THE EFFECT OF MUTUALIZATION AND COLLATERALIZATION ON CREDIT DEFAULT SWAPS PREMIUM

FREDDY ROJAS

DOCUMENTO DE TRABAJO 17

FACULTAD DE CIENCIAS EMPRESARIALES Y ECONÓMICAS

UNIVERSIDAD DE LIMA

The Effect of Mutualization and Collateralization on Credit Default Swaps Premium

Freddy A. Rojas Cama*

Carrera de Economía
Universidad de Lima

July 2025

Abstract

This paper examines the effect of collateralization and mutualization of losses on credit default swap (CDS) premiums in the context of high counterparty risk operating through an opaque derivatives market. This setup shows that clearing practices affect the size of positions, recovery rate and premium. This model not only has the benefit of being realistic in light of the causes and propagation of the Great Recession, but also in assessing clearing practices in a partial equilibrium. I follow closely the contributions of Koeppl and Monnet [38], Koeppl [35], Acharya and Bisin [1] and Stephens and Thompson [55]. I show that the premium is high when mutualization takes place as clearing policy; the new allocation is characterized by a high recovery rate and low risk premium as fully insured contracts spread significantly relative to OTC markets. The risk premium ebbs as different types of default fund calls flow into the clearinghouse. The aforementioned pushes down the premium. It does not, however, offset the upward effect stemming from the increasing recovery rate. Additionally, as the literature suggests that collateralization avoids default, the premium is high and the value of the position (or recovery rate) increases. In these contracts the risk premium is low too. This research contributes to the compression of insurance pricing theory into material that may be a critical input in large macroeconomic models.

Keywords: price discovery; financial economics; clearing; credit default swaps; collateralization; mutualization; OTC; risk premium; CCP. JEL codes: G0; G1.

* Docente de Economía de la Facultad de Ciencias Empresariales y Económicas. Correo electrónico: Frojasc@ulima.edu.pe.

Contents

1 Introduction **4**

2 Literature review **7**

3 The insurance model **10**

3.1 The agents 10

3.2 Equilibrium in the Credit Default Swaps market 11

3.3 Trading in opacity markets 12

3.4 The strategic default 12

3.5 Inefficiency of opacity markets 14

4 The clearinghouse **14**

4.1 Efficient allocation 14

4.2 Implementation of policy 16

4.3 Collateralization 17

4.3.1 Collateral requirements 18

4.3.2 Maximization under collateral requirements 18

4.4 Mutualization 24

4.4.1 Clearing members' default fund contributions 25

5 Numerical exercise **29**

5.1 Optimal collateral κ 32

5.2 Optimal default fund call φ^s 34

5.3 Optimal marginal default fund call φ^b 38

5.4 Size of the seller's default fund and collateral 40

6 Conclusions **41**

1 Introduction

This paper analyses how collateralization and mutualization of losses affect credit default swap (CDS) premiums and discusses further implications of the above practices on counterparty risk and welfare. By setting up a population of risk-averse agents, the effects of embedding mutualization and collateralization are quantitively explored over Acharya and Bisin's [1] mechanism whose measure of risk premium and recovery rate are endogenously determined. An important result is that risk premium diminishes as the insurance market under central clearing is characterized by high levels of premium and recovery rate. Furthermore, clearing practices reduce counterparty risk by spreading fully, partial-insured and collateralized contracts. This paper contributes to building a framework for studying the effects of regulation on asset pricing determination[1].

Price discovery is an important concept for the surveillance of risks and is certainly tethered to policy. Monitoring prices is important since supervisors and monetary policy makers may be able to interpret changes according to a change in fundamentals, such as liquidity and credit risk. For instance, for the eurozone (see Annaert et al. [4]), during the recent financial crisis, there was evidence that CDS spreads rose notoriously and mainly due to an increasing credit risk with a particular role of both individual and market liquidity. In that sense, the current paradigm describes how to do CDS valuation taking into consideration not only the risk of the credit event but also the risk of default from the seller and even the buyer. How agents respond to policy is a research motif that entails reviewing mandates that are widespread and profound, and obviously the source of important systemic implications. Hence, policymakers should be acutely circumspect about the potential of such effects from central clearing and be aware of changes in asset prices.

The interplay between price discovery and regulation is not new in a broader or aggregate framework and the objective of this research resembles the ones in quantitative assessments in general equilibrium models[2]. The ultimate objective is to construct a framework of asset-pricing determination that may be embedded in a general equilibrium model. This extension will certainly be useful in popular topics of regulation nowadays (e.g. macroprudential policies)[3] and others not akin that require the usage of insurance models with extensions to an endogenous price setup[4].

Mutualization and collateralization are standard risk-sharing practices. As for mutualization, the clearinghouse earmarks funds from all participants and distributes them among members whose contracts are under loss or default. Hence, mutualization guarantees a fixed payment to whoever holds the asset and can potentially provide full insurance. On the other hand, collateralization is a standard tool for hedging in the literature of financial markets. A clearinghouse may operate as an escrow-account officer holding collateral requirements for a

specific financial market. It is expected that the above clearing practices should bring an efficient market structure for standardized financial contracts. It is clear that clearing practices do not make risk disappear but reallocate it from those who bear risk at a high cost to those that bear it at a lower cost.

The presence of clearinghouses seems to be critical for the structure of financial markets in the incoming years[5] [6]; clearinghouses hitherto arise as the device that would make the market more transparent, secure, stable and free of contagion (Acharya and Bisin [1]; Pirrong [50]). In the aftermath of the recent financial crisis, the literature started off by evaluating the introduction of central counterparties. Central clearing is ultimately a risk-sharing arrangement; through netting, collateralization and mutualization, a clearinghouse prevents the build-up of excessive risk and consequently it ameliorates the allocation of resources. The concept is not really new and is mostly applied to other markets, e.g. futures. Moreover, the literature points out significant advantages to this arrangement (see Pirrong [50, 48, 49]), and some requirements in the structure are also demanded[7]. This certainly behooves us to examine policy practices through the glass of a microstructure model[8]. Few approaches deal with the collateral policies of ~~clearinghouses; however their financial~~ structures are simple and others are limited to a certain extent, for example in the case of market completeness (see Koeppl and Monnet [38, 37])[9].

Central clearing is intended to achieve transparency of positions. Trade opacity is a fundamental characteristic of the OTC market structure; no trading party has full knowledge of the short or long positions of others. The aforementioned was notorious during the recent financial crisis; AIG's inadequate liquidity position and other potentially unstable insurers as Citigroup and Merrill Lynch[10] produced large costs on the financial system. The recent financial crisis showed that opacity was responsible for allowing the stack-up of large exposures and thus marked the beginning of the consensus on reform by the G20 in 2009. Thus, the foregoing makes regulators ponder distinguishing traits in financial contracts. This demands the exploration of models with relative complexity.

The endogeneity of the recovery rate and CDS premium is a remarkable feature of the proposed model assembled over the next sections. In other words, the terms of transactions in contracts are affected and it clearly marks a difference with the trendy literature which is not only ubiquitously focused on exchanges, but also on assuming constant prices and insurance amounts. Thus, the model delivers a partial equilibrium solution which has the potential to produce endogenous results in an extended general framework; questions arising from the interplay of macro-prudential policies and the financial sector, in the same line as Yellen [60][11], can be addressed with the usage of the model of insurance here proposed.

The remaining sections of the paper are structured as follows. In section (2) the emerging literature regarding central clearing and valuation of securities as well as standard practices for

hedging is reviewed. Empirical evidence of the overall effect of clearing on CDS premiums is also commented on in that section. Section (3) formally presents the model, the functions to maximize and the participants. Also, this section shows the equilibrium of the credit default swap market as well as the main characteristics and consequences of trading in opacity markets. Section (4) discusses the determination of the CDS premium due to collateralization and mutualization. Section (5) shows the results of the numerical exercise applied to a calibrated model. Finally, section (6) presents the conclusions and further research agenda.

2 Literature review

A CDS is a financial derivative contract whereby the buyer attempts to eliminate any possible loss arising from a default event. A CDS seller—typically a financial institution—seeks compensation for absorbing the risk of having to make a future payment. The literature has pointed to CDS as leaky boats or destabilizing-and-contagion triggers. Since the Great Recession, tax payers have requested market reform and regulation, particularly on derivatives instruments. The Dodd-Frank[12] act in 2010 was an immediate response to the recent crisis and this initiative surely continues to be in the spotlight of discussion[13]. Other recent initiatives, such as the Volcker rule, the Lincoln Amendment and Basel III, intend to bring secure provisions and thus end the concept of "too big to fail". In other areas, the proposed regulation has made some progress, but has not gone far enough in others, especially in derivatives markets[14].

Central clearing has gained momentum. Recent literature highlights the effects of standard clearing practices such as netting (see Duffie and Zhu [26]), information dissemination (see Acharya and Bisin [1]) or the segregation of collateral as a commitment device (see Monnet and Nellen [45]). Acharya and Bisin [1] show that the organization of trading via a centralized mechanism or clearing that provides transparency of trade positions can ameliorate counterparty risk which reveals itself as a sign of excessive leverage positions constructed by insurance sellers; the authors precisely coined the term "counterparty risk externality" and argued that social costs are not fully priced into CDS. Stephens and Thompson [55] study price competition when types of insurers are unknown in a model of insurance provision with limited liability in seller obligations. Clearing practices, specifically mutualization, are also explored in Stephens and Thompson [55] suggesting that an equilibrium will result in a high increase in counterparty risk and a prevalence of bad insurers. Another contribution for price determination is found in Koeppl [35] over a general exchange market. An allowance for extracting benefits off the contracts will crowd out prices in current contracts under a clearing mechanism that doesn't involve the fulfillment of promises. Although the above cited works achieve explicitly a price determination, they have different features that make it appealing to explore them in a general and concise setup that could resemble some stylized facts immediately before the recent financial crisis.

The literature offers how to valuate price securities in the presence of defaulting[15]. Important extensions were made studying pricing under a joint default of both buyer and seller and especially when default occurs prior to maturity, i.e. failure of no-jump condition (see Collin-Dufresne et al. [20]; Duffie and Singleton [25]; Duffie et al. [24]). For example, Leung and Kwok [41] and Jarrow and Yu [33] analyze the effects of a change in the probability of CDS's default on spreads jointly with other possible parties' probability default. However, any effect of collateralization that may result in non-defaulting contracts is missing. A structural model that incorporates the effects of collateral on CDS premium into a financial model is hitherto scarce in the literature; however, the existing literature has been adding important pieces to the existing paradigm of price determination especially in a centrally clearing framework. For example, Acharya and Bisin [1] study how to restore an efficient level of insurance by promoting transparent positions in insurers' balance sheets; the price and recovery rate are endogenous to the clearing policy. Also, Stephens and Thompson's [55] setup makes limited liability a key in explaining lower levels of CDS premium under clearing. This result is achieved in parallel to a price equilibrium determined by competition.

Certainly, collateralization is a fair demanding practice under clearing. The requirement of collateral is the cornerstone in the lender-borrower relationship literature. Since borrowers may become insolvent due to either exogenous (or intrinsic) factors or off-the-contract incentives that afflict outcomes ultimately, collateral can be beneficial to avoid some detrimental outcomes to lenders beyond merely offsetting losses. Thus, economic theory explains the existence of collateral in contracts as appeal to either compensating for ex-ante information gaps between agents or reducing ex-post incentive problems[16] [17]. Thus, collateral as a signaling device arises to induce loan applicants to reveal their default risk[18]. As for incentive contracts, the theory points out that pledging collateral is optimal since it potentially reduces effects coming from moral hazards[19]. Precisely, Koeppl [35] studies the effect of agency problems on the role of the clearinghouse as a storage facility and a contract settlement agent arise from novation. Koeppl [35] particularly analyzes an exchange market ~~where asset pricing responds to under~~lying contracts without incentives. The author suggests that clearing can produce contracts that use collateral as an incentive mechanism that lowers counterparty risk; however, when resources are scarce, a contract with partial insurance can be handed out to agents as the price of transactions rises due to clearing. Thereby, the effect of collateralization, especially in a derivative market, has not been studied deeply by construction.

Regarding empirics, the literature delivers a fair amount of empirical evidence about premium changes due to counterparty risk and other interesting variables such as dealer choice risk profile, liquidity and horizon of investment (see Navneet Arora and Longstaff [47], Arakelyan and Serrano [5]). However, empirical evidence on how CDS interact with regulatory policies is incipient. Loon and Zhong [42] examine the impact of clearing on the CDS market using a sample of voluntarily cleared single-name contracts. As expected, the authors find that premiums have a

significant response to the reduction of counterparty risk from different factors; multilateral netting, initial and margin requirements may help to further prevent the excessive stack-up of risk exposures. Precisely, Loon and Zhong [42] found that the CDS premium is higher under clearing. In the same direction, Du et al. [22] investigate whether central clearing has had an impact on how the market prices CDS contracts for different sets of transactions involving different types of dealers. Contrary to Loon and Zhong [42], Du et al. [22] found that premiums on centrally cleared trades are significantly lower relative to spreads on uncleared transactions. Loon and Zhong [42] appeal to the increased value of credit protection when clearing to explain the increase in the premium; on the other hand, Du et al. [22] state that their findings are consistent with the view that counterparty risk has minimal effect on pricing and thereby the net effect is leading by dealer's market advantages[20]. Actually, the former might not be unusual to find, whether or not assuming collateralization and clearing practices fully eliminate counterparty risk. An interesting approach by Shan et al. [53] found that banks that actively use CDS had significantly low-risk ratings in comparison to CDS-inactive ones; the aforementioned could explain why those banks produce high levels of leverage.

