ESSAYS ON THE EFFECT OF CLEARING PRACTICES ON SWAP RATES

BY

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ABSTRACT OF THE DISSERTATION

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This dissertation contributes to understand the interplay between price of derivatives and clearinghouses; the following chapters intend to overcome especific gaps in the literature since the effect of clearing practices is still not well understood in literature.

In the first chapter I study the relationship between the price of derivatives and clearing practices in a theoretical framework. Specifically, I setup this connection by measuring the total exposure (*the loss upon default of a contract*) registered in a clearinghouse and its respective amount of collateral requirement. I find that netting through novation has significant gains in reducing exposures and therefore making a clearinghouse more competitive in terms of prices and collateral requirements thus clearing turns out to be appealing to more participants. Additionally, I also find above gains are large when comparing a financial structure of one clearinghouse respect to other with two specialized clearinghouses. In the case of interest rate swaps I find a relationship between netting and the Libor rate that may potentially affect the difference in prices among clearinghouses; in other words, a linear correlation calculated over time-series data and term structure seems to validate the appearance of a widening basis -*a price differential*- between London Clearing House and Chicago Mercantile Exchange.

In the second chapter I show statistical evidence of a negative and significant impact of clearing practices on price of derivatives. This empirical finding supports the theoretical model discussed in Cama [26] which provides a method for swap valuation that hinges on the size of the exposure in a clearing arrangement; the foregoing is particularly clear when the clearing practices strengthen. In practice, hedging exposures and performing risk management (through collateralization) introduce multilateral netting, compression and other clearing procedures. These practices eventually would affect the price of contracts making possible the observation of a significant wedge in the pricing of derivatives amid markets. I consider the cases of interest rate and credit default swaps for the quantitative assessment. I found that the basis (*difference of swap rates between clearinghouses*) has a higher persistence and its variance may be large when market participation increases, the former -as discussed in the chapter- is a sign of eventual deepening clearing practices. The regression analysis supports previous findings and show that bias is not significant larger when variables measuring additional characteristics of contracts are omitted due to access-to-data issues.

In the third chapter I investigate the effects of collateralization and mutualization on credit default swaps (CDS) premium in a context of high counterparty risk operating through an opaque derivatives market. Literature mostly analyzes clearing in exchange markets and assumes that terms of trade are invariant to policies. My approach certainly makes clearing practices to affect the size of positions, recovery rate and premium. I study the interplay between clearing practices and pricing of the asset in a theoretical framework that allows excessive leverage of short positions. This environment not only has the benefit of being realist to the light of causes and propagation of great recession but also to assess clearing practices in a partial equilibrium. I closely follow contributions of Koeppl and Monnet [71], Koeppl [68], Acharya and Bisin [1] and Stephens and Thompson [99]. I show the premium is low when mutualization takes place as clearing policy; specially when capital requirement ratio is substantially manageable. The allocation is characterized by high recovery rate and non-defaulting contracts spread significantly relative to a bilateral agreement. On the other hand, as literature suggests collateral avoids detrimental outcomes; premium is higher under collateralization practices since the value of the position (or recovery rate) increases. Existent empirical literature finds mixed results after controlling for liquidity and dealer networking. This chapter provides answers to this oxymoron. This research contributes to compress the asset pricing theory into a material that would be critical as input in large macroeconomic models.

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Dedication

This thesis is dedicated to my son Santiago Andrés whose smile and energy have always been a constant source of support, encouragement, and inspiration during the challenges of my whole college life.

This work is also dedicated to my parents, Betty and Felipe, and my wife Marola who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve. I also acknowledge to my brothers Luis, Daniel and Miguel whom I am truly grateful for having in my life.

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I also dedicate this thesis to the memory of my grandparents Juana, Germán, Felipe and Graciela, who always are in my heart.

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Chapter 1

The Impact of Collateralization on Swap Rates Under Clearing

1.1 Introduction

This chapter contributes to understand the interplay between price of derivatives and clearinghouses, relationship that is still not well understood in literature. In the light of the recent financial crisis and its aftermath, clearing of derivatives has become central to the modern financial system. In practice, netting of positions and other clearing procedures question the standard practice of valuation usually affected by hedging and collateralization. Particularly, I explain in a simple theoretical framework how much the swap rate is affected by clearing practices. I thoroughly examine two type of swaps contracts: interest-rate and credit default swaps.

The traditional approach for the valuation of swaps[1] uses information about the current market conditions such as liquidity, supply-demand factors, and spreads between short-term repo rates. More important, latest literature includes the effect of the default risk of multiple counter-parties on these contracts (see Leung and Kwok [77], Johannes and Sundaresan [64] and Duffie and Zhou [50]); it is mostly accepted that credit worthiness of counter-parties significantly affects the fair-market swap rates. Literature seems to deliver a good understanding of the association between the swap rates and its most pertinent underlying factors. However, other factors that are more related to the structure of the financial market remain a pending subject in the literature of swap valuation; financial regulation and their effects on asset pricing are hardly formalized in the literature. As a

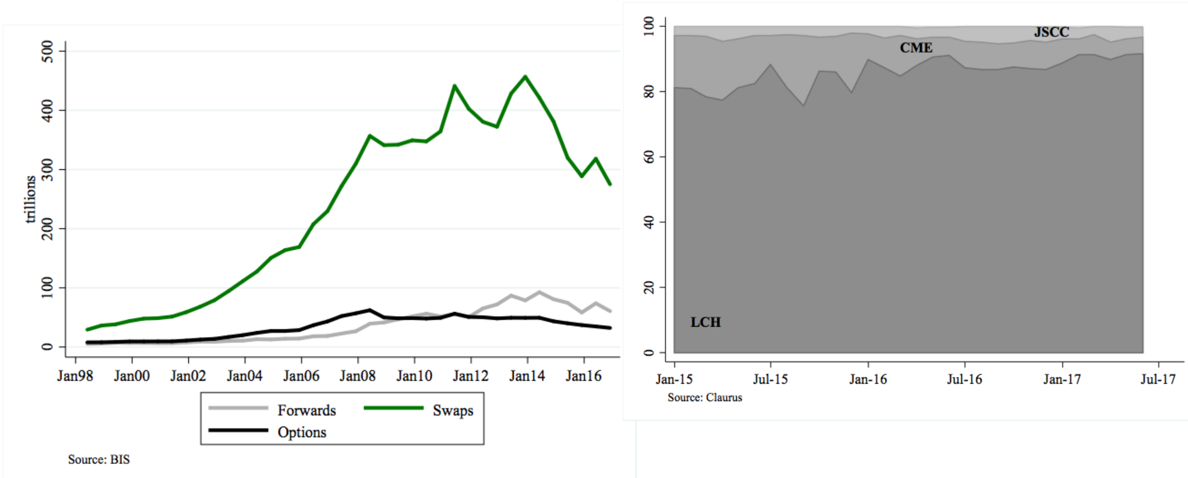
[1] A swap -that is a class of derivative- is a contract between parties whose value is based on an underlying financial asset, index, or security. Source: Investopedia.

consequence, in the light of the recent financial crisis and its aftermath, dynamics of swaps spreads have recently received particular attention not actually being observed since the end of nineties[2]. The Dodd-Frank Act, a key piece of financial reform legislation passed by Obama administration in 2010, opens up to the discussion regarding the effect of clearing practices on price of trading derivatives; clearing is becoming an interesting proposal inside the recent regulatory framework. However, the link between price and clearing practice is still not well understood. This chapter intends to fill out this gap in the literature.

