-dealer trades and increases the share of dealer-to-CCP trades.

reference entities are cleared by the existing European CCP, while all American (including Canada, Central and Latin America, and the United States) reference entities are cleared by the existing American CCP. One CDS reference entity is never cleared by more than one CCP. The case in which multiple CCPs may clear the same CDS is investigated in a later section.

Increased novation to CCPs has opposing effects on collateral demand. On the one hand, bilateral dealer-to-dealer exposures which were not subject to initial margin requirements, or which were left under-collateralized to the extent captured by υ^D, are now subject to full margin requirements. On the other hand, increased novation implies larger portfolios $\mathcal{P}_{i,CCP_h}$ for any i and h, therefore potentially increased cross-counterparty netting and diversification benefits.

Figure 3 plots the decomposition of system-wide collateral demand when the central clearing threshold $\bar{T}$ is reduced from that of the base case (USD 305 billion) to 0 (that is, full clearing), both with and without dealer-do-dealer initial margins. In the absence of dealer-to-dealer initial margins, total collateral demand increases by about 29% when shifting from the baseline scenario to full CCP clearing. This increase is driven by dealer initial margins and short charges, as well as by the velocity drag of collateral. Customers' collateral demand is unchanged at this stage as they are not clearing members (client clearing is investigated below).

Whereas dealer initial margins and short charges increase, the velocity drag decreases, due to the fact that increased central clearing amounts to pooling multiple bilateral exposures with one counterparty, therefore reducing the number of bilateral links and increasing netting opportunities. Accounting for changes in the velocity drag of collateral is therefore important, and had not been considered in previous research on collateral demand. A failure to account for velocity drag would result in an over-estimate of the increase in collateral demand implied by the shift to mandatory central clearing.

At a system level, the rise in collateral demand is found to be smaller than estimated by previous empirical studies. This increase amounts to 0.1% of the gross market notional, below the lower bound provided by Singh (2010b), who estimates this increase at between 0.16% and 0.33% of the gross market notional. Heller and Vause (2012), who study the whole CDS market for G-14 dealers only, provide estimates that depend on the prevailing level of market volatility. With the most conservative hypothesis, they estimate additional initial margin requirements to be above 100 bn USD. A linear extrapolation of our results (as we consider a subset of the CDS market only) yields a much lower estimate for the impact of central clearing on collateral demand.

Although collateral demand by customers does not change with the implementation of full clearing, dealers experience an increase in collateral demand of 134%, (see table 5) from the low "pre-reform" level. Second, among dealers, the increase in collateral demand ranges between 57.5% and 519.7%,

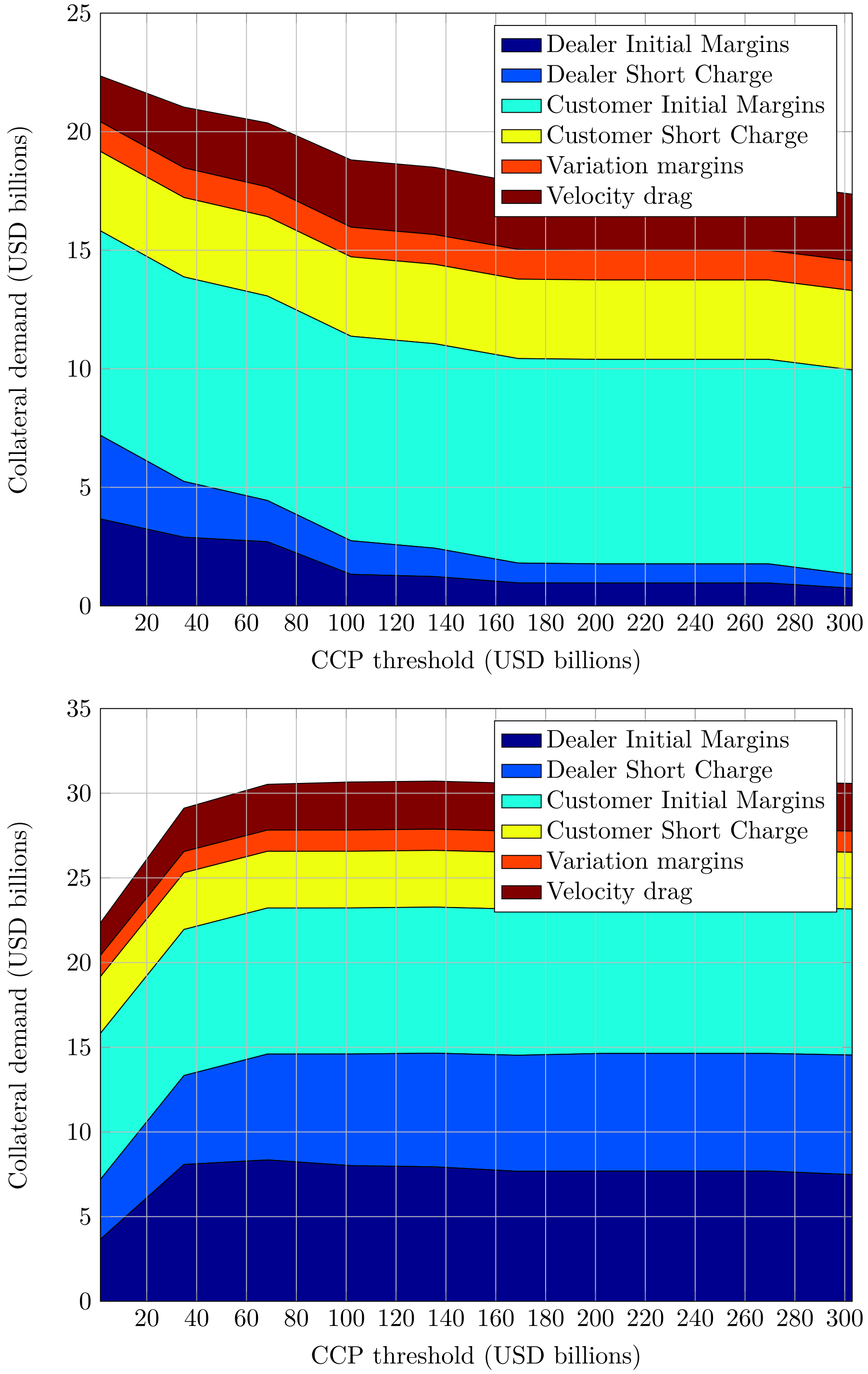
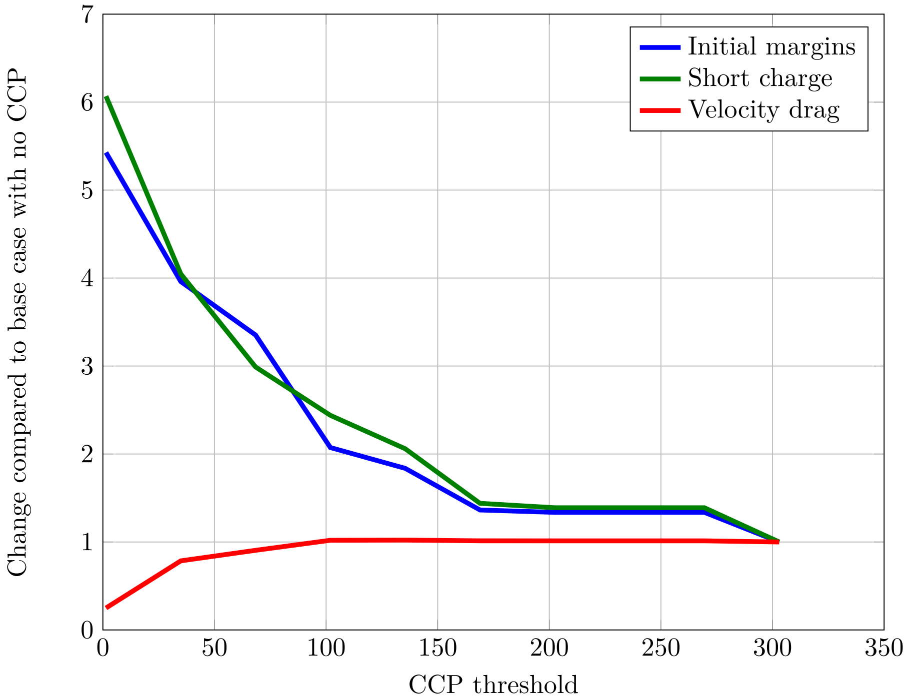