The analysis in models of a possible change in the terms of transaction (size of insurance and premium) due to clearing procedures is still scarce in the literature; Augustin et al. [6] suggest that Dodd-Frank and Basel III effects are under-researched so far and that these will certainly affect other dimensions of CDS trading channels. The change of the premium to the clearing policy is potentially subject to the structure of the financial market and informational asymmetries; a variety of contracts may be offered and thus these may change ex-ante the terms of transaction required by participants. Most of the existing work focuses on showing the higher welfare achieved by implementing mutualization with a minimal cost of collateral (see Monnet and Nellen [45], Koeppl and Monnet [37, 36]); however, the prices are exogenously given. Koeppl [35] has an interesting approach that precludes some transactions from defaulting and is possibly susceptible to observing higher trading prices in equilibrium. To the best of my knowledge, Stephens and Thompson [55] is the only paper that analyzes price determination of CDS prices so far. Stephens and Thompson [55] reckon that clearinghouses would produce some adverse effects and a declining price as a result of price competition. Thus, this paper aims to contribute by showing the different pieces of the mechanism that affect the pricing of CDS.

3 The insurance model

In this section, the model's setup follows Acharya and Bisin's [1] work closely, concerning the moral hazard on the insurer's side. Specifically, the raw model and main features with no clearing policies are discussed.

3.1 The agents

In this section, the provision of insurance is embedded in a model of two periods (0,1) where a seller provides insurance to buyers, both risk-averse. The seller of insurance will provide insurance in the event of the default of a third party; this can be generalized to the occurrence of a bond default. Thus, the probability of the occurrence of the aforementioned event (a.k.a., a credit event) is denoted by λ. The seller's endowment is denoted as ω_S; an additional subscript denotes period 0, otherwise period 1. The insurance contract must be paid at starting period 0 and the price per unit of requested insurance is q; this is known as the CDS price, henceforth premium. The promised payoff is m, where m is the amount or notional of insurance; the CDS seller, henceforth the seller, may go back on their word and only return Rm being $R < 1$. The seller maximizes an expected mean-variance function defined as in Acharya and Bisin [1], i.e. $E[u(x)] \equiv E(x - f(x)) + f(E(x))$. Being $f(x) = \frac{\gamma}{2}x^2$ and γ defines the degree of risk-aversion attitude of the seller.

The CDS buyers, henceforth the buyers, have a position that needs to be covered by purchasing insurance. Specifically, each buyer could previously be engaged in lending the amount ω_b to a third party; with probability $1 - \lambda$ the third party would be successful and will deliver back the loan, with probability λ the buyer gets nothing from the third party. The total size of buyers is $\frac{1}{1-\lambda}$, an expression that normalizes the size of non-defaulting contracts to 1. The matching among participants when they trade insurance is completely random. Only sellers can default, and this assumption is made by construction since the amount qm is payable upfront[21]. In the case of defaulting, sellers undergo a non-pecuniary penalty or deadweight loss as a function of the short positions defaulted upon. Formally, the timing and actions of participants in the insurance market are presented as follows:

(T=0) Each buyer is randomly matched with a seller. They sign a contract specifying the amount of insurance, premium, recovery rate and collateral, if any. The premium is paid upfront.

(T=1) The seller gets an endowment of ω_S if credit even happens and also gets a gross return θ from a portfolio. With probability λ the reference entity or bond defaults; the seller makes a choice from set $\iota = \{ND, D\}$ where ND and D stand for non-default and default respectively. Settlement and payoffs are made for each participant. Otherwise, with probability $1 - \lambda$ no transfers are made.

3.2 Equilibrium in the Credit Default Swaps market

In this section the CDS market is introduced, and it closely follows Acharya and Bisin's [1] setup which is particularly characterized by an excess of leverage recorded in balance sheets,

this due to a dearth of transparency in short positions. This opacity was a key feature during the financial crisis for this type of derivatives contract [22]. At the dawn of the financial crisis, investors realized that protection was quietly lessening on CDS contracts. As a consequence of trading in non-transparent markets, Acharya and Bisin [1] pointed out that exposures on these derivative instruments flourished significantly and recklessly. Thus, central clearing rises as a device that brings transparency in order to reduce the counterparty risk and achieve ultimately the efficient risk-sharing outcome.

The need for protection against default risk causes a party to enter into a derivatives contract. The seller of this derivative (the short position holder) promises to compensate or pay out in the case of a specific event that produces a loss to the buyer. This buyer (the long position holder) agrees to make periodical payments to the seller of the protection. Thus, the elements or parties involved in the CDS contract are the protection buyer, the protection seller, the premium and the reference liability which is triggered when the event materializes. The compensation payment is made at the end of a period known as the settlement period. Formally, the contract for this derivative is as follows:

Definition 1 ***(CDS contract).*** *The CDS contract is formally denoted as* $C(R, q, m)$ *where* R *is the recovery rate,* q *is the price or premium per unit of insurance, and* m *is the amount of insurance. The amount* qm *must be paid at period 0.*

The sellers promise buyers the amount m if the event occurs (the default of a third party); otherwise, buyers do receive amount Rm from sellers; whatever state of nature happens, buyers pay out the total premium denoted as qm.

3.3 Trading in opacity markets

Sellers trade the CDS in non-transparent markets. As in Acharya and Bisin's [1] setup, assumptions are made about the determination of price because buyers do not observe the size of trades. However, buyers anticipate correctly the likelihood of default and the size of the insurance payout relatively to the promised payoff ($R < 1$). Thus, the equilibrium is characterized by the terms of contract C, that is, by the insurance payoff, the cost of insurance or premium and the trading position. In order to determine the terms of this contract, the equilibrium must include the following: (*i*) buyers maximize a specific expected utility by choosing the amount of insurance (m), (*ii*) the market of insurance must clear, and (*iii*) in the case of default, the seller honors their promise by paying the recovery rate established in the contract.

3.4 The strategic default

The seller may default (D) or non-default (ND). In Acharya and Bisin's [1] model, the seller has incentives to default if the event occurs. In the case of seller default, there is a linear penalty whose value depends on short, defaulted positions. This penalty, per unit of insurance, is denoted as *E*. Precisely, the deadweight cost level plays a role in the seller's decision when they maximize their utility function. In order to formally clarify the payments, the profit (Π^S_{ND}) when sellers do not default is defined as follows:

$$\Pi^S_{ND} = \theta + \omega_{s,0} + qm + \lambda(\omega_s - m) - \frac{\gamma}{2}\lambda(1-\lambda)\big[\omega_s - m\big]^2 \tag{1}$$

The payoff when seller default (Π^S_D) is:

$$\Pi^S_D = \theta + \omega_{s,0} + qm - \lambda\epsilon m - \frac{\gamma}{2}\lambda(1-\lambda)\big[\epsilon m\big]^2$$

As in Acharya and Bisin [1], the buyer has the following function to maximize by choosing *m*:

$$\Pi^B = \omega_{b,0} - qm + (1-\lambda)\omega_b + \lambda R m - \frac{\gamma}{2}\lambda(1-\lambda)\big[\omega_b - Rm\big]^2$$

The equilibrium is formally defined in the following lines.

Definition 2 ***(Equilibrium).*** The equilibrium in the insurance market is given by:

(a) Each seller is randomly matched to a buyer, and both agree to the terms in the contract

C(*R*, *q*, *m*)*;*

(b) Each agent maximizes expected utility by choosing the trade position m;

(c) The insurance market clears;

(d) In the case of default, the seller fulfills their promise and pays out the recovery rate times the amount of insurance. Thus, the function R is defined as follows,

$$R = \begin{cases} < 1 & if\ default \\ 1 & Otherwise \end{cases}$$

Thus, each agent chooses the amount of insurance (*m*) respectively. Where premium *q* is as follows[23]

$$q = (\Delta\lambda + \lambda)R \tag{2}$$

According to the above problem to maximize, if *E* is too low, then default prevails. Particularly, the shape of the risk premium and the size of counterparty risk are a direct result from Acharya and Bisin [1]). Thereby, the risk premium is constant and equal to

$\Delta\lambda = \frac{\gamma}{1+N}\lambda(1-\lambda)\left[\sum_{i=0}^{N}\omega_b^i - \omega_s\right]$. The former result stems from the market clearing condition as the seller reaches any result, either a defaulting or non-defaulting one. The restriction $\omega_s = R(N+1)m^b$ is equivalent to the clearing market condition since $\frac{\omega_s}{R} = m^s.N$ is the number of extra buyers per each buyer in the contract. Supra-indices *b* and *s* on the amount of insurance in above notation stand for buyer and seller respectively.

Lemma 1 ***(Counterparty risk).*** This lemma verifies Acharya and Bisin [1]'s claim of the existence of counterparty-risk externality. It is also worth mentioning that the recovery rate can be seen as a measure of that aforementioned externality, too. However, the main point in this lemma isolates the effects stemming from any other factors but the number of participants. Given the definition of equilibrium (2), the market clear condition when a defaulting choice is made by seller produces a positive relation between the recovery rate and the deadweight loss.

3.5 The inefficiency of opacity markets

The inefficiency of equilibrium follows Acharya and Bisin's [1] discussion when there is neither collateralization nor mutualization. This rises from deadweight costs of the insurer's bankruptcy. Any strategy to increase these costs would recover efficiency, for instance, collateral. Since buyers are better off with some collateral size, the planner can improve upon the non-transparent markets when deadweight costs are not negligible. Thus, as a result, the counterparty risk produces still too much demand for insurance in equilibrium, and this gives incentive to default. Figure (1a) shows the quantity of insurance in equilibrium, buyers' and sellers' utilities with a standard parametrization. Also, the realized recovery rate (*R*) and premium (*q*) are shown, all as a function of *E*, the deadweight loss. It is quietly surprising that Tier ratios do not show a sharp increase of risk as additional buyers take part of CDS trading (see figures 1e and 1f). In an empirical work, Chiaramonte and Casu [19] found that balance-sheet ratios as leverage and Tier 1 ratio were not among the determinants of bank CDS spreads during the recent financial crisis even including its aftermath. The authors mentioned that international banks that ran into difficulty, including US banks, almost always had a Tier 1 that was acceptable to regulatory standards. Thus, Chiaramonte and Casu [19] cast doubts in relation to the reliability of the capital index Tier 1 as a regulatory tool.

In this current section, the standard solution in Acharya and Bisin [1] was replicated. A non-defaulting equilibrium exists when the deadweight loss is properly large. In the next section, a clearinghouse, which contributes with collateralization and mutualization policies, is included in the analysis.

4 The clearinghouse

The clearinghouse observes the total size of trading through novation. Then, it can set a collateral policy affecting the amount of insurance. The clearinghouse can therefore require that the seller post collateral (κ) and default funds (φ) fractions in order to setup collateralization and mutualization respectively. The amount φm will be distributed among all buyers whose contracts default, and κm belongs to the buyer in case the contract is under default. The benchmark or first best for allocation is defined in the following section.

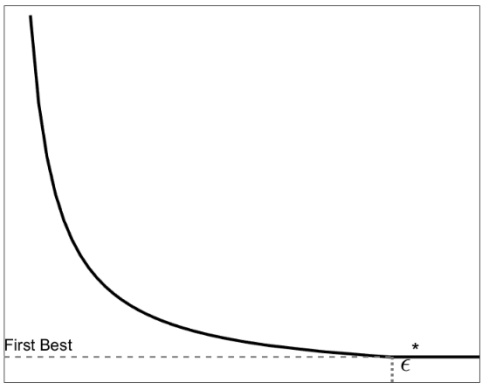
4.1 Efficient allocation

A benchmark allocation that represents an efficient result amid participants in this fictional financial economy is discussed. This allocation ultimately involves a policy of transparency of trade positions.

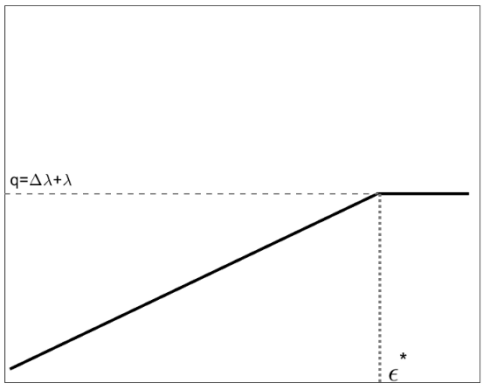
Benchmark. Acharya and Bisin [1] state that if the total amount of insurance and endowments were observable, a planner could impose a pricing rule on $q(m, \omega_s, \Delta\lambda)$ to be $(i)\ [\Delta\lambda + \lambda]$ whenever there is no default, and $(ii)\ [\Delta\lambda + \lambda]\frac{\omega_s}{m}$ when there is default. When substituting the price rule into CDS seller's maximization, the incentive to default vanishes. Buyers continue to purchase insurance in a competitive way, taking the price as given. The result will be no supply of insurance in equilibrium beyond the non-defaulting insurance level (see Acharya and Bisin [1] for details).

However, this allocation would require information about the risk premium and possibly endowments. Therefore, any allocation under limited information represents a constrained Pareto optimum. The clearinghouse, due to novation, observes the size of trading and will collect any funds for mutualization of losses. Since the insurance market is characterized by strategic default, the clearinghouse needs to collect any funds to protect buyers from default; for instance, the clearinghouse can request a particular $\kappa \equiv \kappa*$ that denotes a minimal fraction of collateral, that fraction may guarantee that the seller has no incentive to default when holding the amount of insurance $m*$.

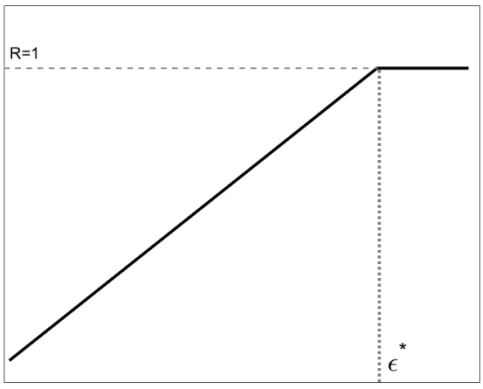
Also, the seller's decision on defaulting is based on the collateral size that the buyer chooses. The observation is that the payoff R and price q are affected by the size of collateral. The buyer knows that imposing collateral may prompt the seller to behave properly within the terms of the contract. However, they do not internalize the effect of collateral on q; thus, buyers will end up requesting a higher size of collateral in equilibrium. This would not be harmful at first sight, since collateral plays the same role as the deadweight cost E (see Acharya and Bisin [1]).