Interest rate and credit default swaps are contingent claims that are massively traded in clearinghouses. An interest rate swap (IRS) is a derivative contract through which two parties exchange fixed and floating rate coupon payments; usually literature presents the structure of swaps as simply affected by not only credit worthiness but LIBOR rate and spreads over repo (see He [56]). On the other hand, a credit default swap (CDS) is another derivative contract whereby the buyer seeks protection from the loss arising from a credit event. In exchange, the seller (typically a financial institution) absorbs the risk of arranging the conditional payment once the credit event occurs. IRS and CDS have the lion's share of derivatives market. In the year 2016, according to Bank of International Settlement (BIS), the market for interest rate swaps reached the notional[3] value of 275 US trillion dollars, while 10 US trillion dollars of credit default swaps were negotiated in the same year (see figure 1.1a). Thus, these two assets comprise around 90% of the total market value of derivatives. The most important clearinghouses are Chicago Mercantile Exchange (CME) and London Clearing House (LCH); their trading-volumes shares in 2016 reached to 10 and 82 percent respectively (see figure 1.1b). Recent analysis of empirical data from clearinghouses show noticeable spikes or persistent unusual behavior of the trading swap rate that raise questions regarding the dynamics of the price determinants of these financial instruments. Specifically, the basis -that shows difference of swap rates traded at two clearinghouses- should not theoretically show a significant wide size since the instrument and its related characteristics as maturity and risk are the same.

[2]Around those years, noticeable volatility over these contingent claims contributed to the financial turmoil that led the US Federal Reserve to modify the path of interest rates (see He [56]).

[3]In swaps, interest payments are computed based on a notional amount, which acts as if it were the principal amount of a bond, hence the term notional principal amount, abbreviated to notional.



(a) Outstanding market value

(b) Clearing participation

Figure 1.1: Swaps Clearing Market

In the following lines I define the role of the clearinghouse. The clearinghouse does the settlement of any contract when novation takes place. Novation is the inherent feature of the clearing process: the clearinghouse is the seller for any buyer and the buyer for any seller. Also, the clearinghouse establishes initial and variation margins or collateral on contracts as well as collects default funds for mutualizing losses among market participants. The two most common forms of collateral are cash and treasuries bonds since they are default-free, they can easily be invested or loaned out[4] (Johannes and Sundaresan [64]; ISDA [60]). Since posting collateral is generally costly, these payments induce economic costs (benefits) to the payer (receiver). More significantly, the clearinghouse offsets positions among participants by performing compression and multilateral netting; precisely I study in this chapter the effects on swap rates of performing netting among all positions hold by participants in the clearinghouse. The result of offsetting positions is called exposure which needs to be hedged by imposing collateral. Thus, the swap rate can be expressed as a function of the exposure ultimately.

I explain in the next lines the relevance of studying the price determination of derivatives in clearinghouses beyond the standard price discovery[5]. The Dodd-Frank Act is the current

[4]The most popular form of collateral is cash. In 2005 ISDA indicated that US dollars and euros cash accounted for 73% of collateral assets.

[5]The pricing of the swap or price discovery is a method of determining the price for a specific commodity

regulation framework for trading financial instruments and constitutes the most comprehensive set of mandatory limits, exceptions and rules made by US government since great depression[6]. The magnitude of the last financial crisis made the previous administration to react properly by proposing a regulation framework for the financial system. However, a potentially mandatory regulation of derivatives poses a new mechanism to take into account that would potentially affect price of derivatives; clearinghouses through novation is able to see positions of participants and reduce significantly requirement of collateral by applying multilateral netting over class of assets. The impact on prices can be significant and financially beneficial in comparison to other proposals that relies on rising higher capital requirements as macro-prudential policies suggest nowadays[7] or other that may inherently be associated to spillovers such as agency problems (see Chami et al. [31][8]). Change in swap prices are generally associated to variations in the implicit risk as standard theory predicts, but under an effective clearing practice i.e. netting, the determination of swap prices needs a different and suitable framework to analyze.

The contribution of this chapter in policy terms is as follows. First, trading in a clearinghouse could make prices of derivatives competitive enough in comparison to bilateral agreements or other specialized framework, for instance, the ones supporting more than one clearinghouse. Moreover, other clearing practices as mutualization of losses among participants may reduce further the costs of default. Second, price arbitrage -in a financial structure that allows multiple clearinghouses- would produce shifts in the direction of the demand for a particular class of assets among clearinghouses. Whether the price depends of the effort of reducing the overall exposure, then a clearinghouse that treats risk properly

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or security through basic supply and demand factors related to the market.

[6]The preliminary "Glass-Steagall Act" was passed by the United States Congress on February 27, 1932, prior to the inclusion of more comprehensive measures in the Banking Act of 1933, which is now more commonly known as the Glass-Steagall Act. Source: Wikipedia.

[7]See Tobias [102] for a quick refresh of macro-prudential policies and challenges. On the other hand, Jihad Dagher and Tong [63] assess the benefits of bank capital in terms of resilience; authors found that a high capital requirement around 15-23 percent of risk-weighted assets would have been sufficient to absorb losses in the majority of past banking crises. The basel rules and further details of extension III can be found in BIS [17], BIS [15] and BIS [16]. Other initiative is The U.S. House of Representatives passed the Financial CHOICE Act (FCA), it was put forward in 2016 by the House Financial Services Committee, and it comprises key elements of the original DFA, leaving certain other DFA elements out. According to Chami et al. [31], a key argument is the introduction of a regulatory "off-ramp", thus providing a relief in demanding capital requirements for so-called "qualifying bank holding companies".

[8]Even clearing -via mutualization of losses among participants- does not circumvent the usual problem of commons associated to public goods, see Stephens and Thompson [99] and Cama [25] for a discussion.

would be efficient. A clear evidence of the former is the behavior of the basis; two swap contracts may have exactly the same features and they will probably be priced differently due to different costs of funding in general. Finally, in this setup, price depends on the regulatory policy; this relationship may affect the decisions of agents in participating in clearinghouses.