FIGURE 3 – Decomposition of the collateral demand as a function of $\bar{T}$. This figure decomposes total collateral demand in six components for two base cases. In the first chart, there are no dealer-to-dealer initial margins. In the second chart, dealer-to-dealer initial margins exist with $\upsilon^D = 0.5$ and $\alpha^D = 0.01$. Other calibrations are those of the baseline case. Results for $\bar{T} = 305$ bn USD correspond to the baseline case.



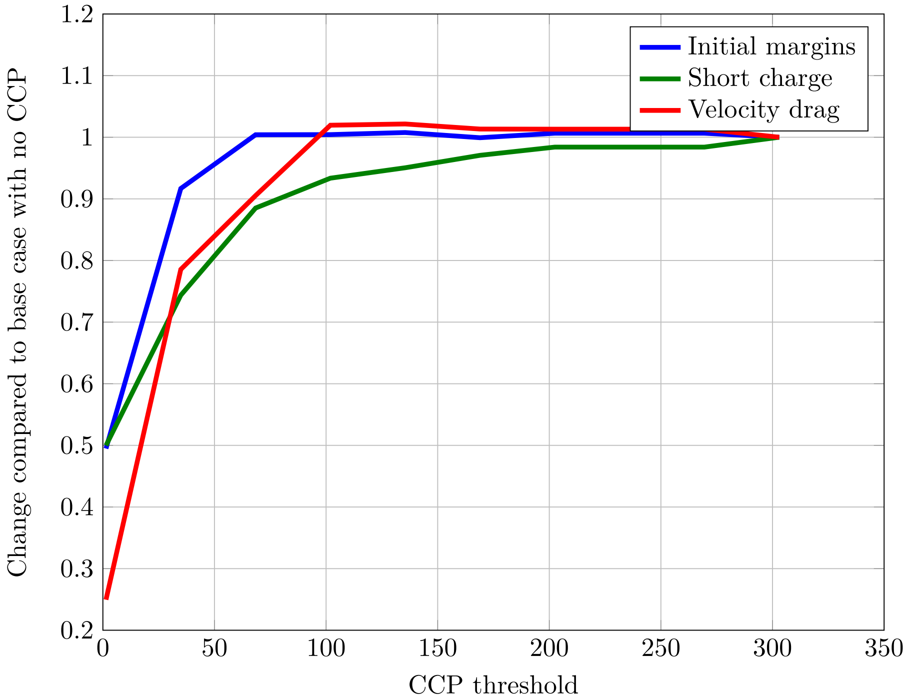


FIGURE 4 – Change in dealers' collateral demand as a function of $\bar{T}$. This figure pictures the change in collateral demand from a base case with $\bar{T} = 305$ Bn USD, when novation to CCPs is increased. The above chart features a base case with no dealer-to-dealer initial margins. The second chart features a base case with dealer-to-dealer initial margins calibrated with $\upsilon^D = 0.5$ and $\alpha^D = 0.01$. Results for $\bar{T} = 305$ bn USD correspond to the baseline case.

depending on the size and composition of the dealer's CDS portfolio. Figure 4 decomposes the change in collateral demand for the 14 dealers. As can be seen, the velocity drag component decreases when central clearing increases, but this effect is more than offset by the increase in initial margin and short charge. When $\bar{T}$ decreases, the short charge increases faster than the primary initial-margin component, because the short-charge computation formula does not allow for the increasing potential effect of diversification as portfolio size increases.

Turning to the case in which dealers post initial margins between themselves, increased central clearing *reduces* total collateral demand whenever these dealer-to-dealer initial margins (parameterized by υ^D) are high enough. At the level of individual positions, increased central clearing implies higher initial margin requirements. At a portfolio level, however, these higher collateral costs are more than offset by the cross-counterparty netting and diversification benefits of a CCP. With $\upsilon^D = 0.9$, the system-wide collateral demand when shifting from the baseline case to full clearing is found to decrease by about 27%. In such a case, collateral demand by dealers falls by about 49%, with individual dealer-level impacts ranging from -24.8% and -65.2%.

Finally, we focus on the case in which dealer-to-dealer initial margins can be repledged (equation 8). This amounts to analysing repledging in the post-reform case. Figure 5 plots dealers' collateral demand as a function of $\bar{T}$ for five values of ρ ranging between 0 and 1. The slope of total collateral demand is found to depend importantly on the rehypothecation ratio. When repledging is not allowed ($\rho = 0$) or allowed only to some limited extent, the collateral demand by dealers decreases when central clearing increases. In policy terms, dealers are given an incentive to novate a larger share of trades to CCPs under these conditions. When ρ is high enough, however, this effect is reversed and novation to CCPs does not provide high enough netting and diversification benefits to outweigh the loss of rehypothecation benefits. Interestingly, for a fairly broad range of values for ρ (e.g. 0.5 or 0.75), collateral demand is not a monotonic function of $\bar{T}$, as the benefits of central clearing outweigh the loss of rehypothecation benefits only when the share of centrally cleared trades is high enough.