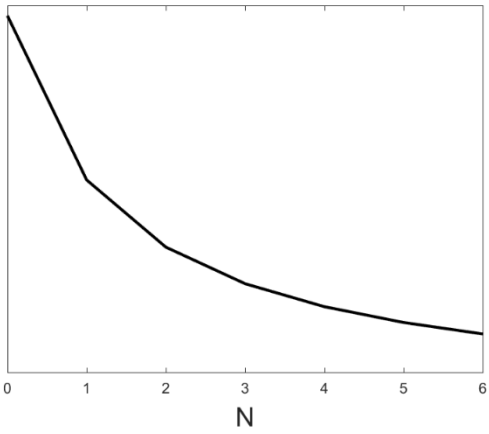
(a) Notional



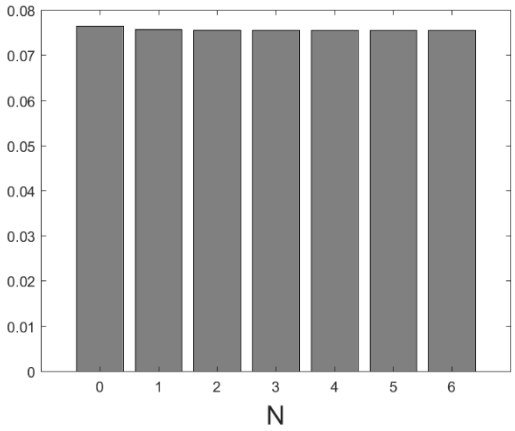
(b) Premium



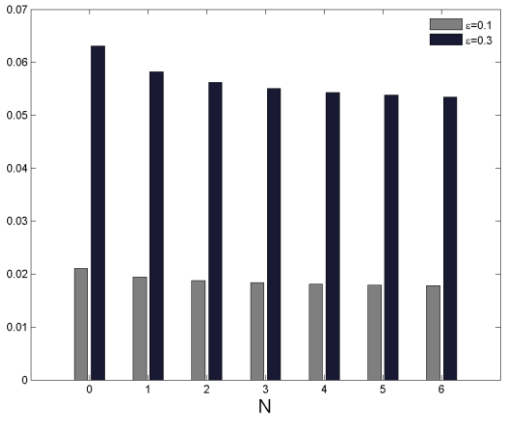
(c) Recovery rate



(d) Ratio *R/q*



(e) Tier 1 ratio



(f) Tier 1 common ratio

Figure 1: Acharya and Bisin (2014) main results.

4.2 Implementation of policy

The timeline figure (2) helps to visualize the implementation of the policy. A previous stage (T=-1) is added to the timeline (see section 3.1) in order to show the observable variable, in this case the historical recovery rate R_H, that determines the sizes of κ, φ^s and φ^b according to the waterfall rules. The central counterparty (CCP) or clearinghouse takes as reference the aforementioned variable for policy, and that choice is critical since an unfeasibly high level of either collateral or default funds would cause sellers and buyers to not want to participate in the clearing market.

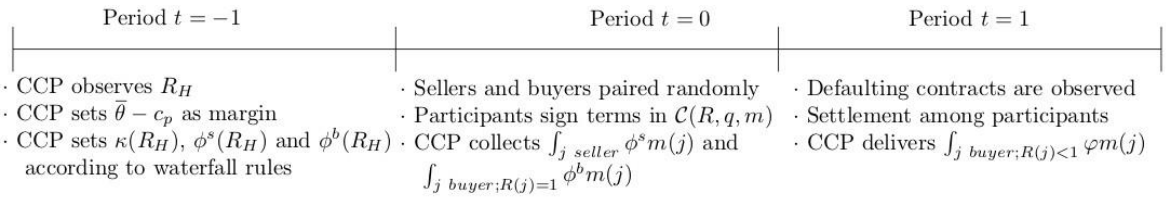


Figure 2: Timeline for central clearing.

The selected approach for policy implementation has similarities with Huang [29]'s work, which solves an optimal problem for the clearinghouse by backward deduction. In that paper, the agents make their participation feasible given a size of collateral or default fund as well as their chosen amount of notional or trading volume, recovery rate and premium. Then, ex-ante utilities are calculated for each stage of waterfall rule. A difficulty to be addressed by the clearinghouse is setting an initial margin[24] that permits sellers to participate, otherwise they would not participate ultimately. The foregoing is circumvented by setting a risk asset θ that is centrally cleared and mutualized, thus part of the individual equity for the seller (θ_j) turns into $E(\theta) = \overline{\theta}$ and consequently the initial margin is right observable and equal to $\overline{\theta} - c_p$. That margin will be used to cover any default fund or collateral call[25] to the seller.

In the setting period the clearinghouse observes the historical (average) recovery rate[26] in the OTC market (R_H) and chooses sizes of collateral or default funds accordingly, i.e. default and collateral calls are functions of that measure. Alternatively, the clearinghouse could have an estimate of E; the aforementioned approach could demand some effort not discussed in this paper and it certainly lies within the mechanism-design's literature. Finally, in period T=0, the participants sign a contract and the clearinghouse collects calls. In period T=1, the settlement or resolution of the contract arises, and the clearinghouse delivers amounts previously collected to buyers whose contracts are under default. As the analysis in the next sections will show, some contracts will be fully insured and others will get insurance to some extent given the parameterization proposed in this paper.

In the next two sections two procedures under a clearing arrangement are discussed: i) collateralization and ii) mutualization. The first one shows the role of clearinghouses as collateral managers and the second shows the policy of mutualizing losses among participants in the clearinghouse. The latter entails asking for default funds in order to finance expected losses due to defaulting.

4.3 Collateralization

In this section the collateral policy and market equilibrium are described when the clearinghouse's main role is the management of collateral. The amount of collateral, as a percentage of the notional value, is collected from each seller and posted as a credit to each respective buyer; in the event of default of the reference asset, the collateral is retained by the buyer and the rest of settlement is enforced. In a clearing setup, since there is a limited liability on the seller's side, clearinghouses have to pledge collateral to prevent strategic default. Therefore, the clearinghouse is able to collect collateral by offering two contracts to buyers and sellers; one contract making it possible to discourage a default and another contract setting an insurance for when there is a default. In this section, Koeppl [35]'s characterization of these two contracts is used for the sake of convenience. Both contracts in the clearing setup deliver a weak Pareto improvement equilibrium. Along this section, some propositions that characterize the equilibrium under clearing are set forth formally.

4.3.1 Collateral requirements

In a clearing arrangement, the clearinghouse sets the collateral requirements. Since collateral needs to be posted up front, sellers need to liquidate some assets from their portfolio. However, there is a cost of v units per each amount earmarked to fulfill collateral requirements. Below, formally:

Definition 3 ***(Collateral set).*** *The set of feasible levels of collateral for the seller in a clearing arrangement is given by the following,*

$$K = \left\{ \kappa \mid \bar{\theta} + \alpha q m \geq \kappa m + \nu\kappa(m - \omega_s) + c_p \right\} \tag{3}$$

Above inequality, henceforth participation constraint, defines the set K. The term $\nu\kappa(m-\omega_s)$ is the cost of posting collateral. Since this contract has been cleared, the clearinghouse performs netting of position through novation. Thus, the seller's net exposure is $m - \omega_s$.

$\bar{\theta}$ is the portfolio average return available at time 0. As said previously, this setup is not an assumption since a clearinghouse can clear these contracts and offer an insurance policy[27].

4.3.2 Maximization under collateral requirements

The next program (P1) is solved in order to show the effect of collateralization on the premium. The seller defaults if the recovery rate and the fraction of the notional, which is collateralized, is less than 1, i.e. $R+\kappa<1$. The recovery rate must be properly adjusted to reflect the transfer of collateral when the seller defaults; the expression that defines the premium is also adjusted accordingly. The risk premium ($\Delta\lambda$) varies and the participation constraint for each seller now includes the value of the collateral that belongs to the set K (see expression 3).

It must be noticed that clearinghouses choose collateral in relation to the size of the notional, thus they setup the collateral policy. Both seller and buyer maximize their profit or utility functions by choosing the level of insurance. Additionally, the market clear condition (see definition 1) is required in equilibrium.

The central counterparty maximizes the product of the seller and buyers' utility functions[28], the parameter σ measures the relative importance of the seller's utility when a policy is implemented. The parameter v is the cost of posting collateral and it is a percentage of the netting and collateralized exposure between the seller and the central counterparty. The first restriction is the market clearing condition. The second restriction is the participation constraint. The third restriction is the CDS premium as in expression (2). This expression is determined by the seller and taken as a given by the clearinghouse. The fourth restriction is an expression given by the terms of the contract that limits the sum of the recovery rate and the collateral to be greater than one. The restriction $\omega_S \geq Rm$ is very significant since it establishes both the seller's limited liability and the position that is observable to the counterparty.

In the following lines, and all the way to the end of this section, a proposition is shown to intend the existence of two separate contracts. This is a useful resource used in Koeppl [35] that is convenient to discuss before simulations, since sellers face a participation constraint that has variables such as a premium and a notional amount of insurance that hinges on the size of collateral. Particularly, the proposition after the following definitions will show that the aforementioned constraint unambiguously binds as collateral fraction κ increases; however, it requires a proper calibration. This is not a trivial result since the amount of notional and premium relax the participation constraints when they are affected by collateralization.

Below, two type contracts are defined when the clearinghouse's main role is to offer a storage facility of collateral.

Definition 4 ***(The incentive contract).*** *The clearinghouse sets a collateral requirement where $R+\kappa=1$ and $\kappa \in K$ for each pair of buyers and seller.*

Koeppl [35] defines an incentive contract aiming to eliminate default in an exchange transaction. The main role of collateral is as a device that clearinghouses can use in order to reduce (to some extent, in some cases) the probability of a seller's default. A seller, in a contract signed in an OTC market, would like to commit to not defaulting but cannot find an arrangement to do it since deadweight losses are badly low.

Definition 5 ***(The insurance contract).*** *The clearinghouse sets a collateral requirement where* $R + \kappa < 1$ *and* $\kappa \in K$ *for each pair of buyers and sellers.*

Koeppl [35] defines an insurance contract as the one that extracts surplus from a seller who defaults in an exchange market; precisely, in this setup the ratio $\frac{R}{q}$ increases and therefore, the buyer can extract surplus from the seller. In the proposition below, the existence of two contracts is defined in the range of deadweight losses values (E) per notional amount of insurance. For the sake of analysis, the linearized version of the binding participation constraint is added (see expression 3). That expression relates the fraction of collateral with the deadweight loss i.e. $\kappa = \varsigma E$ since the amount of insurance and premium are ultimately a function of the aforementioned exogenous variables. In other words, the following proposition's proof shows that the participation constraint is binding and thus that relation between collateral and deadweight loss can be sketched in a $\kappa - E$ plane (see figure 3).

Proposition 1 ***(Existence of an incentive contract).*** *There is an incentive contract for* $\underline{some}\ E \in [\underline{E}, E^*[$ *when* $\underline{E} \leq \varsigma^{-1}$*. Being* E^* *the level of deadweight loss that makes the seller perform properly, i.e. sellers do not default in equilibrium.* $k = \varsigma E$ *is the linearization of the participation constraint that binds.*

Proof. A positive correlation between deadweight loss and collateral ($\varsigma > 0$), i.e. the participation constraint is binding, ensures the existence of an incentive contract; in figure (3b) there is the range $[E^0, E^*]$ where both contracts exist. Level E^0, which is equal to zero, is a reference for any $E > E^0$, thus the slope ς is positive, otherwise that slope is negative. Figures (3a) and (3b) show regions for incentive contracts.

Collateralization in this model has the same effect as an increase in the deadweight loss size. An increase in this parameter produces an increase in the premium and recovery rate. Thus, the clearinghouse achieves a size of collateral fraction, i.e. κ^* that makes it so that sellers do not default. In other words, the level of collateral must lay on the line $R + \kappa^* = 1$.

There is a condition that guarantees a corner solution for incentive contracts over the range for $E < E_0$; figures (3c) and (3d) depict the condition $\underline{E} \geq \varsigma^{-1}$ and the existence of incentive contracts. The participation constraint (red and blue line) and the frontier $R + \kappa = 1$ (black line) are also shown which implicitly set the range for collateral i.e. $\kappa \in (0, 1)$. The gray area shows the set for collateralization in an insurance contract.

Corollary 1 ***(Corner equilibrium for incentive contracts).*** *If $\varsigma < 0$ and $\underline{E} = \varsigma^{-1}$ there is an incentive contract with collateral level $\kappa = 1$. If $\varsigma < 0$ and $\underline{E} > \varsigma^{-1}$ there is no incentive contract.*

By definition, an incentive contract delivers the outcome $R + \kappa = 1$. The binding participation constraint for a corner solution is $1 = \varsigma E$. Thus, as explained in the proof of proposition (1) the lowest possible level of deadweight loss in order to guarantee an incentive contract is $\underline{E} = \varsigma^{-1}$

Regarding the effect of collateralization on welfare, the sign of the change in the payoff function is ambiguous as the buyer chooses the notional amount of insurance knowing rationally the recovery rate. However, a relation emerges among the change of objective functions that unveils the sign and magnitude of the change in welfare among participants.

The following corollaries show the determination of the collateral size under the aforementioned two contracts.

Corollary 2 ***(Collateral level for insurance contract).*** *For any E, the collateral fraction for an insurance contract is in the set* $K^{ins}(\epsilon) = \left\{\kappa \mid \kappa \leq \varsigma\epsilon \;\&\; \kappa < 1 - R(\epsilon,\kappa)\right\}$.