The chapter is organized as follows. The following section presents the literature related to valuation of swaps and the progress made so far by including counter-party risk in the valuation models. The third section in this chapter explain the steps for achieving an analytical expression for the interest rate and credit default swap as a function of the exposure under a clearing arrangement; I also make a comparison of this exposure with bilateral agreements that currently are negotiated in over-the-counter markets. The following fourth section explains how to calculate the exposure using data, I further explain the respective assumptions behind the formulas. The fifth section explains the quantitative exercise in order to provide insights regarding what drives the difference of swap rates between clearinghouses. The calibration of parameters in the exercises is thoroughly explained and discussed; the baseline values are mostly taken from recent literature. The last section gathers the conclusion of this research and provide further questions to pursuing in a future research.

1.2 Literature review

An extensive literature has developed that studies price determination for derivative contracts. In the case of the credit default swaps, Leung and Kwok [77] and Jarrow and Yu [62] analyze the effects of a change in the joint probability of default on spreads (prior to maturity). Duffie and Singleton [45, 46] developed a methodology that derives reduced-form models of the valuation of contingent claims subject to risk; more interesting, this chapter introduces the effect of different recovery rates on swap valuation. In a different approximation Acharya and Bisin [1] show -using a theoretical model- the effect of releasing information on CDS premium; this analysis would be equivalent to the effect of a explicit clearing method -or transparency of positions- on price of derivatives. On the same approach, Stephens and Thompson [99] study price competition with different type of insurers and show that mutualization may increase counterparty risk as responsible insurers leave the market. Other contribution for price determination is found in Koeppl [68]; in order to extracting benefits the seller of contracts will rise prices under a clearing mechanism that not involves fulfillment of promises.

Collateral requirement is the cornerstone in the lender-borrower literature. Johannes and Sundaresan [64] study the use of marking-to-market (MTM) and collateralization on swap rates as they modify the flow of cash in the contract whereas risk of default rises. Johannes and Sundaresan [64] derives an analytical expression where MTM and time-varying net costly collateral alter the discount factor. The authors discusses limitations in evaluating the importance of collateral. Precisely, comparing market swap rates with a par representation -constructed from LIBOR bond prices- would be misleading since the par representation needs the market swap rates. Finally, Johannes and Sundaresan [64] setup a zero-coupon structure made from eurodollar futures, a strategy that does not require assumption regarding collateralization and counter-party credit risk. On other hand, Duffie et al. [49] show, using pre-reform exposure data set, that demand of collateral is increased significantly by the application of initial margin requirements even if CDS are cleared or not. Most importantly, Duffie et al. [49] state that mandatory central clearing is shown to lower collateral demand only when there is no significant proliferation of clearinghouses. Duffie et al. [49]'s work is closely related to Heller and Vause [57], Sidanius and Zikes [97] and Johannes and Sundaresan [64] that simulate exposure data. I extend their work establishing a measurable and theoretical relationship between exposure, collateral needs and swap rates.

The clearinghouses can potentially reduce the size of the exposures through netting when novation is performed. Specifically, Duffie and Zhu [47] and Cont and Kokholm [40] show the tradeoff between multilateral and bilateral netting when a particular asset from individual portfolio is moved to central clearing reducing the net exposure calculated among trading partners and assets. Duffie and Zhu [47] assume normality and no particular correlation between assets when clearing, the foregoing assumption is relaxed by Cont and Kokholm [40] as showing that number of optimal participants for reduction of the exposure is significant low. Also Cont and Kokholm [40] shows that different methods do deliver different sizes of the credit exposure; however take into account a particular distribution seem to be irrelevant when comparing results against a gaussian distribution. Other important result in Cont and Kokholm [40] shows the exposure shrinks significantly for cleared interest-rate swap contracts.

The empirical treatment of identifying the determinants of swap spreads is mostly standard and relies on term structure models. For instance, He [56] uses a multi-factor term structure framework assuming swaps are default-free and show that this structure is driven by market expectations, risk premium and liquidity differentials. Johannes and Sundaresan [64] model the short rate using a ad-hoc two-factor model from Collin-Dufresne and Solnik [38]; previously this author used calibration of models[9] to compute hypothetical swap rates assuming swaps are priced as a portfolio of forwards or futures. Thus, any difference between actual swaps would be attributed to collateral or margin strategies.

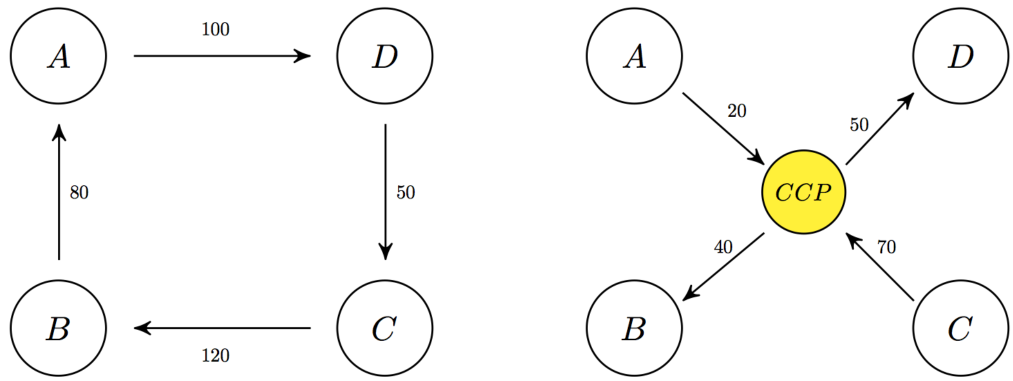
1.3 A model of swap determination under clearing

In this section I determine the swap rate for the exchange of flows between counter-parties i.e. interest rate swap contract, and for the insurance contract signed among participants in the credit default swap market. In each contract, by using novation, the clearinghouse nets positions and calculates the size of collateral required to hedge them. The first two subsections deal with the determination of the swap rate as a function of the size of the exposure under clearing. The last section constructs the size of the exposure following the method developed in Duffie and Zhu [47] and Cont and Kokholm [40].

The process of netting exposures in central clearing of OTC trades can lead to a decrease in the sum of total bilateral exposures. For instance, as shown in Cont and Kokholm [40], consider a market of four participants (A,B...) with bilateral exposures like shown in the left panel of figure (1.2). In this market the swelling of bilateral exposures amounts to 350.

[9] Authors use some ad-hoc adjustments following the treatment in Vasicek [105] and John Cox and Ross [65] as well as calibration procedures made in Hull and White [59].

Introducing a clearinghouse (or CCP) enables netting of the exposures across all participants which reduces the total net exposure to 180.



(a) Bilateral exposure

(b) Centralization

Figure 1.2: How clearing works (Cont and Kokholm [40])

The arrows above represent the positive or negative (net bilateral) position of the contract among participants; the direction of the arrow may be read as *"... has an exposure to..."* and amount above them indicates the size of the exposure. The above representation of a trading market highlights the benefits of multilateral netting through a clearinghouse; positions are offset among participants since clearinghouse centralizes them in any direction. However, there are also situations where central clearing of a single asset class may actually increase overall net exposures. For instance, Duffie and Zhu [47] and Cont and Kokholm [40] show that multilateral clearing may actually increase the size of exposure when number of participants are fewer enough. Besides, given a fixed number of participants, the size of exposure -according to Cont and Kokholm [40]- would be highly sensitive to the assumptions of correlation and distribution amid asset classes. In other words, performing novation is not a guarantee of an effective reduction of the exposure.