4.2 Number of clearing members

In this section, we increase the set of clearing members. Customers satisfying an exposure-size criterion are assumed to become clearing members. Customers are ranked according to their total gross notional amount bought and sold on the CDS market [13], that is, $\sum_k \sum_j \left[G^k(i,j) + G^k(j,i)\right]$ for all

13. Given the anonymization of the data at a counterparty level, the set of counterparty-specific variables to be used to construct quantiles is limited. Other possible characteristics

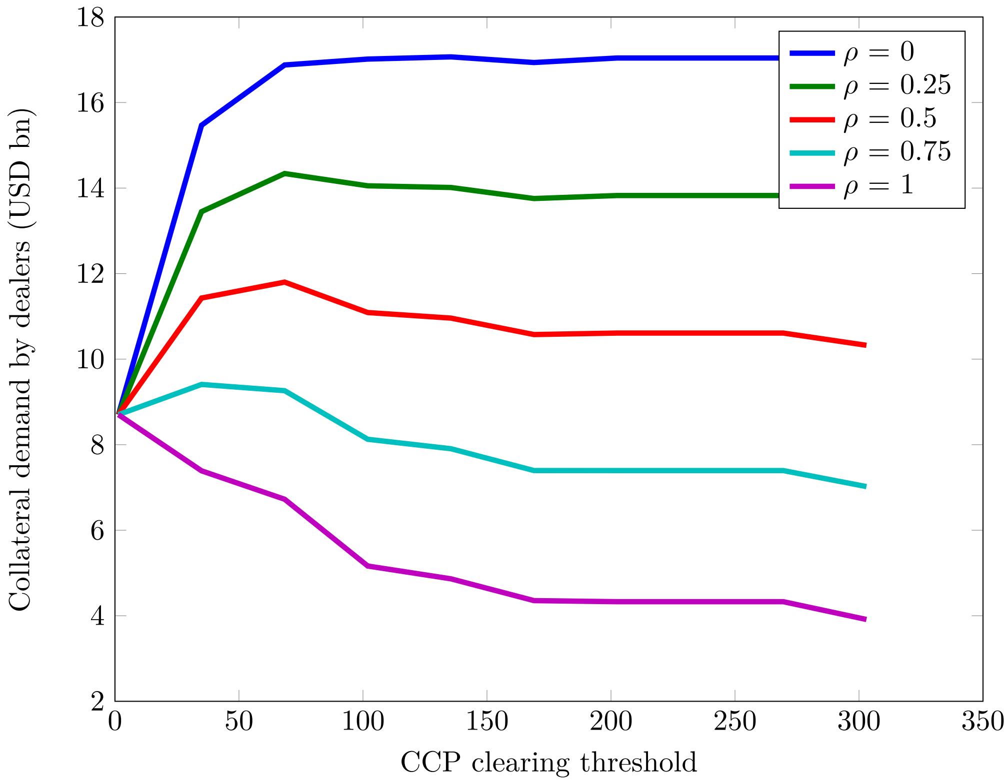


FIGURE 5 – Collateral demand as a function of ρ and $\bar{T}$. This chart shows collateral demand by dealers when the clearing threshold $\bar{T}$ is varied, for five values of the rehypothecation ratio ρ. The base case is with dealer-to-dealer initial margins. The sign of the change of total collateral demand depends on the extent to which rehypothecation is practiced. Collateral demand by dealers drives the system-wide effect on demand in this setup.

i. Market participants for which this exposure is above some threshold are gradually assumed to become members of the two existing central clearing parties, and are then effectively treated as dealers.

The increase in the number of clearing members has a non-trivial effect on the global demand for collateral. On the one hand, there are benefits from acquiring a dealer status, as dealers do not post initial margins to customers, and post no margins to other dealers in the base case (if $\upsilon^D = 0$) or reduced margins (whenever $\upsilon^D < \upsilon^C$). On the other hand, central clearing may be associated with higher collateral requirements than bilateral clearing for a given set of exposures (whenever $\upsilon^D < 1$). Finally, central clearing may offer both cross-counterparty netting opportunities and diversification benefits, especially for institutions with a large number of bilateral counterparties. Which of these effects dominate depends on the CCP-clearing threshold $\bar{T}$, that is, on the share of cleared trades.

Figure 6 plots total collateral demand as the number D of clearing members and the clearing threshold $\bar{T}$ are varied. For a high CCP-clearing threshold (that is, a low share of centrally-cleared trades), an increase in the number of clearing members lowers total collateral demand. When a strongly increasing share of trades being centrally cleared, total collateral demand no longer depends monotonically on the number of clearing members. This effect is further illustrated in figure 7, where initial margins (including the short charge) delivered by customers to dealers and by dealers to CCPs are decomposed for three values of $\bar{T}$ as the number of clearing members is varied. The increase in dealer-to-CCP initial margins is offset to a large extent by a shrinkage in customer-to-dealer initial margins, but the overall effect on collateral demand depends on $\bar{T}$.

4.3 Number of CCPs

In this subsection, we focus on the loss of netting efficiency due to increasing the number of CCPs. In contrast with the existing literature (Duffie and Zhu, 2011), where the increase in the number of CCPs is investigated regardless of CCP specialization in subsets of CDS reference entities, we distinguish two cases. CCP specialization is a common market practice, as documented in section 1.2.

First, the set of reference entities, partitioned in the baseline case between European and American names, is further split. We create one new CCP for each geographic area. Each CDS reference entity is randomly made eligible by one of two area-wide CCPs, with equal probability of assignment. One characteristic of such a clearing scheme, similar to the baseline case, is that a CDS can be cleared at one CCP only. Such CCPs are here called

include the number of traded CDS or the number of counterparties. Spearman rank correlation with the total gross notional traded are respectively 0.77 and 0.84.