The collateral in this contract is bound by the participation constraint when it is binding. However, particularly for this model with collateralization, $\kappa = 0$ is assumed as a unique solution for the sake of simplicity. On the other hand, the collateral size would be different from zero in a default region under an incentive contract.

Corollary 3 ***(Collateral level for incentive contract).*** *For any E, the collateral fraction for an incentive contract is in the set* $K^{inc}(\epsilon) = \left\{\kappa \mid \kappa \leq \varsigma\epsilon \;\&\; \kappa = 1 - R(\epsilon,\kappa)\right\}$.

The collateral in this contract fulfills the condition $R + \kappa = 1$. In other words, there are enough resources to implement an incentive contract.

Corollary 4 ***(Unobservable type of contract).*** *If the deadweight loss level of the CDS seller is unobservable, an outside observer cannot necessarily infer the type of the contract from the collateral level alone when $E \in [E^0, E^*]$. However, if $E \in [\underline{E}, E^0)$ low and high levels of collateral are related to insurance and incentive contracts respectively.*

Corollary (4) follows Koeppl [35]'s insights about how informative the size of collateral is in order to foresee the seller's default. Insurance and incentive contracts give different levels of collateral; small enough deadweight losses allow the association of incentive contracts with higher levels of collateral. For a low level $(\bar{\theta} - c_p)$ and small E, collateral levels are low and related to insurance contracts. On the other hand, a low level of $(\bar{\theta} - c)$ and higher $E < E*$ are related to more insurance than incentives contracts.

Definition 6 ***(Counterparty risk under collateralization).*** *In the credit-default-swap market allocation with collateral policy, the ratio* $\frac{R+\kappa}{q}$ *is a measure of counterparty risk.*

Fraction $\frac{R^{stge}}{q^{stge}} \equiv \frac{1}{\Delta\lambda+\lambda}$ varies with respect to κ since Δλ varies under collateralization.

4.4 Mutualization

In this section the clearinghouse's problem under mutualization policy is assembled. The clearinghouse, according to waterfall rules, calls for a default fund (φ^s) to sellers and a marginal fund (φ^b) to buyers[29]. In other words, each participant must contribute to a fund that is proportional to the total value of the liability established by the contract. Thus, the amount of resources collected from sellers, per unit of notional amount, is $\frac{1}{1-\lambda}\phi^s$. Additionally, resources collected from buyers are equivalent to $(N+1)\varphi^b$ since the normalized size of agents that do not see the event occur is $N+1$. In the first exercise, the optimal φ^s is the argument that maximizes a welfare function, that the amount of resources represents the usage of the immediate line of defense that the clearinghouse has after collateralization. Since the seller's participation constraint confines the provision of full coverage, i.e. $R + \phi = 1$, then the clearinghouse calls for a marginal fund to buyers. That scenario is considered in the second and last exercise according to waterfall rules. ϕ represents the amount per buyer provided by the clearinghouse whether the contract is under default.

In this section also there will be propositions in order to show the direction of the recovery rate and risk premium when mutualization policy takes place, i.e. calls for default funds. The complexity of the model that reveals many endogenous variables encourages the display of the aforementioned results. This section ends with a proposition that shows the behavior of the risk premium in equilibrium when E changes.

4.4.1 Clearing members' default fund contributions

Before stating the problem to maximize, the equilibrium as the clearinghouse sets a mutualization policy is defined as follows:

Definition 7 ***(Equilibrium).*** *The equilibrium in the insurance market is given by:*

(a) Each seller is randomly matched to a buyer, and both agree to the terms of the contract $C(R, q, m, \varphi^s, \varphi^b, \phi)$*;*

(b) Each agent maximizes expected utility by choosing the trade position "m";

(c) The insurance market clears;

(d) In the case of default, the seller fulfills their promise and pays out the recovery rate times the amount of insurance. Thus, the function "R" is defined as follows:

$$R = \begin{cases} < 1 & if\ default \\ 1 & Otherwise \end{cases}$$

(e) In the case of full coverage, the buyer receives the total amount of the notional. Thus, buyers receive the following per one unit of insurance:

$$R + \varphi = \begin{cases} = 1 & full\ coverage \\ < 1 & Otherwise \end{cases}$$

Here are some points to discuss after the definition of equilibrium. When the clearinghouse applies any mutualization policy aiming at full coverage, the seller responds by providing $m = \frac{\omega s}{R}$. The seller can realize a full coverage scenario when the clearinghouse is fully funded by either a guaranteed default fund or a moneyed clearinghouse. In any clearinghouse's response to $R < 1$, the seller will always get Π_D as payoff, and the amount of insurance provided will be equal to $mR = \omega_s$. The visible difference with the OTC scenario is that the premium through risk premium ($\Delta\lambda$) will be affected by resources collected from the clearinghouse.

The first restriction in the program (*P* 2) refers to the reallocation of resources to buyers who see their CDS contracts under default; $\varphi_s m$ is the default fund posted by the seller, whereas resources $\varphi_b m$ come from buyers who do not experience the trigger of the event. The second restriction is the market clearing condition. The third restriction is the participation constraint, as usually all calls must be collected in cash in period 0. The fourth expression is the CDS premium which is determined by the seller and taken as given by the clearinghouse. The following constraints are related to non-negative bounding conditions (for any kind of corner solution), the seller's limited liability and the buyer's constraint that limits the funds available for marginal calls. In order to solve the program (*P* 2), the solution involves fixed values for φ_s and φ_b, and then each participant finds the *m* level of insurance that maximizes the embedded function that appears on the objective function for the program (*P* 2). Consequently, the optimal insurance level for buyers is as follows:

$$m^b = \frac{1}{\phi^b + R + \varphi}\left[\omega_b - \frac{q + (1-\lambda)\phi^b - \lambda(R+\varphi) + \psi_b \phi^b}{\gamma_b \lambda(1-\lambda)(\phi^b + R + \varphi)}\right]$$

ψ_{br} is a lagrange multiplier associated with the last restriction in the program (*P* 2). The optimal insurance level for sellers when they default (m_D^s) and do not default (m_{ND}^s) respectively are as follows:

$$m_D^s = \frac{q - \lambda(\epsilon + R) - \phi^s + \eta\psi_{pc}(\alpha q - \eta\phi^s) - \psi_{ll} R}{\gamma\lambda(1-\lambda)(R+\epsilon)\epsilon}$$

$$m_{ND}^s = \omega_s$$

Being ψ_{pc} the lagrange multiplier associated with the participation constraint. In the case of a mutualization policy the risk premium is affected by the policy.

Claim 1 Sellers cannot hold the participation constraint slack at low levels of *E* since *m* is high. If they did not participate, sellers would not mutualize their contracts' losses. Some high level of *E* causes sellers participate, and the clearinghouse can get more funds since the participation constraint becomes less tight. Therefore, the sign of $\frac{\partial \phi^s}{\partial \epsilon}$ is positive when $R + \phi \leq 1$ and negative when $R + \phi = 1$. The latter certainly holds since the clearinghouse is offering a full-coverage contract and more funds are no longer needed as R increases. Second, high levels of *E* cause agency problems to become weak, and therefore contracts may be offered with a larger R than before; thus, $\frac{\partial R}{\partial \epsilon}$ is always positive and the claim is true.

The following proposition states that the risk premium decreases in a mutualization policy.

Proposition 2 ***(Risk premium when default funds are called).*** *The risk premium dwindles as more funds are earmarked for mutualization purposes starting at some specific level* φ^s.

In relation to the marginal contribution provided by the buyers, that is only applicable, according to waterfall rules, when existing resources managed by the clearinghouse are used up. In order to simulate that scenario, the participation constraint is assumed to be almost binding. Under the aforementioned outline the clearinghouse pins φ^s and finds a φ^b that maximizes welfare. It is worth mentioning that higher values of φ^s tighten the participation constraint and cause the seller to abstain from participating. The following lines show the effect of marginal contributions on *R* and the risk premium and the response of that risk premium to levels of deadweight losses at optimal levels of marginal contributions.

Claim 2 $(Sign\ of\ \frac{\partial R}{\partial \phi^b}).\ Since\ \frac{\partial R}{\partial \epsilon} > 0\ then\ sign\left(\frac{\partial \phi^b}{\partial \epsilon}\right) = sign\left(\frac{\partial R}{\partial \phi^b}\right)$

The claim is verified following same steps as in the case for $\frac{\partial R}{\partial \phi^b}$ (claim 1). Some *E* makes the restriction $\omega^b - \phi^b m$ less tight; thus, $\frac{\partial \phi^b}{\partial \epsilon}$ is positive when $R + \phi < 1$ and negative when $R + \phi = 1$. As before, $\frac{\partial R}{\partial \epsilon}$ is always positive and the claim (2) is true too.

In the following lines, as done previously for the default-call φ_S, the last proposition is presented regarding the change of the risk premium to φ_b.

Proposition 3 ***(Risk premium when marginal default funds are called).*** *The risk premium to change in the marginal default fund call is ambiguous. The risk premium dwindles as more funds are earmarked for mutualization purposes starting at some level specific* φ^b.

5 Numerical exercise

The model proposed in the previous sections is used to simulate the impact of clearinghouse policy (collateralization and mutualization) on the premium. Two illustrative exercises are performed in this section in order to show the effects of clearing policies. Figure (4) shows the interaction among participants in the CDS market. The parameter *N* refers to extra buyers, which controls the leverage position of each seller. After the Great Recession, these positions are believed to be small due to

regulation; thus $N = 1$. In the model there are I sellers. Thus, taking the foregoing assumptions into account, there are twice as many buyers as there are sellers. As said before, a fraction λ of sellers default, given the size of deadweight-loss parameter.

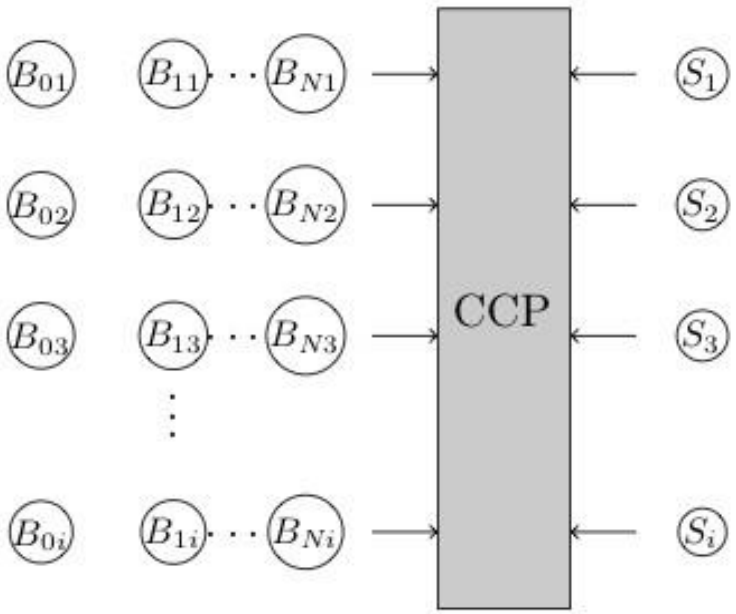


Figure 4: Clearing with $(N+1) \times I$ Buyers and I Sellers.

The first exercise shows the size of the default fund and collateral as a fraction of notional for different probabilities of the credit event. The second exercise analyzes the impact on premium when the participation constraint binds, and more funds are requested by the clearinghouse.

Table (1) shows the baseline parameterization. The probability of occurrence of the event (λ) is fixed to 5% and it represents the last figures from the rating agencies' data[30]. The analysis for higher values of λ (see table 2) is also included. The risk aversion parameter for the buyer (γ_b) is conservative and equal to 0.7, according to our own calculations and supported by the figures reported in Amato [3][31]. On the other side of contracts, the literature usually sets a low-risk parameter value for the seller (γ_S), for instance Huang [29] pins the parameter to zero. In the exercise, the value for γ_S is assumed to be lower and fixed to 0.2; the aforementioned value is somehow arbitrary, but low enough low to catch a significance response of the recovery rate. The parameter α is fixed to 20% and it represents the fraction of premium available to face any calls from the clearinghouse. It certainly has an impact on the size of the seller's participation constraint and allows the available resources to peter out in a controlled way (as discussed in the proof of proposition 1). The possible loss or endowment (ω_b) in the last period for the buyer is equal to 7; since it assumed a leverage of 40% for each seller, then the number of buyers per each contract is

equal to 2, i.e. $N = 1$. The average return of portfolio (θ) is equal to 3, whereas the fixed costs of participation in clearing (c_p) are equal to 1. The endowment received in last period for seller (ω_s) is equal to 10.

Table 1: Baseline parameterization.

Parameters	Value	Definition
λ	0.05	Probability of the event – benchmark, see table (2)
σ	0.25	Weight – benchmark, see table (2)
γ_b	0.70	Risk aversion parameter of buyer
γ_s	0.20	Risk aversion parameter of seller
ω_s	10.0	CDS seller's endowment
$\omega_{s,0}$	0.0	CDS seller's endowment at t=0
θ	3.0	CDS seller's portfolio
c	1.0	Participation costs
ω_b	7.0	CDS buyer's loss
$\omega_{b,0}$	0.0	CDS buyer's endowment at t=0
α	0.2	Limited liability parameter
N	1.0	Number of extra buyers

Different scenarios are constructed in order to show the significance of clearing practice on the magnitude of the CDS premium and other relevant variables such as welfare. These scenarios are shown in the following table 2. The scenario (S0) replicates the baseline scenario as shown in the previous table. An increasing probability of the credit event (λ) is the main feature of those further scenarios. Additionally, the parameter σ, which measures the relative importance of the sellers in the clearinghouse's utility function, is nailed down according to the value of (λ). The foregoing is explained in the next lines.

Table 2: Scenarios.