1.3.1 Determination of the interest-rate swap rate

In this section I follow the theory behind the determination of the interest rate swap rate as shown in McDonald [83] and Johannes and Sundaresan [64]. Specifically, I provide a swap valuation theory under marked-to-market[10] and costly collateral and examine the theory's empirical implications. A interest rate swap (henceforth swap) is a contract calling for an exchange of payments over time. Specifically, companies use swaps to modify their interest rate exposures. Thus, the swap makes payments -under contract- as if there were an exchange of payments between a fixed-rate and a floating-rate bond. For instance, a fund manager might own floating-rate bonds and wish to have fixed-rate exposure while continuing to own the bonds. Thus, investors may change the structure of payment flows and hedge risk whether their balance sheet face uncertainty or just they engage into this asset market due to just merely speculative reasons. A swap generally has less credit risk than the bond in reference since only net swap payments are at risk whereas the principal is not. Figure (1.3) illustrates the cash flows for a company that borrows at LIBOR and swaps to fixed-rate. If one party defaults, it owes to the other party at most the present value of net swap payments at current prices.

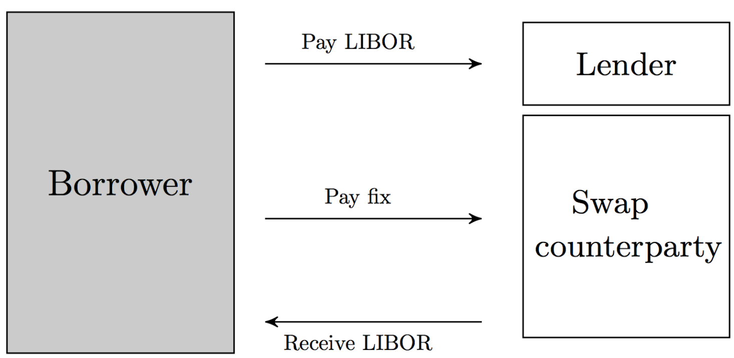


Figure 1.3: Cash flows for company swapping rates (McDonald [83])

Hedging counter-party risk makes the market value of the swap an important variable under consideration. At inception of the swap the market value is zero, meaning that either party could enter or exit the swap without having to pay anything to the other party. Once the flows are effectively interchanged, however, its market value will generally no longer be zero. McDonald [83] mentions at least two reasons for the foregoing: first, forward and zero-coupon bonds rates change over time, and second, once the first payment is made there

[10]Mark to market is a measure of the fair value of accounts that can change over time, such as assets and liabilities. This measure aims to provide a realistic appraisal of an institution current financial situation. Source: investopedia.

would be a difference of new swaps relative to the forward rate; hence, in order to exit the swap this counter-party needs to be either compensated or affected by a convenient fee (see McDonald [83] for details).

Swap rate with no collateralization

I thoroughly examine the calculation of the swap rate under regular conditions i.e. no collateralization. I assume T swap settlements occurring on dates t_i, $i = 1, ..., T$. The floating interest rate from date t_{i-1} to date t_i known at date 0 is $r_0(t_{i-1}, t_i)$ and the swap rate is denoted by s^w. The price of a zero-coupon bond maturing on date t_i is $P(0, t_i)$. Following McDonald [83], the requirement that the swap have a zero net present value (V_0) is:

$$\sum_{i=1}^{T} P(0, t_i)[s^w - r_0(t_{i-1}, t_i)] = V_0 \equiv 0$$

Above expression can be rewritten for an easy interpretation (see expression (1.1)); this preliminary result will help later to construct a swap rate that incorporates collateralization under clearing as a consequence of counter-party risk.

$$s^w = \sum_{i=1}^{T} \left[\frac{P(0, t_i)}{\sum_{j=1}^{n} P(0, t_j)} \right] r_0(t_{i-1}, t_i) \tag{1.1}$$

The only risk in this transaction is associated to the uncertainty of the floating rate; this risk is hedged by entering into a forward rate agreement. This is a result of netting the payment on forward and an unhedged net swap payment (see details in McDonald [83]).

The above expression in square brackets sum to one. Thus, for sake of understanding, the meaning of this expression can be expressed differently; the (fixed) swap rate is a weighted average of the implied forward rates where zero-coupon bond prices are used to determine the weights. An alternative and popular expression can be derived using the fact that the implicit forward rate can be calculated from bond prices, see McDonald [83] for details.

Swap rate with collateralization

The trading of swaps or options in the over-the-counter (OTC) market can create counter-party credit exposures; the party that was "in-the-money" would have to replace the deal at current market prices. Thus, the positive MTM value is a credit exposure. One way to reduce the credit risk is to use a break clause i.e. replacement of the whole contract and a final payment must be made each period, and then the parties can enter a new contract the following period. However, there exist the option of collateral management. Basically, collateralization involves the delivery of the collateral from the party with the negative MTM on the trade portfolio to the party with the positive MTM. As prices move and new deals are added up, the change in the valuation of the trade portfolio ensues.[11]

First, I start with a motivation by using a discrete-time model based on Duffie and Singleton [46] and Johannes and Sundaresan [64] and then I formally extend the model to continuous-time including costly collateral. I defined the contract from the side of the counter-party that holds the fixed-rate leg and I assume that counter-party who holds the floating-rate leg is potentially subject to defaulting; in terms of van Egmond [104] the marked-to-market value of a bilateral swap is negative to the agent who holds the fixed-rate leg, therefore it has to post collateral.

Formally, I consider a defaultable contract that exchanges fixed and floating interest rates. h is the conditional probability under a risk neutral probability measure Q of default between periods; it is defined by a set of information given a state of nature of non-default at each period i.e. I assume that this probability is constant for sake of simplicity[12]. The amount of collateral posted is denoted as $c\varphi$ where φ denotes the exposure and c is the fraction of the exposure that is collateralized. I assume the foregoing -for sake of tractability of the solution- is equivalent to the fraction β_s of the market value of the contract at time s (V_s), see Duffie and Singleton [46]. Additionally, as in Johannes and Sundaresan [64] I assume the amount of collateral is free of default[13]. The discount factor in the contract is

[11] The valuation is repeated at frequent intervals-typically daily. Thus, the collateral position is then adjusted to reflect the new valuation.

[12] This is relaxed in the empirical chapter of Cama [27].