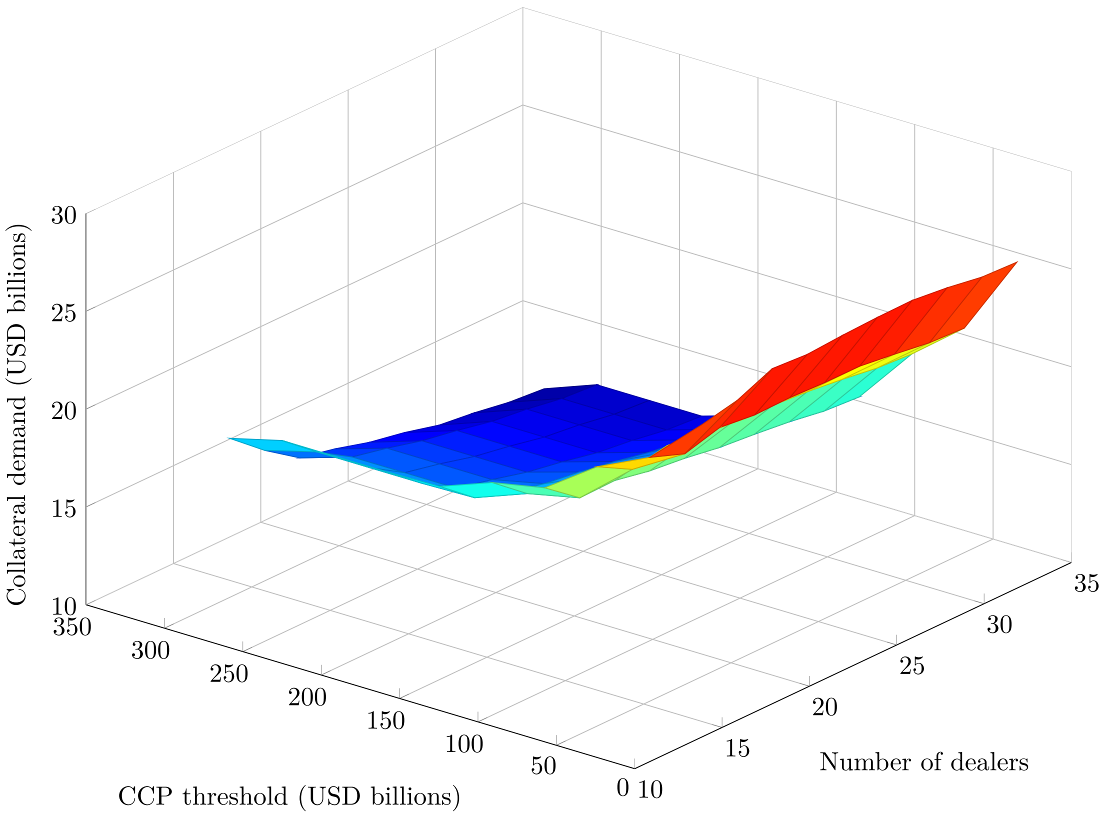


Figure 6 – Collateral demand as a function of the number of clearing members and of $\bar{T}$. This surface chart plots total collateral demand as a function of both the number of clearing members (or dealers) and the CCP clearing threshold $\bar{T}$. The base case is with no dealer-to-dealer initial margins. Other calibrations are those of the baseline model. Results for $\bar{T} = 305$ bn USD correspond to the baseline case.

"specialized," as there is no overlap in the set of reference entities cleared by each of them.

Second, we consider the case in which multiple CCPs clear the same CDS, within a given geographical area. Two new CCPs are added, with the same coverage and eligibility critera as those described for the baseline model. Whenever an exposure between any two dealers meets the eligibility criteria, it is randomly novated to one of the two CCPs, with equal probability. Such CCPs are called "non-specialized," given the overlap, at an area level, in the set of reference entities cleared by each of them.

In figure 8, total collateral demand with four specialized and non-specialized CCPs is compared with collateral demand when there are two CCPs only. The results are presented for base cases, without and with dealer-to-dealer initial margins. First, in both cases, an increase in the number of CCPs reduces the netting and diversification benefits of a reduced set of CCPs,