Parameters	Scenarios			
	S0	S1	S2	S3
λ	0.05	0.15	0.30	0.40
σ	0.25	0.45	0.75	1.00

As said previously, σ is a mere weight affecting the seller's expected utility. Any value of that parameter but the value of one causes the clearinghouse to quantitively value any change in the seller and buyer's utilities unequally. A clearing policy executed at low values of λ certainly makes the clearinghouse ponder on the fall of a seller's utility and, additionally, the clearinghouse becomes more responsive to gains in the buyer's utility. The aforementioned setup could arise easily when the clearinghouse has an active role in quiet financial markets. At high values of λ the clearinghouse faces the effects of bulgy defaulting contracts; thus, the clearinghouse becomes more responsive to changes in the seller's utility, and hawk-eyed of clearing policies that could discourage agents from participating.

5.1 Optimal collateral κ

Figure (5) shows the recovery rate and CDS premium affected by the collateral policy. In particular, the below figure shows three cases—three sizes of E—where an incentive contract can be implemented; the incentive contract shows that for a large level of deadweight loss, there is some collateral level κ^* that causes the seller not to default. The existence of κ^* is a possibility since the participation constraint must remain slack. Depending on the level of E, there are different collateral requirements implemented by an incentive contract. Here are two points to consider: *i*) collateral requirement makes both recovery rate (R) and premium (q) increase; and *ii*) Ratio $(R + \kappa)/q$ is increasing, which is a consequence of a decreasing risk premium ($\Delta\lambda$). The contracts related to the aforementioned sizes of E are no longer under default, a result that holds in equilibrium, a result only possible when E is large enough and the participation constraint is slack enough.

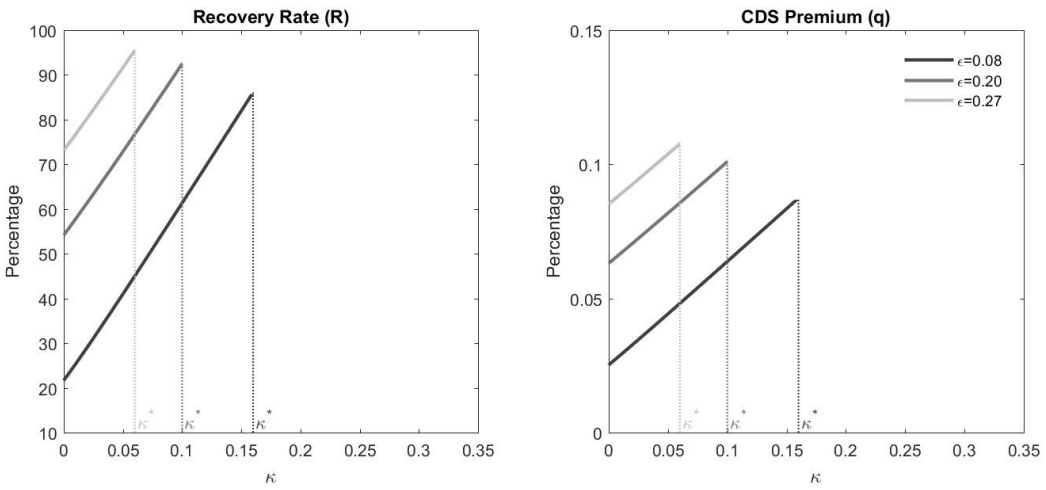


Figure 5: Recovery rate and CDS premium; non-defaulting contracts when $E < E^*$.

Also, figure (5) shows that collateral size is correlated to recovery rate levels; lower initial R requires a higher amount of collateral for incentive contracts. However, if insurance and incentive contracts are pooled and the specific details of the contracts are not public, collateral size is not informative about the type of contract, as the corollary (4) claims.

Figure (6) shows that CDS' notional amount is affected by the clearinghouse's collateral policy. Since $R + \kappa$ and q increase due to collateralization, then the notional amount of insurance decreases accordingly; collateral requirements negatively affect the demand for insurance *(mb).* On the other hand, collateral requirements for the seller affect insurance supply in the same way as E increases.

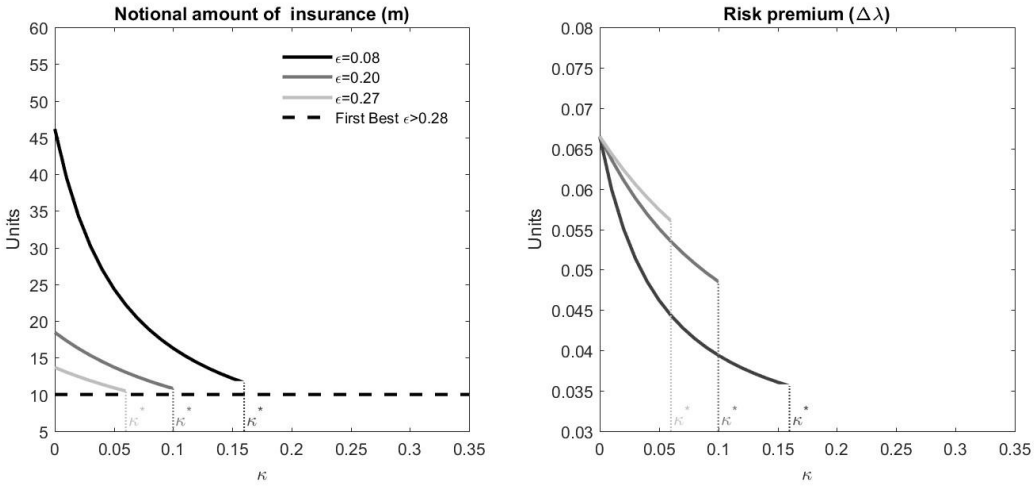


Figure 6: Notional and risk premium when E < E*.

Also, the above figure shows that, as long as the recovery rate is equal to $1 - \kappa$, the amount of insurance reaches a value above the first best. Higher E means higher recovery rates and therefore the clearinghouse will require less collateral, and a non-defaulting outcome will hold in equilibrium. The figure (6) also shows the risk premium as a function of collateral levels. The risk premium declines as collateral

increases. The aforementioned effect on risk premium is produced by the restriction $\omega_S = Rm$ (limited liability) that holds as solution to the problem solved by the clearinghouse. That restriction only holds when the contract is cleared and also the foregoing permits a clear distinction with a contract traded in an OTC market, which will be explained in the next lines. In a clearing market, the clearinghouse can see all participants' positions, and it particularly observes the size of the amount that will be used as amount recovered from the contract, i.e. ω_S. Therefore, it is necessary to emphasize that the clearinghouse not only does netting[32] and compression of contracts; it also enforces the terms of the contract by using the resources of sellers available and observable through recorded transactions. The clearinghouse observes exposures to a third party originated by seller at inception, and it uses it as an amount recovered from a defaulting contract. In an OTC contract the limited-liability feature guarantees the restriction $\omega s = (R + \kappa)m$ to hold as a solution to the seller's problem. The restriction makes a difference in terms of risk premium effects on the premium; the size of the risk premium under an OTC contract is constant, as Acharya and Bisin [1] point out.

5.2 Optimal default fund call φ^S

In this section, the program (P2) is solved by considering the scenario S0 shown in table (2). For the numerical exercise in this section, the value for the marginal default call is fixed to zero according to waterfall rules or lines of defense that establish the call of resources. At this stage the clearinghouse uses default funds from the sellers and no other marginal funds are needed.

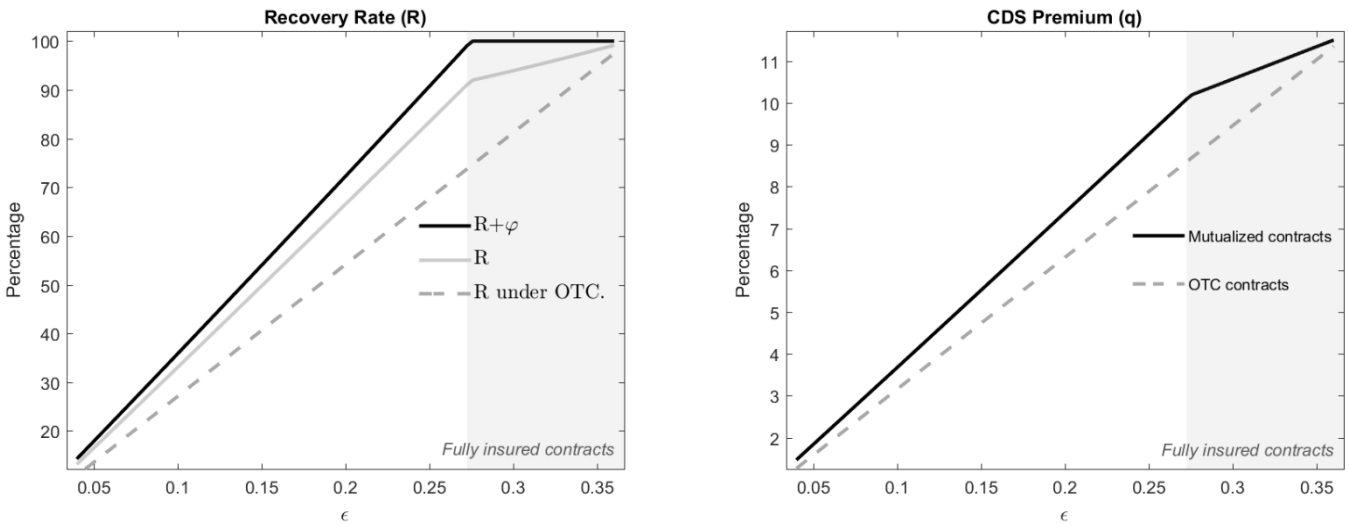


Figure 7: Recovery rate and CDS premium, scenario S0.

Figure (7) shows the effect of mutualization on recovery rate and premium. Low values of E imply high levels of notional; this feature makes the participation constraint to be tight. As notional values decrease, more resources are collected for mutualizing losses. These resources stem from all sellers and are equal to $(1-\lambda)^{-1}\varphi_S m$. Notice that default fund calls decrease for any case when $R + \phi = 1$, an indication that full insurance is possible. Precisely, figure (8) shows that variable R/q increases in the range when $R + \phi < 1$; this means that risk premium ($\Delta\lambda$) decreases through that range. Since there

are more resources coming from mutualization, the gap between available and demanded funds shrinks. This feature under a mutualization policy offsets the effect of the increasing recovery rate on the premium. Figure (7) also shows that the premium under mutualization is high in comparison to the pricing in the OTC case; even the gap among them is large when $R + \phi < 1$. Full insurance allows one to dispense with resources since the recovery rate increases. This has an immediate effect on the risk premium and consequently on our variable of interest: the CDS premium. Figure (7) also shows that under full coverage the premium does not depart significantly from the OTC case. The literature agrees that clearing practices incentivize agents to fulfill and improve the terms of contracts, to some extent, whenever default happens. This effect is measured by the increase of the recovery rate in the model. However, there is a notorious effect that pushes down the premium and it is measured by the existence of resources collected by all participants from the market.

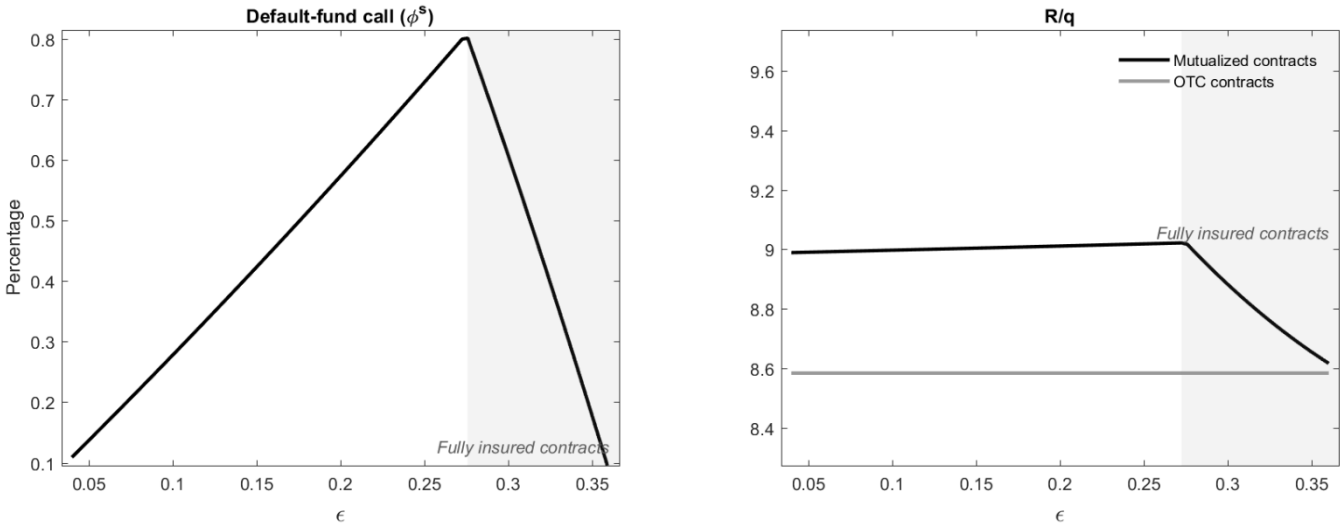


Figure 8: Default fund and ratio $\frac{R}{q}$, scenario S0.

Figure (9) shows the decline of a notional amount of insurance when mutualization takes place as a clearing policy. This effect is similar to the one with a collateralization policy. Mutualization improves welfare. Once there is no need to collect more resources since full coverage is achieved, welfare decreases. Overall, the welfare level is higher under mutualization than in an OTC case but less than the welfare obtained when $R = 1$.