[13] They also introduce cost of collateral as a benefit/cost of holding it.

the default-free short rate (r_s). If the contract has not defaulted by time t its market value V_t would be the present value of receiving $c\varphi_{t+1}$ in the event of default between t and $t+1$ plus the present value of receiving V_{t+1} in the event of no default, this is as follows,

$$V_t = he^{-r_t} E_t^Q(c\varphi_{t+1}) + (1-h)e^{-r_t} E_t^Q(V_{t+1}) \tag{1.2}$$

where E_t^Q denotes expectations under a martingale measure conditional on information available at period t. Above expression represents a joint distribution between φ and the discount factor (r) over various horizons. According to Duffie and Singleton [46] the problem simplifies when the expected collateral at time s is a fraction of the risk-neutral expected survival-contingent market value at time $s+1$. Taking into account the foregoing, I define the amount of collateral as follows;

Definition 1 (Market Value of Collateral - MVC) *Under a risk-neutral probability measure Q the market value of collateral is defined as;*

$$E_s^Q(c\varphi_{s+1}) = \beta_s E_s^Q(V_{s+1})$$

Thus, using the definition (1), the expression (1.2) can be expressed as follows;

$$\begin{aligned} V_t &= \beta_t he^{-r_t} E_t^Q(V_{t+1}) + (1-h)e^{-r_t} E_t^Q(V_{t+1}) \\ &\equiv E_t^Q\left(\exp\left\{-\sum_{j=0}^{\Delta-1} R_{t+j}\right\} X_{t+\Delta}\right) \end{aligned} \tag{1.3}$$

where t is set before default time i.e. $t < T^d$. The above expression is obtained by recursively solving (1.2) forward over the life of the bond, see appendix (A) for details. Then, a period before default, the promised payoff ($X_{t+\Delta}$) is default-free. Δ is the number of periods immediately ending before default time ($t+\Delta$) and finally R is obtained as follows;

$$e^{-R_t} = (1-h)e^{-r_t} + \beta_t he^{-r_t}$$

As in Duffie and Singleton [46] for time periods of small length, the former can be seen as

$R_t \simeq r_t + h(1-\beta_t)$. So, the fraction of market value posted as collateral positively influences the (adjusted) interest rate R_t. In other words, the swap spread, i.e. $R_t - r_t$, is a function of β_t. As an informal corollary, if $h = 0$ i.e. there is no counter-party risk, then the swap contract, that originally gathers multiple short-term contracts of swapping payments i.e. $X_t = r_{f,t} - s^w$, will be as expressed as in (1.1) where $r_{f,t}$ is the floating rate calculated at time t. In the calculation of s^w I will refer to the floating rate as Libor with maturity T; the foregoing is denoted by $L(T)$. In the next lines I add the collateral requirements into the model. The solution requires a continuous setup since the default time (τ) lies on the set $(0,T)$. Since posting collateral is costly but adds more value to the contract then I calculate the current value of keeping collateral up to τ. The solution also requires to evaluate V_t under the probability de default over the maturity of the claim. Thus, the expected value under a martingale measure Q includes the indices $\mathbf{1}_{\{\tau>T\}}$ and $\mathbf{1}_{\{\tau\le T\}}$, those expressions denote a dummy variable or binary result relying on default time (τ). Finally, all expected streams of paymets up to maturity T are discounted at interest rate r.

Formally, in a continuous solution and following the setup in Johannes and Sundaresan [64] that includes a costly collateral, the market value is

$$
\begin{aligned}
V_t = E_t^Q\Big[&e^{-\int_t^T r_s ds}\Phi_T \mathbf{1}_{\{\tau>T\}} + e^{-\int_t^\tau r_s ds} c\varphi_\tau \mathbf{1}_{\{\tau\le T\}}\Big] \\
&+ E_t^Q\Big[\mathbf{1}_{\{\tau>T\}} \int_t^T \exp\Big\{-\int_t^s r_u du\Big\} y_s c\varphi_s ds + \mathbf{1}_{\{\tau\le T\}} \int_t^\tau \exp\Big\{-\int_t^s r_u du\Big\} y_s c\varphi_s ds\Big]
\end{aligned}
$$

where y_s is the benefit of posting collateral at time period s that increases the value of the contract V_t[14]; Φ_T is equal to the difference between the swap rate and the annualized Libor applied to the contract up to maturity. The solution of the market value of the contract when φ_s is equal to βV_s is

$$
V_t = E_t^Q\Big[\exp\Big\{-\int_t^T (r_s + h(1-\beta_s) - y_s\beta_s)ds\Big\}(L(T) - s^w)\Big] \tag{1.4}
$$

$L(T)$ is the Libor for the contract under maturity T; this floating rate will be effectively

[14] Johannes and Sundaresan [64] points out that net benefit stemming from the amount $y_s c\varphi$ accrues up to end of maturity or default time and it must appropriately be discounted back.

swapped according to the contract[15]. Details of the derivation in the appendix. Since the market value of the contract at the inception is equal to zero then the swap rate under collateralization is defined in the following lemma (1). This result implicitly assumes non-full recovery of the value of the contract after default which is a variation of Johannes and Sundaresan [64]'s main result.

Lemma 1 (Swap rate under collateralization) . *The swap rate including collateralization and cost of posting collateral as in Johannes and Sundaresan [64] is*

$$\begin{aligned} s^w &= E_t^Q\left[\frac{\exp\left\{-\int_t^T (r_s + h(1-\beta_s) - y_s\beta_s)ds\right\}L(T)}{p(0,T)}\right] \\ &= E_0^Q[L(T)] + cov_0^Q \frac{\left[\exp\left\{-\int_t^T (r_s + h(1-\beta_s) - y_s\beta_s)ds\right\}, L(T)\right]}{p(0,T)} \end{aligned} \tag{1.5}$$

Being $p(0,T)$ the discount factor up to maturity date (T).

Above lemma states that the swap rate depends on the expectation over the measure Q of the Libor[16] and the linear association between R and the Libor. More important, the variable of interest is β is going to be critical under clearing practices; once novation facilitates netting β shrinks and consequently the swap rate decreases since there is less requirement of collateral. A positive correlation between libor and above adjusted interest rate is required for having the foregoing statement true[17]. Formally, the definition of β is as follows.

Definition 2 (β) *β_s denotes the exposure (φ_s) in terms of units of the value of the contract (V_s); i.e. $\beta_s = \frac{c\varphi_s}{V_s}$.*

The fraction β varies over time since the exposure can change due to clearing methods. The exposure calculation is discussed in section (1.4).

[15] For instance, whether the contract previously requires swapping the rates after 6 months then the Libor under consideration will be the expected rate to 6 months at the inception of the contract.

[16] This contract is not hedged; however the treatment with forwards will be the same as in section under no collateralization.

[17] Johannes and Sundaresan [64] points out the covariance term in (1.5) is always negative, henceforth swap rates are less than a future rate as libor. The former associated to the "convexity" correction.