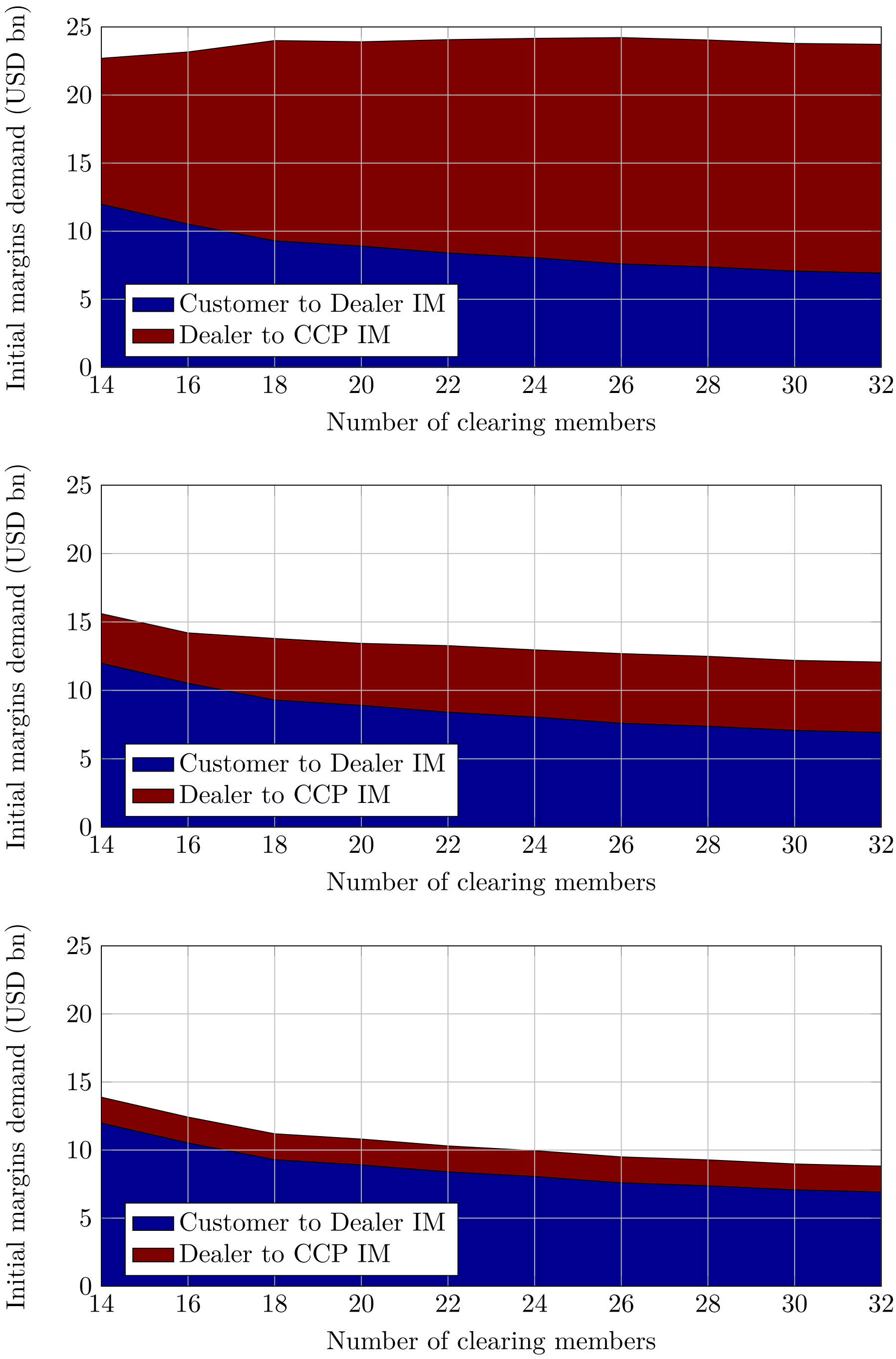
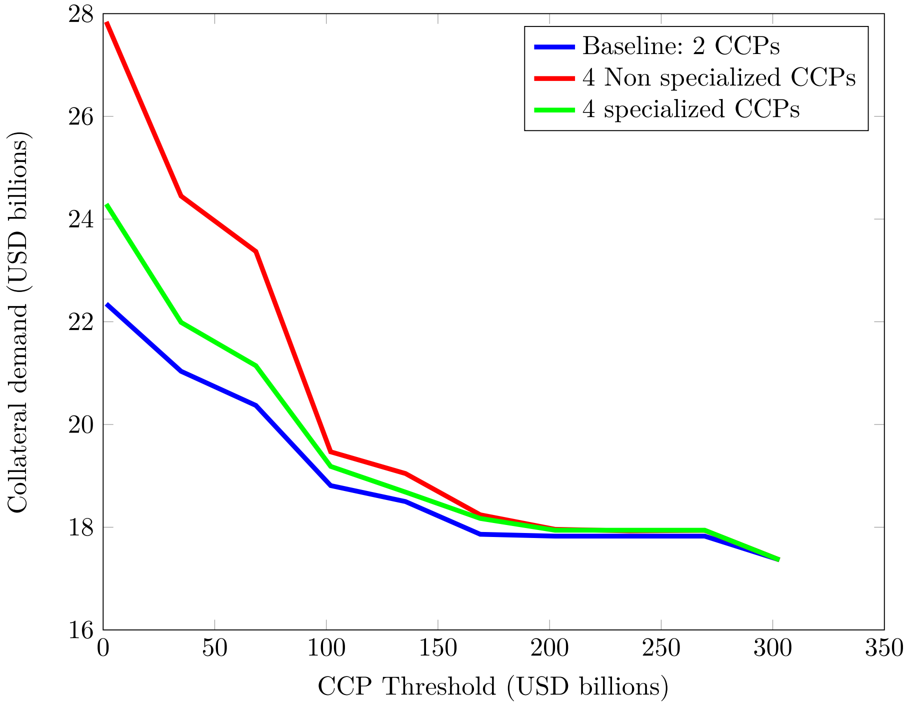


FIGURE 7 – Decomposition of initial margins demand as a function of the number of clearing members. These chart decompose system-wide initial margins between customers and dealers initial margins. In the first chart, $\bar{T} = 1$ Bn USD ; in the second $\bar{T} = 135$ Bn USD ; in the third $\bar{T} = 305$ Bn USD. The base case is here with no dealer-to-dealer initial margins. Other calibrations are those of the baseline model.



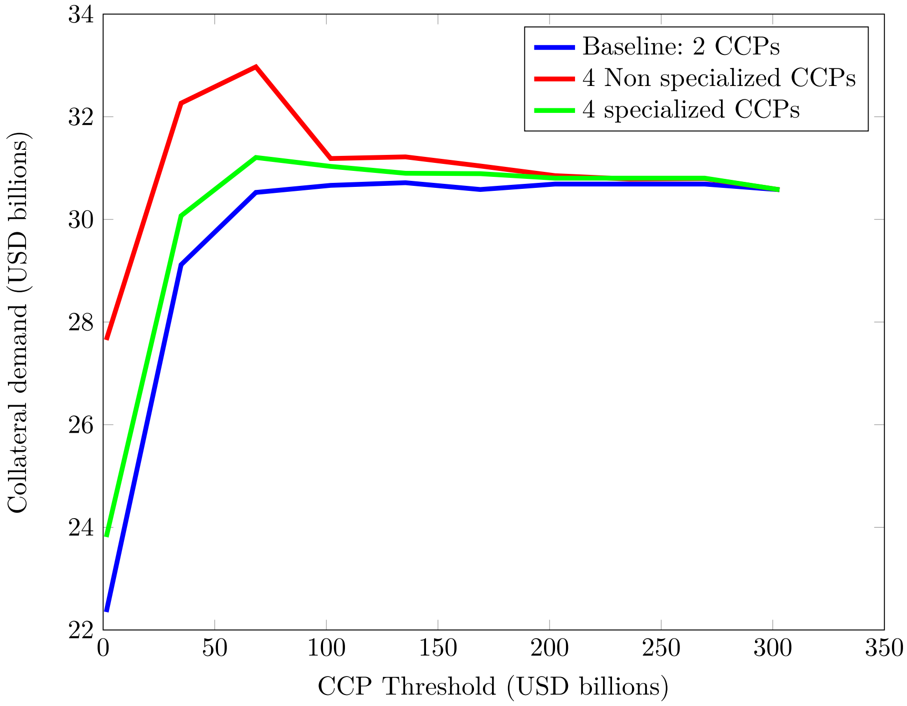


FIGURE 8 – Collateral demand as a function of the number of CCPs and of $\bar{T}$. $D = 14$. In the first chart, there are no dealer-to-dealer initial margins. In the second chart, dealer-to-dealer initial margins exist with $\upsilon^D = 0.5$ and $\alpha^D = 0.01$. For "specialized" and "non-specialized" CCPs, the collateral demand is the average over 10 simulations. Other calibrations are those of the baseline model. Results for $\bar{T} = 305$ bn USD correspond to the baseline case.

therefore implying a higher collateral demand regardless of the clearing threshold $\bar{T}$. Second, whereas specialized CCPs imply only a loss of diversification benefits, non-specialized CCPs imply both netting and diversification losses. Thus, collateral demand increases to a much larger extent with non-specialized CCPs. With full clearing, an increase in the number of CCPs from 2 to 4 results in a 7.2% increase in collateral demand if CCPs are specialized, and otherwise an increase of 22.4%. In order to gauge the impact of CCP proliferation on collateral demand, it is thus crucial to account for the degree of specialization of the proposed new CCPs.