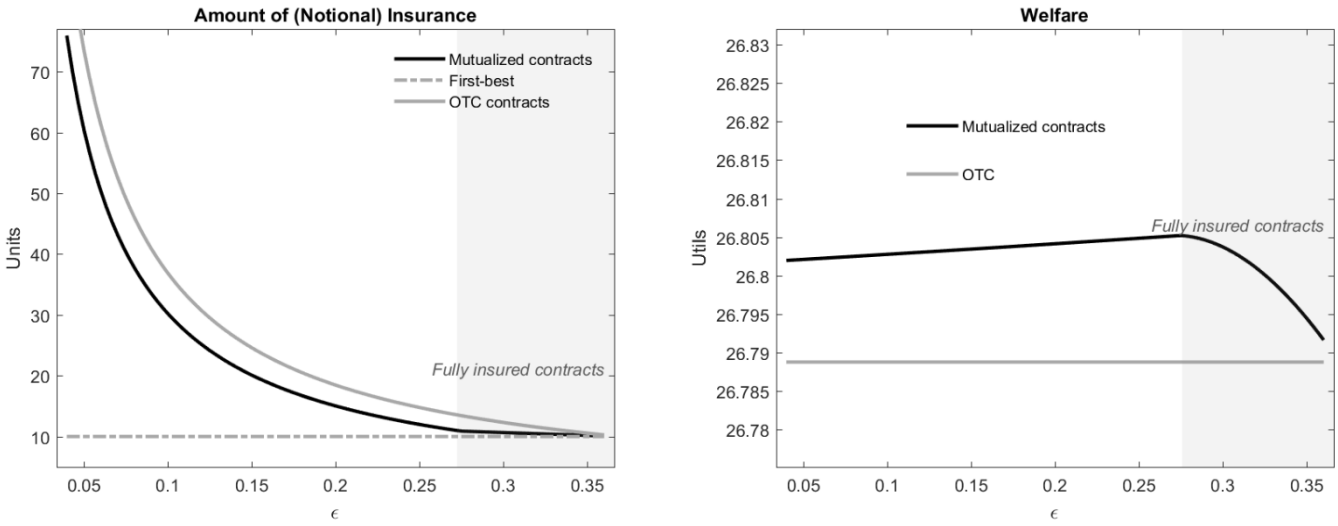


Figure 9: Notional and welfare, scenario S0.

The effective insurance, measured by $(R+\phi)m$, increases in comparison to an OTC contract. Also, this amount of insurance gets smaller when full coverage is achieved or offered by the clearinghouse.

The results of the simulation are summarized in the following table (3). This table shows the change for the premium, recovery rate, risk premium, notional amount of insurance, welfare and the share of defaulting contracts under clearing in relation to OTC contracts. The statistics are calculated over the range of E. The maximum value of changes for premium, recovery rate and welfare are obtained when mutualization achieves a fully insured contract; the size of those changes varies according to the probability of the credit event (see table 2). The change in the risk premium in percentage points is -0.56 and -2.21 for scenarios where the aforementioned probability is low and high, respectively. In terms of welfare, a negligible improvement of 1.28% is obtained under a value for λ of 0.4. Small changes are achieved for the rest of the scenarios. The impact of mutualization on notional amounts is depicted as the average size of the drop of the notional amount over the range of E. An important indicator is the reduction in the number of defaulting contracts from the buyer's viewpoint[33]. In the simulation, fully insured contracts arise significantly; for high values of λ, the number of those contracts are 33.3% and 41.7% of all OTC defaulting contracts over the range E.

Table 3: Change (Δ) and level of variables (Changes are in relation to OTC levels)

Variables	Stat	Units	Scenarios			
			S0	S1	S2	S3
$\Delta\, q$	max	b.p.	+150.0	+401.0	+1235.0	+1816.0
$\Delta\, R$	max	p.p.	+17.30	+15.40	+24.40	+27.40
$\Delta\, (\Delta\lambda)$	min	p.p.	-0.56	-1.13	-2.34	-2.21
$\Delta\, m$	average	%	-16.10	-14.20	-22.70	-23.90
Δ Welfare	max	%	+0.06	+0.18	+0.83	+1.28
Fully insured contracts	share	%	26.0	25.0	33.3	41.7

Note: Statistics are calculated on the range of E. Fully insured contracts are expressed in a share of all OTC defaulting contracts.

At this point it is useful to compare the above numbers with Loon and Zhong [42]'s empirical results. According to Loon and Zhong [42], central clearing increases the pricing of credit protection. The authors found evidence that immediately after clearing the CDS price change 170.3 basis points when using CMA data, similar results for MARKIT data[34]. Also, according to Loon and Zhong [42][35], 60 b.p. decrease in counterparty credit risk—here an increase in R[36]—results in an 8 b.p. increase in CDS spreads on average. Since scenarios with low probability of the credit event are related to an increase of 16% in recovery rate (see table 3), Loon and Zhong [42]'s finding would predict a 213 b.p. increase in CDS prices. The ~~above predictions are actually not far apa~~rt from our results for low levels of λ. Also, it must be included in the analysis that Loon and Zhong [42]'s estimates assume a broad definition of clearing practices; there is an effect on CDS premium due to a proper collateralization of contracts. The calculations in table (3) only include mutualization and netting, though.

5.3 Optimal marginal default fund call φ^b

In the following exercise, the clearinghouse calls for marginal funds from buyers whose contracts are not under default. According to waterfall rules, if the resources are scarce the next line of defense will be the aforementioned calling. As previously said, waterfall rules may suggest applying marginal calls to sellers who did not experience the credit event. However, this exercise intends to simulate extreme cases where different types of participants can be affected by policy.

In order to create the tightening participation-constraint scenario, the parameter $\bar{\theta}$ is assumed to be equal to 0.5, which permits an optimal default fund call from sellers of 1%. The foregoing shrinks the budget significantly and rules out the possibility of asking for additional funding calls to sellers; otherwise, they would decline to participate in the clearinghouse. The scenario requires solving the program (P2) keeping φ^s fixed.

The below figure shows the case when an extreme case of probability default is assumed, i.e. λ = 0.4. In the case of a small probability default (λ = 0.05) the corner solution arises (φ^b = 0) and there is no change in the CDS premium. The aforementioned result is driven by the large number of buyers with non-defaulting contracts affected by the marginal call. In other words, a possible fully insured contract does not completely offset the costs produced by the marginal calls on average.

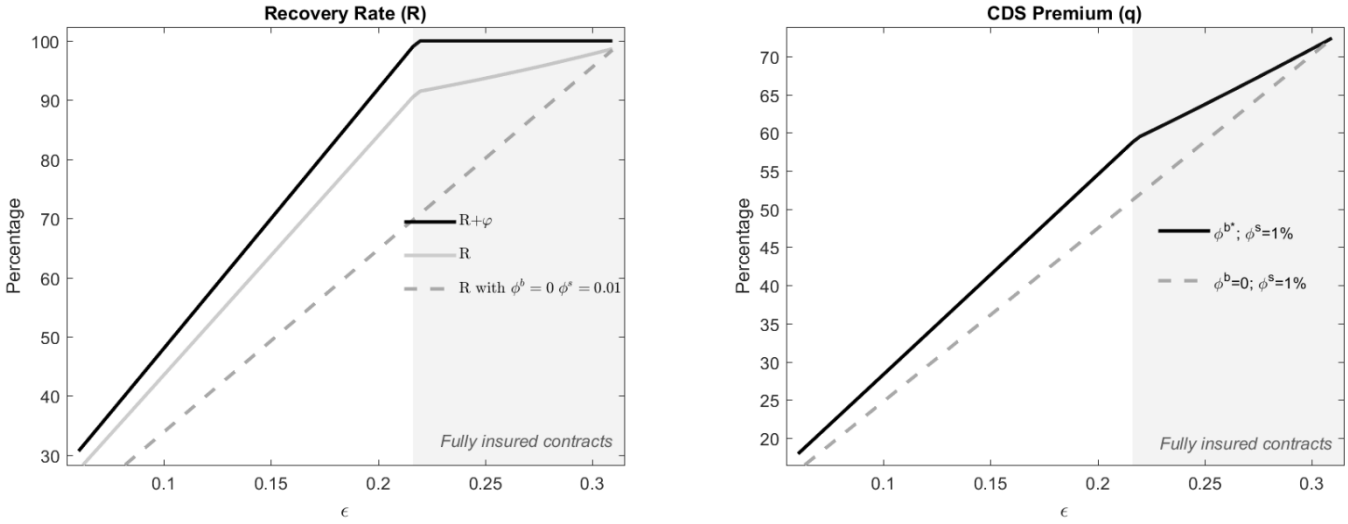


Figure 10: Recovery rate and CDS premium, scenario S3.

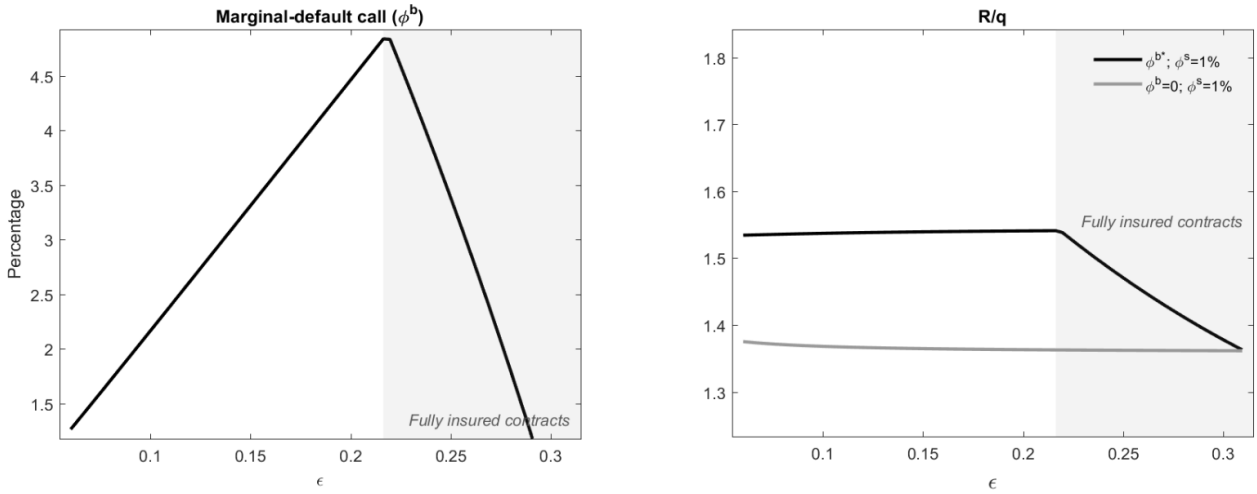


Figure 11: Marginal-default fund and ratio $\frac{R}{q}$, scenario S3.

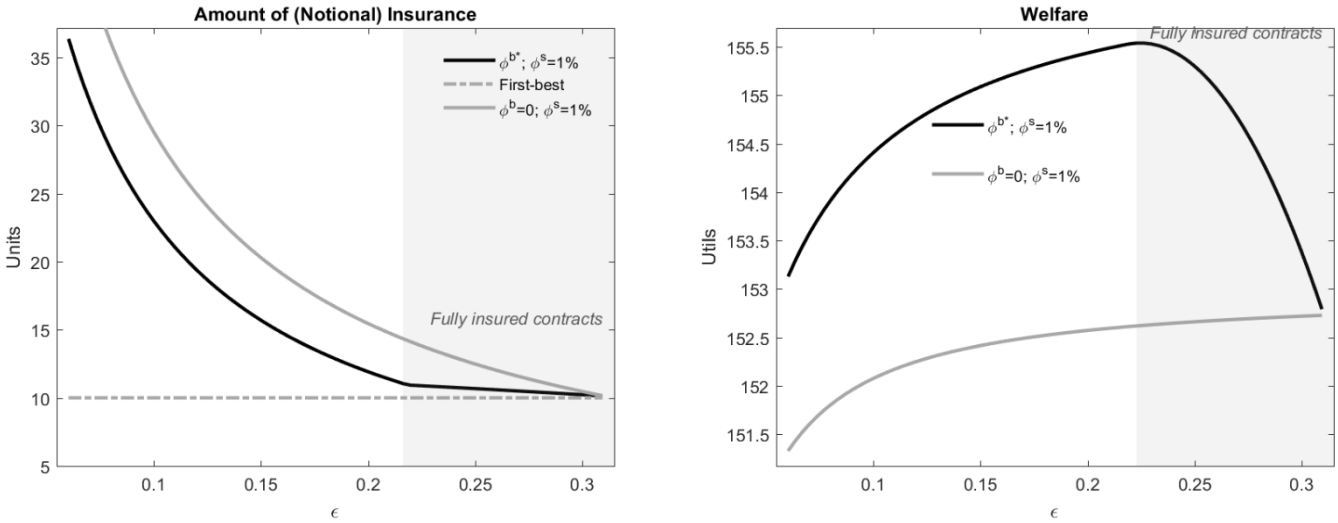


Figure 12: Notional and welfare, scenario S3.

The results of the simulation are summarized as before. There is no change in the variables of interest for scenarios S0 and S1 since the optimal response is $\varphi^b = 0$. For the rest of scenarios, the size of the changes is more or less moderate in comparison to the first line of defense that mutualization offers (see table 3). The change in the risk premium in percentage points is -3.96 and -8.49 for scenarios where the aforementioned probabilities are high. In the case of welfare, a feeble improvement is obtained again. The impact of mutualization on notional amounts is around -18.2% and -9.5% for the relevant scenarios. In the simulation the fully insured contracts arise significantly; for high values of λ, those contracts are around 21.1% and 36.8% of all OTC defaulting contracts.