Difference in swap rates

The final objective of this chapter is to bring up discussion about the determinants behind the difference between swap rates among clearinghouses; thus the expression in discussion for analyzing is as follows being superscripts on β, s^w and y_s related to clearinghouses. I formally specify the expression under interest for this chapter in the following corollary;

Corollary 1 (Basis) *The difference in swap rates or basis among clearinghouses A and B is as follows;*

$$\begin{aligned} s^{w,A} - s^{w,B} &= cov_0^Q \frac{\left[\exp\left\{\int_t^T -(r_s + h(1-\beta_s^A) - y_s^A \beta_s^A) ds\right\}, L(T)\right]}{p(0,T)} \\ &- cov_0^Q \frac{\left[\exp\left\{\int_t^T -(r_s + h(1-\beta_s^B) - y_s^B \beta_s^B) ds\right\}, L(T)\right]}{p(0,T)} \end{aligned} \tag{1.6}$$

In the next section I follow the same approach for determining an analytical expression that relates clearing practices with the premium of credit default swaps.

1.3.2 Determination of the credit default swap premium

In this model of determination of the CDS premium there is an agent that is susceptible to some loss of wealth. There is also other agent that sell insurance against that loss. Finally, there is another agent that have access to some investment project but requires some funding in order to effectively undertake the project. Summarizing and formalizing the setup of the model: there are three agents, the buyer of the protection (henceforth the buyer or B), the seller of the protection (henceforth the seller or S) and a third party (henceforth the investor or I) that has access to some investment project. The investment and protection have a maturity of two periods ($t = \{0, 1\}$); the contract is set at the first period. I describe in the following lines the timing of the actions involved, states of nature and availability of endowments with uncertainty.

At $t = 0$, the endowment for the buyer ω_B is known with certainty; a quantity qm is transferred to the seller with the promise -subject to default- of receiving m if the event happens (the loss of wealth); q is the price of the contract per unit of m. Once qm is received by the seller then z is transferred to the third-party with the promise to return $z(1+\frac{r}{2})$. A different counter-party risk arises also from the foregoing contract since this third party may default. The following restriction applies: $\omega_B \geq qm \geq z$. I assume that the buyer engages in purchasing insurance; otherwise it will receive a penalty or cost L (see Duffie and Zhou [50] for details of this setup[18]).

At $t = 1$, the endowment for the seller ω_s is unveiled at no cost[19]; ex-ante the availability of this endowment happens with some probability and this determines the default or not of the original insurance contract. The third-party can seize both return r and notional amount z of the project and declares default with some probability greater than zero. This action may be verifiable but it is costly. The variable that remains indeterminate in the model is z. I assume that contingent claim related to the amount z is exogenous given[20]. Since seller has a short position in CDS, the seller must post collateral. Also, cross subsidization of costs of collateralization among contingent claims is possible and realistic, I will give more details in the section of payoffs by arrangement on the foregoing.

The basic structure under discussion is depicted in the figures (1.4) and (1.5). These figures show participants, the size of the exposures among them and the type of arrangement. The bilateral arrangement supposes netting amid class of assets for each partner separately. Instead, the clearing (or multilateral) arrangement supposes netting of different class of assets amid all participants. For sake of simplicity, the formalization of these arrangements -i.e. the calculation of exposure- is left to section (1.4). Also in this structure each pair seller-buyer and seller-investor only trade one asset; it is possible to have a more complicated structure that allows trading of a different class of assets amid same pair of participants. However, any arrangement would produce the same size of exposures due to netting ultimately. Finally, relative to the bilateral arrangement, the clearing arrangement

[18] Duffie and Zhou [50] assumes that if banks experiences a loss of principal on a loan, it incurs an additional deadweight cost. Moreover, if the bank does not purchase insurance, then it also incurs some multiple of above deadweight cost.

[19] The quantity ω_s is verifiable.

[20] Actually it could be related to a contract of interest-rate swaps in general terms for instance.

produces a shrinkage of the exposure of the seller due to opposite positions among different participants. The main result of this section is as follows. Even though the total exposures in the multilateral arrangement increases, the seller reduces her exposure significantly thus affecting the price of the contingent claim.

The price determination is standard as asset valuation suggests. The method needs a discounted premium and protection legs. The former takes into account the premium payments and possible accrue value if the credit event occurs. The protection leg calculates the protection amount when credit event happens. Then, after setting the values of these two legs, the premium is determined by equalizing these two terms to each other.

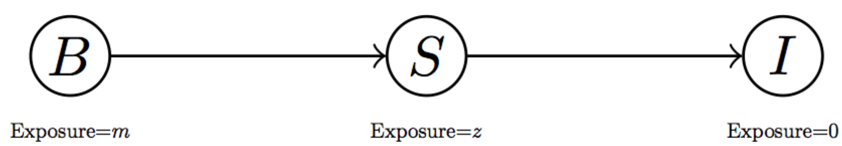


Figure 1.4: Bilateral arrangement

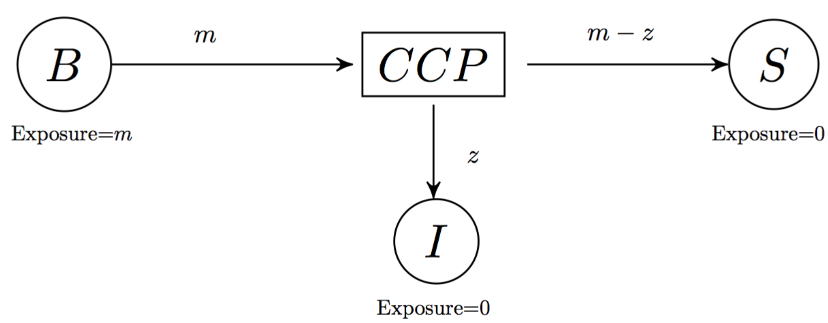


Figure 1.5: Clearing arrangement

The figure (1.6), that shows the timming of actions and resolution of the contracts, summarizes above discussion.

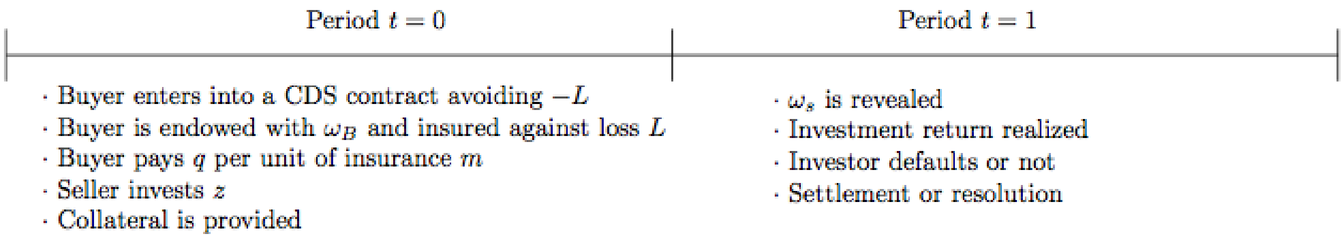


Figure 1.6: Timming of the model

Trading Frictions

In this section I describe the three frictions in the environment described by the model. First, the event -the loss of wealth (L)- encourages buyers to get a CDS contract. I assume that an agent made choices (*of investment or production*) before the realization of this shock of size L. They could insure against the shock by demanding full payment, however the former is costly. For instance, intermediate producers -that expect a demand shock after production- would demand to pay the whole bill off at stage 0. Thus, the shock would potentially halt the production process or discourage the demand for the intermediate good. In order to avoid the foregoing result, the producers buy a CDS contract in which promises a compensation if the event happens.