For the case of non-specialized CCPs, we consider the baseline case with dealer-to-dealer initial margins (second chart on figure 8). Here, total collateral demand is not monotonic in the clearing threshold $\bar{T}$. An increasing degree of novation to CCP first raises collateral demand, as additional margin requirements and the change in netting sets outweigh the potential cross-counterparty netting and diversification benefits a CCP may provide. Once a large share of trades are cleared, however, these benefits prevail and collateral demand decreases relative to the base case.

4.4 Client clearing

In the preceding sections, only dealer-to-dealer trades were centrally cleared. However, all—or most—trades, including customer-to-dealer trades, are required to be centrally cleared in the post-reform regime. To face this constraint, a large number of institutions with a relatively low level of activity on the CDS market are not likely to become direct clearing members, as the implied costs (compliance to prudential standards, contribution to the default fund, etc.) may outweigh the benefits of central clearing. Such institutions are thus likely to use instead client clearing services. Client clearing services are typically offered by large CCP members to smaller market participants. A dealer offering client clearing services collects margins from its clients, in order to meet margins calls by the CCP. Client clearing services allow a large number of investors to trade over-the-counter derivatives without being a member of a CCP, even though central clearing is mandatory.

We refer to dealers offering client clearing services as "client clearing dealers." Each customer is assumed to have its entire CDS portfolio cleared by a unique client clearing dealer. In order for a customer-to-dealer trade to be centrally cleared, client clearing services cannot be offered by the dealer which is counterparty in the CDS trade, as there would then be no room for a CCP interposing between the two institutions. For each customer, a client clearing dealer is randomly assigned (with equal probability) among the set of clearing members to which it has no direct exposure. In case a customer is linked to all D dealers, the one to which its exposure is the lowest (as measured by the number of CDS trades) is assigned as its client clearing dealer. Direct exposures to this client clearing dealers are assumed to remain uncleared. In the dataset, we find 32 such customers, and their exposure remaining uncleared represents 0.03% of the sample gross notional amount.

When posting collateral to their client clearing dealer, customers are assumed to post (on that part of their portfolio which is eligible for clearing) the amount of collateral they would deliver to a CCP in case they were direct members. This amounts to setting $\upsilon^C = 1$ and $\alpha^C = \alpha^{CCP}$ in equation 3, thus requiring higher collateralization, *ceteris paribus*, for a given portfolio. However, customers also enjoy potential netting and diversification benefits, as trades with several counterparties are pooled to one dealer. Whether one effect or the other dominates depends on the size of the portfolio of each customer, as we shall emphasize later.

In this model, dealers clear the portfolios of their clients together with their own CDS portfolio. Thus, they enjoy potentially large netting and diversification benefits on their own initial margin requirements. However, as the size of their portfolio under management is larger, margin requirements in absolute terms are likely to be larger. We assume that dealers can immediately re-use a fraction λ of the collateral supplied to them by customers. In the absence of regulatory constraints, λ could be below one if client-clearing dealers offer collateral transformation services or if CCPs accept a narrower range of assets as collateral compared to the range accepted by dealers (or if CCPs impose tougher concentration limits on the share of particular assets to be delivered as margins). We note the distinct roles of λ and ρ, as the former concerns only collateral received through client clearing services, whereas ρ is related to collateral received from dealers on uncleared trades.

Total collateral demand in the presence of client clearing is compared with the baseline case in figure 9, both with and without dealer-to-dealer initial margins. In both cases (with minor exceptions for high values of $\bar{T}$), implementing client clearing reduces collateral demand at a system level, provided that λ is high enough. The system-wide effect is driven by several mechanisms. First, customers face higher initial margin requirements at a position level, as exposures toward client-clearing dealers are assumed to be fully collateralized ($\upsilon^C = 1$). However, as all their bilateral exposures are pooled towards their client-clearing dealers, they also enjoy cross-counterparty netting and diversification benefits. Which of these effects dominates depends on the size and composition of the CDS portfolio under management, as discussed below.

Turning to dealers, two potentially offsetting effects are at play. Larger portfolios must be centrally cleared by dealers at CCPs, implying higher collateral requirements in absolute terms. However, these larger portfolios offer increased netting and diversification benefits. This is likely to be even more the case when a sizeable share of dealers' exposures arises from their market making or intermediary activity, thus allowing for large cross-client