Table 4: Change (Δ) and level of variables (Changes in relation to OTC levels)

Variables	Stat	Units	Scenarios			
			S0	S1	S2	S3
$\Delta\, q$	max	b.p.	+0.00	+0.00	+290.00	+758.00
$\Delta\, R$	max	p.p	+0.00	+0.00	+11.10	+20.80
$\Delta\,(\Delta\lambda)$	min	p.p	+0.00	+0.00	-3.96	-8.49
$\Delta\, m$	average	%	+0.00	+0.00	-9.49	-18.20
Δ Welfare	max	%	+0.00	+0.00	+0.50	+1.91
Fully insured contracts	share	%	+0.00	+0.00	21.10	36.80

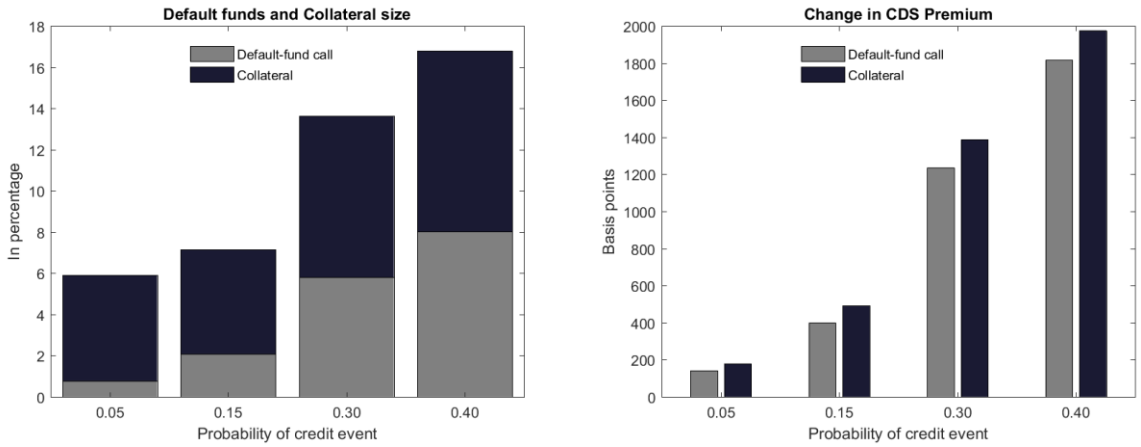
Note: Statistics are calculated on the range of E. Fully insured contracts are expressed in a share of all OTC defaulting contracts.

5.4 Size of the seller's default fund and collateral

In this section, the optimal sizes of default fund calls and collateral are compared to each other, which summarizes the analysis in the previous section. In order to make the comparison fair, the aforementioned sizes make the contracts either fully insured or non-defaulted; that can be shown by choosing a proper E for both cases above.

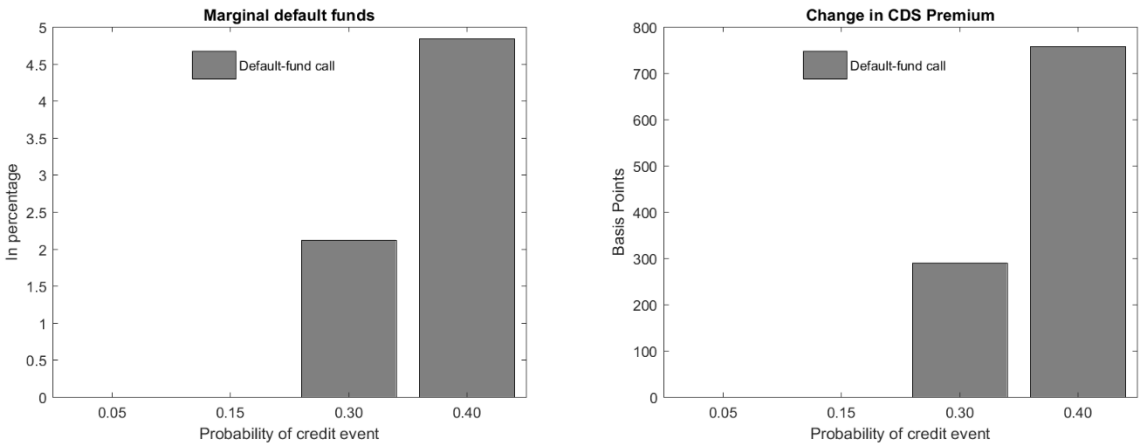
Figure (13) depicts the size of the calls to different probabilities of default λ. The amount of given resources is relative to the notional amount, i.e. fractions κ and φ_S. As the figure suggests, as the risk of defaulting increases, collateral size increases in more basic points in comparison to the default fund. Particularly, figure (13b) shows the impact in the CDS premium whether collateralization and mutualization practices are applied.

In the following figure (14), the size of the marginal-default fund and the change in the premium are shown. As explained previously, a corner solution arises for low values of λ. In the case of probabilities equal to 0.3 and 0.4, the size of the marginal call is 2.12% and 4.83% respectively. Those aforementioned sizes have a significant impact on the premium (see 14b); those changes are around 290 and 758 basis points.



(a) Size of default fund (b) Change in premium

Figure 13: Size of default fund and collateral and change in the CDS premium.



(a) Size of marginal-default fund (b) Change in premium

Figure 14: Size of marginal fund and change in the CDS premium.

6 Conclusions

Derivatives contracts have become a moot topic before and after the recent financial crisis. This paper sets up a quantitative exercise in order to show the effects of mutualization of losses and collateralization on CDS premiums. Acharya and Bisin [1]'s original model is modified to include a clearinghouse in the insurance market that observes the size of participants' positions and collects from them either default funds or collateral. The main finding of this paper is not only that clearing practices increase recovery rates—a decrease in the expected loss by the buyer of the contract—but also that risk premium decreases to some significative extent.

A collateral policy implemented by clearinghouse avoids default, premium is high and the value of the position (or recovery rate) increases. If deadweight losses pinned by the parameter E- are high, an *incentive* contract can be offered by the clearinghouse when collateralization takes place as clearing policy. The premium is higher for this practice relative to OTC agreements and there is no default in equilibrium. If deadweight losses or penalties are small, an *insurance* contract is offered by the clearinghouse when collateralization takes place as clearing policy.

This paper shows that the CDS premium is higher under mutualization at least when waterfall rules are designed to affect mainly sellers. The allocation is characterized by a higher recovery rate pulled by default fund calls. Marginal default funds calls do not decrease the premium either, and an unambiguous increase is given by the size of the probability of the credit event. The ratio R/q, a measure of counterparty risk, increases for contracts whose losses are mutualized in general. Fully insured contracts spread out significantly and the range of outcomes where buyers do receive fully insured contracts increases and the significance of the magnitude of the CDS premium's response hinges on the type of call

and the size of the probability of the credit event. The notional amount of insurance (*m*) declines significantly, and the welfare increases upwardly through levels of *E* up to the point where fully insured contracts are offered. However, welfare gains are not significantly large. The risk premium ($\Delta\lambda$) decreases as long as there are more resources under the clearinghouse management. This forces the premium to decrease. Thus, the extent of this fall in the premium is attributed to the size of resources collected by the clearinghouse. However, there is an increasing premium that is driven by the upward effect stemming from the increasing recovery rate.

Regarding specific results of the numerical exercise, the first exercise intends to measure the effect of the default fund calls as first line of defense in the waterfall rules. The CDS premium is higher when mutualization takes place as clearing policy in comparison to contracts traded in OTC markets. In the scenario S0, which is characterized by a low probability of a credit event (λ = 5%), the premium reaches a maximum of 150 basis points higher under clearing. As a benchmark, a numerical prediction based on Loon and Zhong [42]'s findings suggests an increase in the premium of around 170 basis points for low levels of λ. If the above probability is set to 15% (and it is accompanied by a slight increase in the importance of a seller's utility by the clearinghouse) the premium increases 401 basis points. The recovery rate increases by 17.3 percentage points (p.p.) at most, and fully insured contracts spread; the size of those fully insured contracts is 26% of all OTC defaulting contracts. The default fund call (ϕ^s) reaches at most 0.8% and the ratio *R/q* increases at most 0.43 p.p. The notional amount of insurance *(m)* declines significantly, and the welfare increases upwardly through levels of *E* up to the point where fully insured contracts are offered.

The second simulation exercises a scenario where clearinghouses call for additional funds according to the ordering established by the waterfall rules. In the scenarios S0 and S1, the optimal marginal default fund (ϕ^b) is equal to zero and the CDS premium does not change. However, for high values of λ, the exercise turns out to be more interesting. For instance, in scenario S3, where the probability of a credit event increases significantly (λ = 0.4), the CDS premium increases 758 basis points and the recovery rate increases 20.8 p.p. The size of the outcomes where buyers do receive fully insured contracts is around 36.8% of OTC defaulting contracts. The default fund call (ϕ^b) reaches at most 4.8% and the ratio *R/q* increases at most 0.178 p.p. As in all the previous scenarios, the notional amount of insurance drops and welfare is high for the range of *E* under analysis.

The results of this paper are similar to the empirical ones shown in Loon and Zhong [42], suggesting that clearing practices cause an increase in CDS that spreads through its impact on the value of the contract. The novel approach in this paper lays out a theoretical model that allows the parsing of other new and significant channels. Thus, this paper finds a force that pushes down the premium in an environment where fully insured contracts spread significantly; the model offers a channel where the risk premium is affected by clearing policies. This finding draws a parallel with Stephens and Thompson's [55] work, which shows that price competition is a necessary and sufficient condition for a low premium under mutualization of contracts with high counterparty risk. This paper, with an assumption of no

competition (random matches), shows that there is a channel where a component of the CDS premium declines. However, in the proposed setup, a different channel—via recovery rate—prevails and causes the premium ultimately to increase.

Regarding future research, in this paper collectable resources are no longer needed when $R + \phi = 1$, i.e. fully insured contracts. In a dynamic scenario, more resources would be necessary for trading in illiquid scenarios. If there are more resources in the current period, the premium may decrease. Also, it is possible to cause clearinghouses to actively participate by adding their own funds to performing mutualization; this would impact, to some interesting extent, the size of the risk premium, a key component of the premium as discussed in this paper.

Footnotes

[1]Recent mainstream discussion discourages the usage of large economic models. Instead, proper surveillance and a good understanding of how specific markets work in partial equilibrium would provide useful insights. For example, Smith [54] suggests that instead of focusing on consumption or other aggregates, economists might try to think more about the long-term buildup of problems in financial markets.

[2]For instance, juxtaposing monetary models by easing credit conditions, an ad-hoc regulation policy, may have an impact on the real interest rate even in the absence of any direct change in the federal funds rate.

[3]A theoretical model will certainly be helpful for appraising the next stream of reforms. Trump's plan to reduce financial regulations has been the subject of scathing debate and certainly still provides a spotlight for discussing the benefits of mutualization and collateralization versus other practices as capital requirements fostered by macroprudential policies especially in opacity markets.

[4]See Borensztein et al. [17] for details on the impact of natural disasters using a sovereign insurance model.

[5]The first clearinghouses can be traced to 18th century Japan (Schaede [52], Kroszner [39]). The evolution of their operation ranges from controlling quality to delivery, thus reducing risk and improving the channel of distribution.

[6]Since the crisis subsided, various initiatives have arisen to better contain and mitigate systemic risks (see IMF [32]). These are: i) preventive measures using higher liquidity and capital buffers, ii) containment measures such as better resolution frameworks under crises; and iii) improvements to financial infrastructure that provide firewalls to help prevent the knock-on effects of an institution's failure and a better standing for absorbing shocks.

[7]On the other hand, there is literature that questions the nature of clearinghouses. This side of the literature finds that clearinghouses can hastily impose inefficient outcomes in trading volume, collateralization levels (Koeppl and Monnet [38, 37, 36]), and other matters arising even from asymmetric information (Pirrong [49]). Moreover, IMF [32] includes that recommendations and contingency plans should also be coordinated to ensure that the failure of a clearinghouse does not lead to systemic financial disruptions.

[8]Recent criticism about aggregate models and their predictions leads researchers to turn to specific markets (see Blanchard [14, 13]). A rich model with exogenous shocks and consequent feedback from asset markets would give us better forecasting models and strong policy proposals. This has been a concern from the deeply worrisome dearth of ability to predict the last recession. For instance, Rajan [51] expressed concerns regarding CDS trading back in 2005. The author argues that changes in the financial sector had consequently altered incentives and risk, with potential for distortions.

[9]Most microstructures are related to futures markets (see Koeppl and Monnet [38]).

[10]See Thompson [57].

[11]This is related to the effects on the regulation of asset pricing. According to Yellen [60], the accommodation of liquidity being provided in response to financial crisis might itself generate new financial risks. Risk-taking can go too far and excessive short position can be generated under some unknown scenarios without cushions or buffers. It may be the case that low interest rates may induce investors to take on too much leverage and reach aggressively for yield. Early signs are credit and mortgage growth as well as assets price bubbles. This requires the construction of a framework that includes a financial sector with a determination of asset pricing.

[12]The reform and its impact are tracked by federal independent financial regulatory agencies such as The Fed, the Office of the Comptroller of the Currency (OCC), the Federal Deposit Insurance Corporation (FDIC), the Commodity Future Trading Commission (CFTC), the Securities and Exchange Commission (SEC), and the Consumer Financial Protection Bureau (CFPB). The treasury has an implicit supervisory role.

[13]The Basel III Leverage Ratio (Supplementary Leverage Ratio - SLR) is an important metric that introduces a credible supplementary material to the risk-based capital requirements in a simple and transparent understanding (see BIS [12]). According to CLARUS—a financial advisory company—this regulation will help with the implementation of public disclosure requirements, thus allowing for calibration/comparison and a smooth transition by banks prior to regulatory implementation in 2018/19.

[14]See Baily et al. [7] for a general assessment of the regulation-related steps still in progress.

[15]The literature encompasses what are called structural and reduced-form models. The former explicitly define a firm's value dynamics and some limited-commitment style compromise after the default of a reference entity or bond. In contrast, approaches using reduced-form models abstract from the valuation of a firm; thus, the default process is exogenous. According to Duffie and Lando [23] a fair equivalence among models may be established when firm asset value is imperfectly observed, although the reduced form is mostly preferred due to its tractability.

[16]The former represents the presence of adverse selection and credit rationing (see Stiglitz and Weiss [56] and Martin [43]).

[17]In addition, collateral also eases any limitation in contract enforceability (Cooley et al. [21]) and still remains in some cases a feasible alternative to monitoring project outcomes at sufficiently low cost (Townsend [58]).