Second, sellers may declare default. Thus buyers that trade with a specific seller in the first period face a defaulting exposure. In other words, while being insured against the related event, the buyer who writes a CDS contract now faces a default risk. Why not get insurance against the default of the CDS seller? Buyers would need to trade another CDS contract with other potential sellers; the new contract should hedge the counter party risk at some particular state of nature, however the shock is aggregated in nature i.e. other sellers also have $\omega_s = 0$. The only way to hedging is by getting collateral. This setup reveals the incompleteness of the market.

Third, as Townsend [103] and Radner [93] suggest, output or result of projects may be verifiable to some cost; in the model, the agent I is informed on the actual state of nature of the project and in which this information may be transmitted to the rest of agents only at some costs. In this chapter, I assume that these costs are important and additionally I invoke the conditions established in Ordonez [88] that allow to observing the borrowing of the amount z and the report of *some* result of the project. Thus, there some states of nature where the agent I only walks away from terms of contract.

Summarizing, the environment formalizes the fundamental frictions that will allow us to endogenize the need for a CDS contract and setup a proper clearing arrangement. CDS contract between a buyer and a seller can partially insure against the main event but exposes the buyer to counter-party default. Collateral in form of pre-payment is available from endowments but it is costly. This setup provides a rationale for clearing arrangements that can provide cheaper and better insurance against default risk.

Bilateral arrangement: payoffs by state of nature

Figure (1.4) shows the financial structure for a bilateral arrangement; buyer (B) has an exposure of m to seller and this same seller (S) has an exposure of z to third-party (I). Requirement of collateral is exogenous given and denoted by c as a fraction of the exposure. The nature of the exposure of the seller to the agent I may be related to the investment of the whole or some fraction of the total premium[21] (qm) into a technology that returns $1+r$; seller and third-party share r equally. The availability of the (observable) endowment ω_s makes the seller to default or not default. I also take into account that costs per unit of collateral i.e. $\mu - 1$ can be split for calculation of benefits amid markets. In other words, the seller would consider a fraction ω_1 of these costs for calculation of benefits when sell CDS; and $1 - \omega_1$ is earmarked when benefits are calculated for other contingent claim. This feature adds the fact that competition in prices make sellers to consider subsidization among markets.

In the following table (1.1) I show the size of exposure for each participant in the basic structure depicted in figures (1.4) and (1.5). As defined early, amount z is related to some class of derivatives, for instance interest-rate swaps or loans; while m is related to CDS asset specifically.

[21] It also may be related to the purchase of insurance - the seller buying insurance from others.

Participant	ϕ^b	ϕ^{cl}
S	z	0
B	m	m
I	0	0

Table 1.1: Exposure for the basic structure

The symbols ϕ^b and ϕ^{cl} denote exposures in a bilateral and clearing arrangement. In the case of clearing practices, as shown in above table the exposure of the seller is equal to zero since $z - m < 0$. The foregoing is a result of netting practices. This exposure must not be confused with the exposure of the clearinghouse to the seller which is equal to $m - z$ as shown in figure (1.5). The following table (1.2) shows the cost of posting collateral.

Participant	Bilateral	clearing
S	$cm(\mu - 1)$	$c(m - z)(\mu - 1)$
B	0	0
I	$cz(\mu - 1)$	$cz(\mu - 1)$

Table 1.2: Cost of posting collateral

I calculate both the cost of posting collateral and the value of the collateral in each arrangement, I introduce the symbol $\varphi(m, z)$ that represents aforementioned costs per unit of $c\mu$. Notice that foregoing definition of exposure (φ) is different from the exposure given by ϕ, the former incorporates the cost of posting and maintaining collateral. More important, φ gauges the amount of collateral that seller and third-party need to put at front. The value of the collateral is expressed in netting terms since the seller receives and posts collateral.

Participant	Bilateral	clearing
S	$-(m - \frac{z}{\mu})$	$-(m - z)$
B	$\frac{m}{\mu}$	$\frac{m}{\mu}$
I	$-z$	$-z$

Table 1.3: Function $-\varphi(m, z)$

In order to determine the premium of the CDS I explicitly state the payoffs of each participant. Thus, I consider the following events;

- The (credit) event occurs 1; Otherwise 0.
- Seller defaults 1; Otherwise 0.
- Investor defaults 1; Otherwise 0.

For example the triplet (1; 0; 0) means: the event occurs and the seller and third party keep the promise to pay back. I also consider a different notation for the costs of posting collateral in the case either the seller or investor do not default. I denote this as $\Psi_s^x \equiv c\varphi^x(m,z)(\mu-1)$, where x denotes the type of arrangement and s identifies the participant. I early mentioned the possibility of cross-subsidizing costs of collateralization between markets. I denoted as ω_1 the fraction of collateral costs that enters into calculation of profits.

- State 1: (1;1;1)

$$\begin{aligned}\Pi^B =& \omega^B - qm - L + cm\\ \Pi^S =& qm - c\varphi^b(m,z)\mu\omega_1 - z\\ \Pi^I =& z(1+r) - cz\mu\end{aligned}$$

- State 2: (1;0;1)

$$\begin{aligned}\Pi^B =& \omega^B - qm - L + m\\ \Pi^S =& qm - m - z(1-c) + \omega^s - \Psi_s^b\omega_1\\ \Pi^I =& z(1+r) - cz\mu\end{aligned}$$

- State 3: (1;0;0)

$$\begin{aligned}\Pi^B =& \omega^B - qm - L + m\\ \Pi^S =& qm - m + z\frac{r}{2} + \omega^s - \Psi_s^b\omega_1\\ \Pi^I =& \omega_I + z\frac{r}{2} - \Psi_I^b\end{aligned}$$

- State 4: (1;1;0)

$$\Pi^B = \omega^B - qm - L + cm$$
$$\Pi^S = qm - c\varphi^b(m,z)\mu\omega_1 + cz + z\frac{r}{2}$$
$$\Pi^I = \omega_I + z\frac{r}{2} - \Psi_I^b$$

- State 5: (0;1;1)

$$\Pi^B = \omega^B - qm$$
$$\Pi^S = qm - z(1-c) - \Psi_s^b\omega_1$$
$$\Pi^I = z(1+r) - cz\mu$$

- State 6: (0;0;1)

$$\Pi^B = \omega^B - qm$$
$$\Pi^S = qm - z(1-c) + \omega^s - \Psi_s^b\omega_1$$
$$\Pi^I = z(1+r) - cz\mu$$

- State 7: (0;0;0)

$$\Pi^B = \omega^B - qm$$
$$\Pi^S = qm + z\frac{r}{2} + \omega^s - \Psi_s^b\omega_1$$
$$\Pi^I = \omega_I + z\frac{r}{2} - \Psi_I^b$$

- State 8: (0;1;0)

$$\Pi^B = \omega^B - qm$$
$$\Pi^S = qm + z\frac{r}{2} - \Psi_s^b\omega_1$$
$$\Pi^I = \omega_I + z\frac{r}{2} - \Psi_I^b$$

Clearing arrangement: Payoffs by state

Below the payoffs under a clearing arrangement.