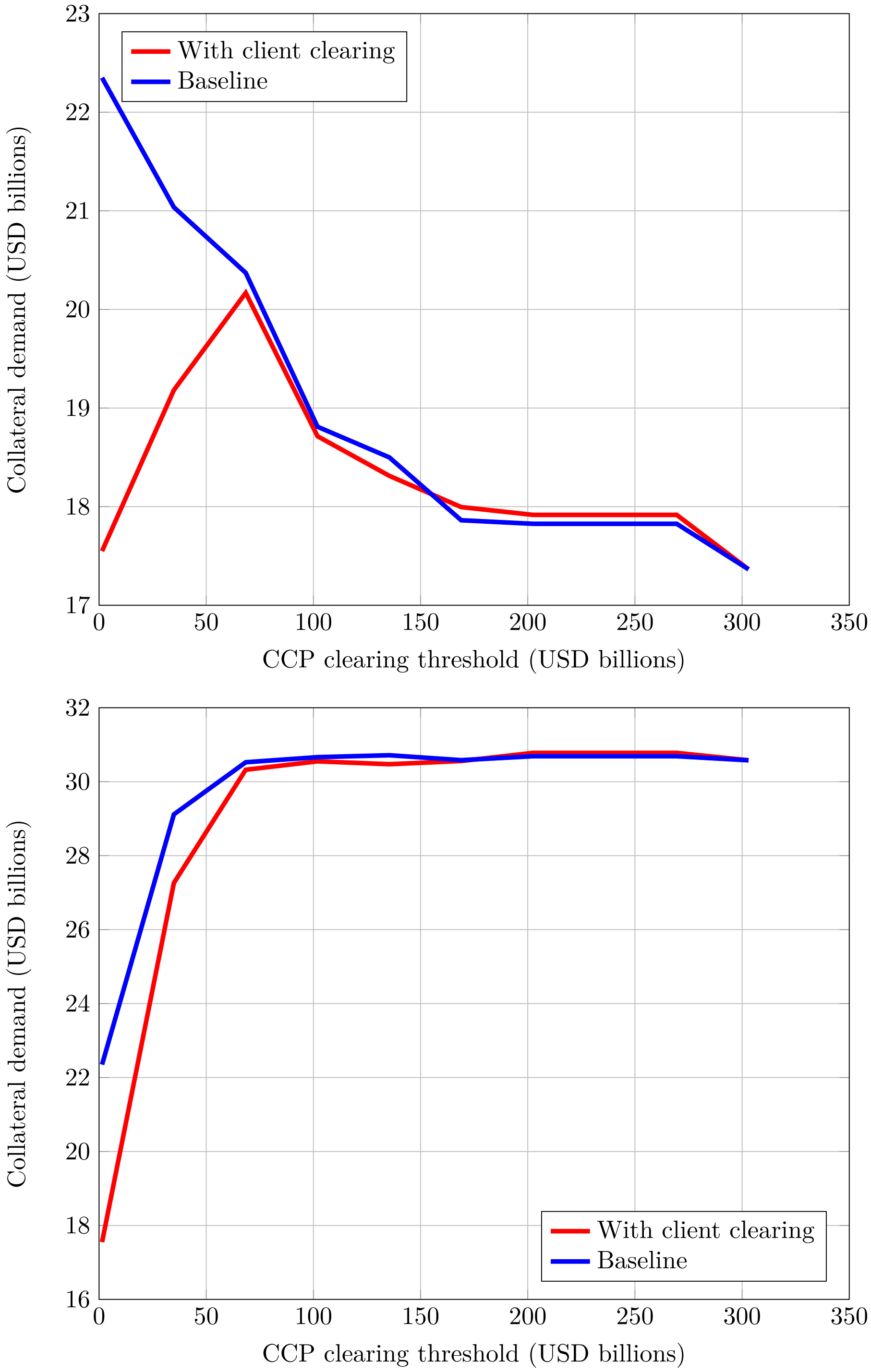


FIGURE 9 – Collateral demand with client clearing. Both charts compare the system-wide collateral demand with and without client clearing for two base cases with a varying CP-clearing threshold $\bar{T}$. In the first chart, there are no dealer-to-dealer initial margins. In the second chart, dealer-to-dealer initial margins exist with $\upsilon^D = 0.5$ and $\alpha^D = 0.01$. Both are calibrated with $\lambda = 0.5$. Results for $\bar{T} = 305$ bn USD correspond to the baseline case.

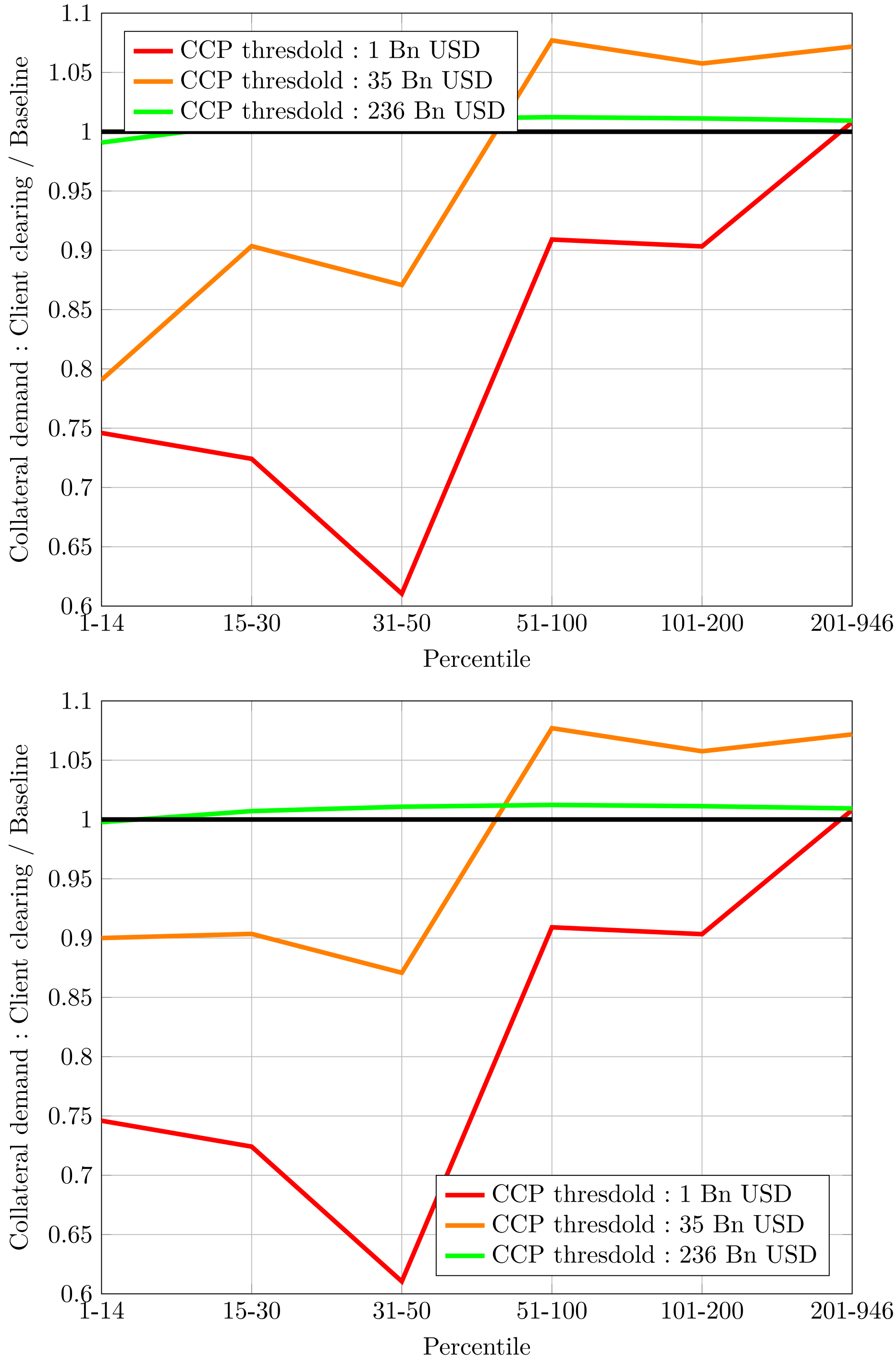


FIGURE 10 – Distributional effects of client clearing. The first chart pictures the distributional effects of client clearing, as captures by the ratio of collateral demand with client clearing over collateral demand in the baseline case. In the first chart, the baseline case does not feature dealer-to-dealer initial margins for uncleared trades. In the second chart, dealer-to-dealer initial margins exist with $v^D = 0.5$ and $\alpha^D = 0.01$. Both are calibrated with $\lambda = 0.5$. Percentiles are constructed based on each counterparty's total gross notional bought and sold on the CDS market.

netting benefits. Whenever dealers re-use a high enough share of the collateral that they receive from their clients, the latter effect dominates. In the absence of dealer-to-dealer initial margins (and $\lambda = 0.5$), total collateral demand decreases by 14.7% when shifting from the baseline case to full clearing (compared to an increase by 29% in the absence of client clearing). Both with and without dealer-to-dealer initial margins, system-wide collateral with client clearing for $\bar{T} = 0$ is 21.5% lower compared to a case with full clearing but no client clearing.