[18]See for details Bester [10, 11], Besanko and Thakor [8, 9], Chan and Thakor [18], Boot et al. [16], Mas-Collel et al. [44].

[19]See Boot et al. [16], Boot and Thakor [15], Aghion and Bolton [2], and Holmstrom and Tirole [28].

[20]This assertion is also tested empirically by Du et al. [22]. The authors found statistically significant but small effects of counterparty credit spreads on premiums.

[21]See Leung and Kwok [41] for CDS pricing when buyers default with an exogenous hazard-rate environment.

[22]It follows the discussion regarding AIG.

[23]The functional form for the risk premium is a suitable guess supported by first order conditions.

[24]In the setup of the model an initial margin of 100% is assumed; in other words, the seller faces any liability with their own money.

[25]Although the literature—in the case of collateralization—suggests that the margin must be dubbed "maintenance", in this paper, due to the characteristics of the model, the terms are interchangeable to some extent.

[26]Hull and White [30] assume that there is no systematic risk, so those are expected rates in the risk-neutral sense. Thus, the foregoing allows the expected recovery rate to be estimated from historical data.

[27]Regarding this, let's assume that each CDS seller compromises in a two-period investment that pays θ, which is uniformly distributed with a mean equal to $\bar{\theta}$. The underlying assumption hinges on that the clearinghouse implements marginal calls (φ) on each individual i when seller defaults. Thus, the participation constraint for each individual (i) is as follows:

$$\alpha q(R)m(R) + \theta(i) - \lambda\phi(i) \geq c$$

By aggregating over all individuals and then subtracting previous restrictions, I have the following result $\phi(i) = \frac{\theta(i)-\bar{\theta}}{\lambda}$. Finally, the participation constraint is:

$$\alpha q(R)m(R) + \bar{\theta} \geq c \tag{4}$$

[28]In order to calculate the total welfare, the expression in program P1 must be multiplied by $N(1-\lambda)^{-2}$.

[29]For the sake of simplicity it is assumed that the clearinghouse contribution is zero; thus, the marginal is applied according to the waterfall tranche ordering and rules (see IMF [32], Exchange [27], LCHCLEARNET [40]).

[30]According to Fitch data reported in Kenny [34] the high-yield bond default rate is around 4.7%, as the last figure for 2017. S&P rating services (see Vazza [59]) reported 3.9% of default rate in 2016 and also calculated a pessimistic scenario of 5.2% for 2017. Although the default rate is historically low, there are vulnerable companies that are more likely to slide into default. Usually those companies' operational fields are commodity related, such as oil, gas and steel mining. Furthermore, Moodys [46] shows that the global speculative-grade default rate declined quickly immediately after the Great Recession; thus, sectors such as banking, non-bank finance, transportation and utilities had default rates of less of 1%. The sectors with the highest rates were media and retail, with 3.6% and 3.3% respectively.

[31]Amato [3] reckons a CDS spread equivalent to the expected loss times a risk adjustment which provides a definition of price of default risk, a.k.a. a risk aversion measure. The aforementioned is equivalent to the expression $\frac{\Delta\lambda}{\lambda};$; thus, assuming a value of 1.42 (average value reported in Amato [3]) and a leverage of 1.4 (ratio of exposure to equity), the parameter γ is equal to 0.7.

[32]The netting of positions in the model presented in the previous section reduces the cost of posting collateral and it is measured by the parameter *v*.

[33]The seller's contracts are always under default for the range of *E* under analysis.

[34]See table 2, panel A and the following analysis in section 5.1 of Loon and Zhong [42]'s paper. The authors test the significance of the above result by using the distribution of regression coefficients and controlling by spread percentage change of North American Investment Grade CDS index as a proxy for market risk. The regressions are made for each reference entity.

[35]See table 5 and analysis in section 5.4 of Loon and Zhong [42]'s paper.

[36]Loon and Zhong [42] consider the CDS spread of CDS dealers as a proxy of default risk premium, whereas Hull and White [31] estimate that an improvement of that magnitude (60 b.p.) is equivalent to reaching a rating of AAA from A for the dealer, here the CDS seller. In order to connect the default risk premium of a bond (issued by the seller) to the recovery rate of the CDS contract, the expression (4) in Hull and White [30] is taken into account and the following assumptions are made for sake of simplicity only: i) the bond can only default at maturity, ii) the claim of the bond is equal to the value of any forward contract and iii) since the seller has defaulted on CDS contracts, due to a low *E*, then it is assumed that the seller defaults on the bond as well, thus the probability of bond default is equal to one. Thus, a reduction of the seller's default risk premium is equal to an increase in the recovery rate of the defaulted bond. Finally, it is assumed that the dealer has the same recovery rates for all short assets including CDS contracts.

References

[1] Acharya, V. and Bisin, A. (2014). Counterparty risk externality: Centralized versus over-the-counter markets. *Journal of Economic Theory*, 149:153–182.

[2] Aghion, P. and Bolton, P. (1997). A theory of trickle-down growth and development. *The Review of Economic Studies*, 64-2:151–172.

[3] Amato, J. (2005). Risk aversion and risk premia in the CDS market. *BIS Quarterly Review, December 2005*.

[4] Annaert, J., Ceuster, M. D., Roy, P. V., and Vespro, C. (2010). What determines Euro area bank CDS spreads? *National Bank of Belgium, Working Paper Research*, 190.

[5] Arakelyan, A. and Serrano, P. (2016). Liquidity in credit default swap markets. *Journal of Multinational Financial Management*, 37-38:139–157.

[6] Augustin, P., Subrahmanyam, M. G., Tang, D. Y., and Wang, S. Q. (2016). Credit default swaps: Past, present, and future. *The Annual Review of Financial Economics*, 8:10.1–10.22.

[7] Baily, M. N., Klein, A., and Schardin, J. (January 2017). The impact of the Dodd-Frank act on financial stability and economic growth. *The Russell Sage Foundation Journal of the Social Sciences*.

[8] Besanko, D. and Thakor, A. (1987a). Collateral and rationing: Sorting equilibria in monopolistic and competitive credit markets. *International Economic Review*, 28-3:671–689.

[9] Besanko, D. and Thakor, A. (1987b). Competitive equilibrium in the credit market under asymmetric information. *Journal of Economic Theory*, 42:167–182.

[10] Bester, H. (1985). Screening vs. rationing in credit markets with imperfect information. *American Economic Review*, 25-4:21–42.

[11] Bester, H. (1987). The role of collateral in credit markets with imperfect information. *European Economic Review*, 31-4:887–899.

[12] BIS (April 2016). Revisions to the Basel III leverage ratio framework. *BIS (Bank for International Settlements) Consultative Document*.

[13] Blanchard, O. (January 12, 2017). Article: The need for different classes of macroeconomic models. *Peterson Institute for International Economics*.

[14] Blanchard, O. (October 3, 2016). Article: Further thoughts on DSGE models. *Peterson Institute for International Economics*.

[15] Boot, A. and Thakor, A. (1994). Moral hazard and secured lending in an infinitely repeated credit market game. *International Economic Review*, 35-4:899–920.

[16] Boot, A., Thakor, A., and Udell, G. (1991). Secured lending and default risk: Equilibrium analysis, policy implications and empirical results. *The Economic Journal*, 101-406:458–472.

[17] Borensztein, E., Cavallo, E., and Jeanne, O. (2017). The welfare gains from macro-insurance against natural disasters. *Journal of Development Economics*, 124:142–156.

[18] Chan, Y.-S. and Thakor, A. V. (1987). Collateral and competitive equilibria with moral hazard and private information. *The Journal of Finance*, 42-2:345–363.

[19] Chiaramonte, L. and Casu, B. (2012). The determinants of bank CDS spreads: Evidence from the financial crisis. *The European Journal of Finance*, 19(9):861–887.

[20] Collin-Dufresne, P., Goldstein, R., and Hugonnier, J. (2002). A general formula for pricing defaultable securities. *Econometrica*, 72:1377–1407.

[21] Cooley, T., Marimon, R., and Quadrini, V. (2004). Aggregate consequences of limited contract enforceability. *Journal of Political Economy*, 112:817–847.

[22] Du, W., Gadgil, S., Gordy, M. B., and Vega, C. (2016). Counterparty risk and counterparty choice in the credit default swap market. *Finance and Economics Discussion Series - Board of Governors of the Federal Reserve System*, 087.

[23] Duffie, D. and Lando, D. (2001). Term structures of credit spreads. *The Annals of Applied Probability with Incomplete Accounting Information*, 69:633–664.

[24] Duffie, D., Schroder, M., and Skidas, C. (1996). Recursive valuation of defaultable securities and the timing of resolution of uncertainty. *The Annals of Applied Probability*, 6:1075–1090.

[25] Duffie, D. and Singleton, K. J. (1999). Modeling term structures of defaultable bonds. *The Review of Financial Studies*, 12:687–720.

[26] Duffie, D. and Zhu, H. (2011). Does a central clearing counterparty reduce counterparty risk? *The Review of Asset Pricing Studies,* 1(1):74-95.

[27] Chicago Mercantile Exchange (2017). Chapter 8-H. Credit default swaps clearing. *CME Rulebook*.

[28] Holmstrom, B. and Tirole, J. (1997). Financial intermediation, loanable funds, and the real sector. *The Quarterly Journal of Economics*, 112-3:663–691.

[29] Huang, W. (2019). Central counterparty capitalization and misaligned incentives. *Bank for International Settlements Working Paper Series*, 767.

[30] Hull, J. and White, A. (2000a). Valuing credit default swaps I: No counterparty default risk. *NYU Stern School of Business Finance Department Working Paper Series*, 21.

[31] Hull, J. and White, A. (2000b). Valuing credit default swaps II: Modeling default correlations. *NYU Stern School of Business Finance Department Working Paper Series*, 22.

[32] IMF (2010). Meeting new challenges to stability and building a safer system. *Global Financial Report, International Monetary Fund (IMF)*, April 2010.

[33] Jarrow, R. and Yu, F. (2001). Counterparty risk and the pricing of defaultable securities. *Journal of Finance*, 56:1765–1799.

[34] Kenny, E. (2005). Relative default rates on corporate loans and bonds . *Journal of Banking & Finance* 29(6):1575-1584.

[35] Koeppl, T. (2013). The limits of counterparty clearing: Collusive moral hazard and market liquidity. *Queen's Economics Department Working Paper*, 1312.

[36] Koeppl, T. and Monnet, C. (2009a). Central counterparties. *Queen's Economics Department Working Paper, unpublished*.

[37] Koeppl, T. and Monnet, C. (2009b). Collateral policies for central counterparties. *Queen's Economics Department Working Paper, unpublished*, 24:3–30.

[38] Koeppl, T. and Monnet, C. (2010). The emergence and future of central counterparties. *Queen's Economics Department Working Paper,* 1241, 24:3–30.

[39] Kroszner, R. S. (1999). Can the financial markets privately regulate risk? The development of derivatives clearinghouses and recent over-the-counter innovations. *Journal of Money, Credit and Banking*, 31:596–618.

[40] LCHCLEARNET (2014). LCHCLEARNET limited default rules. *LCHCLEARNET*, June 2014.

[41] Leung, S. Y. and Kwok, Y. K. (2005). Credit default swap valuation with counterparty risk. *The Kyoto Economic Review*, 74(1):25–45.

[42] Loon, Y. C., and Zhong, Z. K. (2014). The impact of central clearing on counterparty risk, liquidity, and trading: Evidence from the credit default swap market. *Journal of Financial Economics*, 112(1), 91-115.

[43] Martin, A. (2009). A model of collateral, investment and adverse selection. *Journal of Economic Theory*, 144:1572–1588.

[44] Mas-Collel, A., Whinston, M. D., and Green, J. R. (1995). *Microeconomic Theory*. 1995. Oxford University Press Inc.

[45] Monnet, C. and Nellen, T. (2014). The collateral costs of clearing. *SNB Working Papers*, 4.

[46] Moodys (2011). Corporate default and recovery rates, 1920-2010. *Special Report, Moodys Investors Service.*

[47] Arora, N., Gandhi, P., and Longstaff, F. A. (2012). Counterparty credit risk and the credit default swap market. *Journal of Financial Economics*, 103(2), 280-293.

[48] Pirrong, C. (2008). Clearing misconceptions on clearing. *Regulation.*

[49] Pirrong, C. (2009). The economics of clearing in derivative markets: netting, asymmetric information, and the sharing of default risks through a central counterparty. *Working paper.*

[50] Pirrong, C. (2011). The economics of central clearing: Theory and practice. *ISDA Discussion Paper Series.*

[51] Rajan, R. G. (2005). Has financial development made the world riskier? *NBER Working paper.*

[52] Schaede, U. (1989). Forwards and futures in Tokugawa-period Japan: A new perspective on the Dōjima rice market. *Journal Of Banking & Finance*, *13*(4-5), 487-513.

[53] Shan, S. C., Tang, D. Y., and Yan, H. (2014). Did CDS make banks riskier? The effects of credit default swaps on bank capital and lending. *Working paper.*

[54] Smith, N. (2017). *When economics failed*. Bloomberg. https://www.bloomberg.com/view/articles/2017-04-04/when-economics-failed

[55] Stephens, E. and Thompson, J. R. (2011). CDS as insurance: Leaky lifeboats in stormy seas. *Working paper.*

[56] Stiglitz, J. E. and Weiss, A. (1981). Credit rationing in markets with imperfect information. *The American Economic Review*, 71-3:393–410.

[57] Thompson, J. (2010). Counterparty risk in financial contracts: Should the insured worry about the insurer? *Quarterly Journal of Economics*, 125(3):1195–1252.

[58] Townsend, R. (1979). Optimal contracts and competitive markets with costly state verification. *Journal of Economics*, 21:1–29.

[59] Vazza, D. (2016). CNBC interview.

[60] Yellen, J. L. Many targets, many instruments: Where do we stand? In George A. Akerlof, Olivier Blanchard, D. R. and Stiglitz, J. E., editors, *What Have We Learned?* MITPress e-book.