In this setting of client clearing, and in the absence of dealer-to-dealer initial margins, total collateral demand is not monotonic in $\bar{T}$, as seen in figure 9. From the base case, increasing central clearing increases collateral demand, with the effect being driven by dealers (as uncollateralized trades become subject to initial margin requirements). When the share of cleared trades is high enough, the netting and diversification benefits of client clearing (together with those of central clearing) outweigh these costs, so that collateral demand decreases. Thus traders may favour large-scale—rather than gradual—novation to CCPs.

At the level of a particular market participant, whether collateral demand decreases or not is ultimately driven by the size and composition of the portfolio under management, as well as by the parameter λ (for dealers). Whereas the previous analysis has focused on aggregate collateral demand only, we here go to a more granular level by investigating the distributional effects of client clearing across market participants. Given the anonymization of market participants in the dataset, one approach to distinguish counterparties can only be according to their total level of activity (or, eventually, other portfolio-related characteristics). Counterparties are ranked according to the sum of the gross CDS notional amount they buy and sell on all underlying reference entities. Quantiles are constructed on this basis.

The distributional effects of client clearing are depicted in figure 10, where the ratio of collateral demand in the presence of client clearing over the demand in the base case is plotted for three values of the clearing threshold $\bar{T}$. We see first that the distributional effects of client clearing, and whether particular sets of institutions must post more or less collateral compared to the baseline case, depend importantly on the share of cleared trades captured by $\bar{T}$. Customers in the lowest quantile must always post more collateral with the implementation of client clearing, because their increased margin requirements outweigh cross-counterparty netting and diversification benefits. This arises from the fact that they trade relatively few CDS with a very small number of counterparties. At the other end of the size spectrum of market participants, dealers always benefit from client clearing (for $\lambda = 0.5$) even when $\bar{T}$ is high. In the range between these values, for large customers (market participants 15 to 200), whether netting and diversification benefits are sufficient to offset increased initial margins or not depends importantly on $\bar{T}$.

Conclusion

Our model and empirical analysis of extensive bilateral CDS exposure data allows a decomposition of collateral demand for both customers and dealers into four components. We investigated the relative and absolute impacts on collateral demand of four models of central clearing. The collateral decomposition for the most salient specifications of each of these models is summarized in figure 11.

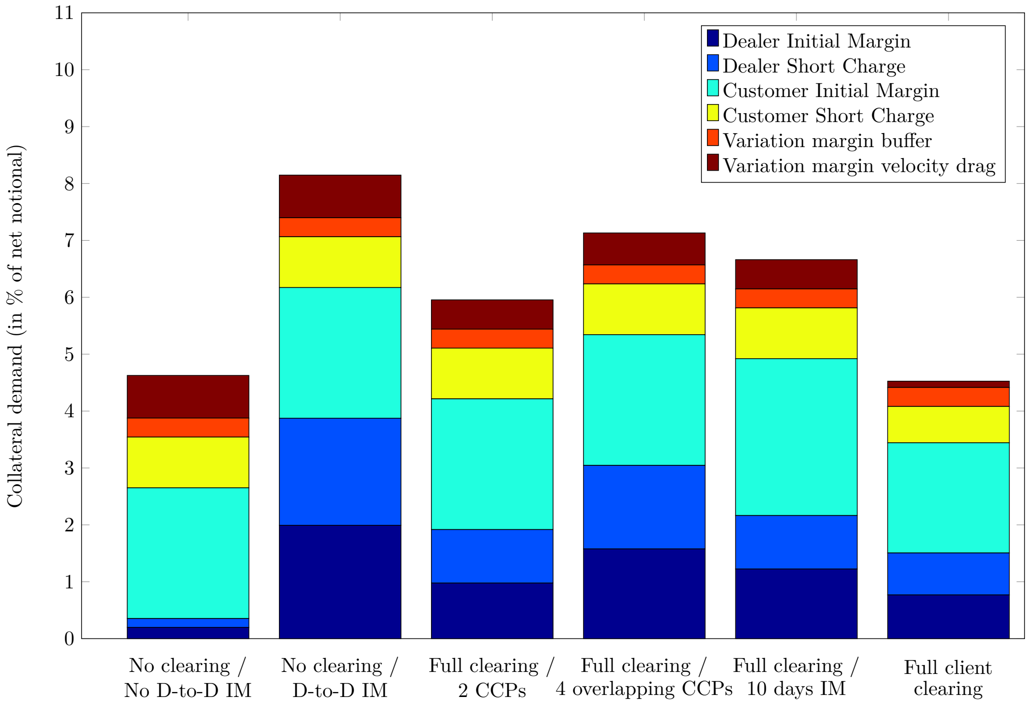


FIGURE 11 – Summary of the results. This chart summarizes the decomposition of system-wide collateral demand under six scenarios. The results are presented as a percent of the system-wide net notional exposure. "D-to-D IM" denotes dealer-to-dealer initial margins. All calibrations are those used in the models' respective sections and summarized in table 4.

Among our main results is the fact that, from end-2011 data, mandatory central clearing has lower system-wide consequences on collateral demand than previous studies suggest, but has large distributional consequences. Conditional on all CDS being centrally cleared, both the risk model used to compute initial margins and the exact type of prevailing market structure are shown to have sizeable effects on collateral demand and decomposition. Our analysis provides a distinction, when considering the impact of CCP proliferation on collateral demand, between specialized and non-specialized CCPs. We show the large cross-counterparty netting and diversification benefits that central clearing provides to dealers, and its distributional effects on customers, which depend on the size of the portfolios that they manage.

We have also analyzed, for the first time, the effect on collateral demand of client clearing. Our results indicate significant distributional consequences of this emerging market practice.

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