- State 1: (1;1;1)

$$\begin{aligned}
\Pi^B =& \omega^B - qm - L + cm \\
\Pi^S =& qm - c\varphi^{cl}(m,z)\mu\omega_1 - z \\
\Pi^I =& z(1+r) - cz\mu
\end{aligned}$$

- State 2: (1;0;1)

$$\begin{aligned}
\Pi^B =& \omega^B - qm - L + m \\
\Pi^S =& qm - m - z(1-c) + \omega^s - \Psi_s^{cl}\omega_1 \\
\Pi^I =& z(1+r) - cz\mu
\end{aligned}$$

- State 3: (1;0;0)

$$\begin{aligned}
\Pi^B =& \omega^B - qm - L + m \\
\Pi^S =& qm - m + z\frac{r}{2} + \omega^s - \Psi_s^{cl}\omega_1 \\
\Pi^I =& \omega_I + z\frac{r}{2} - \Psi_I^{cl}
\end{aligned}$$

- State 4: (1;1;0)

$$\begin{aligned}
\Pi^B =& \omega^B - qm - L + c(m-z) + z(1+\frac{r}{2}) \\
\Pi^S =& qm - c\varphi^{cl}(m,z)\mu\omega_1 - z \\
\Pi^I =& \omega_I + z\frac{r}{2} - \Psi_I^b
\end{aligned}$$

- State 5: (0;1;1)

$$\begin{aligned}
\Pi^B =& \omega^B - qm \\
\Pi^S =& qm - z(1-c) - \Psi_s^{cl}\omega_1 \\
\Pi^I =& z(1+r) - cz\mu
\end{aligned}$$

- State 6: (0;0;1)

$$\begin{aligned}
\Pi^B =& \omega^B - qm \\
\Pi^S =& qm - z(1-c) + \omega^s - \Psi_s^{cl}\omega_1 \\
\Pi^I =& z(1+r) - cz\mu
\end{aligned}$$

- State 7: (0;0;0)

$$\begin{aligned}\Pi^B =& \omega^B - qm \\ \Pi^S =& qm + z\frac{r}{2} + \omega^s - \Psi_s^{cl}\omega_1 \\ \Pi^I =& \omega_I + z\frac{r}{2} - \Psi_I^{cl}\end{aligned}$$

- State 8: (0;1;0)

$$\begin{aligned}\Pi^B =& \omega^B - qm \\ \Pi^S =& qm + z\frac{r}{2} - \Psi_s^{cl}\omega_1 \\ \Pi^I =& \omega_I + z\frac{r}{2} - \Psi_I^{cl}\end{aligned}$$

Since I assume that there is a separated profit function for trading CDS. Thus, I put aside any settlement related to z into the profit function Π_z.

$$\Pi_s = \Pi_{CDS} + \Pi_z$$

In the following lines I calculate the payoffs by state when trading CDS. It is worth mentioning that function Π_{CDS} is always zero (assumption: insurance market is competitive). Accepting trading CDS avoids the deadweight loss L thus it is optimal for sellers to issue CDS.

- State 1: (1;1;1) $q^x m - c\varphi^x(m, z)\mu\omega_1$
- State 2: (1;0;1) $w_s + q^x m - m - \Psi_s^x\omega_1$
- State 3: (1;0;0) $w_s + q^x m - m - \Psi_s^x\omega_1$
- State 4: (1;1;0) $q^x m - c\varphi^x(m, z)\mu\omega_1$
- State 5: (0;1;1) $q^x m - \Psi_s^x\omega_1$
- State 6: (0;0;1) $w_s + q^x m - \Psi_s^x\omega_1$
- State 7: (0;0;0) $w_s + q^x m - \Psi_s^x\omega_1$

- State 8: (0;1;0) $q^x m - \Psi_s^x \omega_1$

Premium determination. As before, premium is obtained under the assumption of zero profits. So, I state the zero profit condition for the seller. As before, for sake of notation, I pinpoint the probability of the event or state i as p_i. Since some states deliver same payoff, the probability for the foregoing payoff will have a proper notation that gather the sum of respective probabilities.

$$q^x m - p_{1,4} c\varphi^x(m,z)\omega_s - p_{2,3} m + p_{2,3,6,7}\omega_s - p_{2,3,5,7,8}\Psi_s^x \omega_1 = 0$$

Thus the premium traded in clearinghouse or strategy x is;

$$q^x = p_{2,3} + p_{1,4} c\varphi^x(m,z)\frac{\omega_1}{m} - p_{2,3,6,7}\frac{\omega_s}{m} + p_{2,3,5,7,8}\Psi_s^x \frac{\omega_1}{m}$$

Since $\Psi_s^x = c\varphi^x(m,z)(\mu - 1)$, then above expression can be arranged as follows:

$$q^x = p_{2,3} + c\varphi^x(m,z)\frac{\omega_1}{m}\Big[\mu - 1 + p\Big] - p_{2,3,6,7}\frac{\omega_s}{m} \tag{1.7}$$

Where $p = p_1 + p_4$; in other words it is the marginal probability of seeing the seller defaulting when the main event occurs.

Difference in premium

I compare the premium between a bilateral and clearing agreement (see expression (1.8)). It is worth noticing that collateral requirements may be potentially different under each arrangement; however, I assume that collateral fraction c under a clearing and bilateral agreements are the same.

$$\begin{aligned} q^b - q^{cl} &= c\Big[\mu - 1 + p\Big]\Big(\varphi^b(m,z) - \varphi^{cl}(m,z)\Big)\frac{\omega_1}{m} \\ &= c\Big[\mu - 1 + p\Big]\Big[m - \frac{z}{\mu} + z - m\Big]\frac{\omega_1}{m} \\ &= c\Big[\mu - 1 + p\Big]\frac{(\mu - 1)}{\mu}\frac{z}{m}\omega_1 \end{aligned} \tag{1.8}$$

Below figure 1.7a shows the difference in premium between clearing and bilateral arrangements under the following parameterization: $c = 0.20$; $\frac{z}{m} = 0.8$ and $\omega_1 = 0.20$.

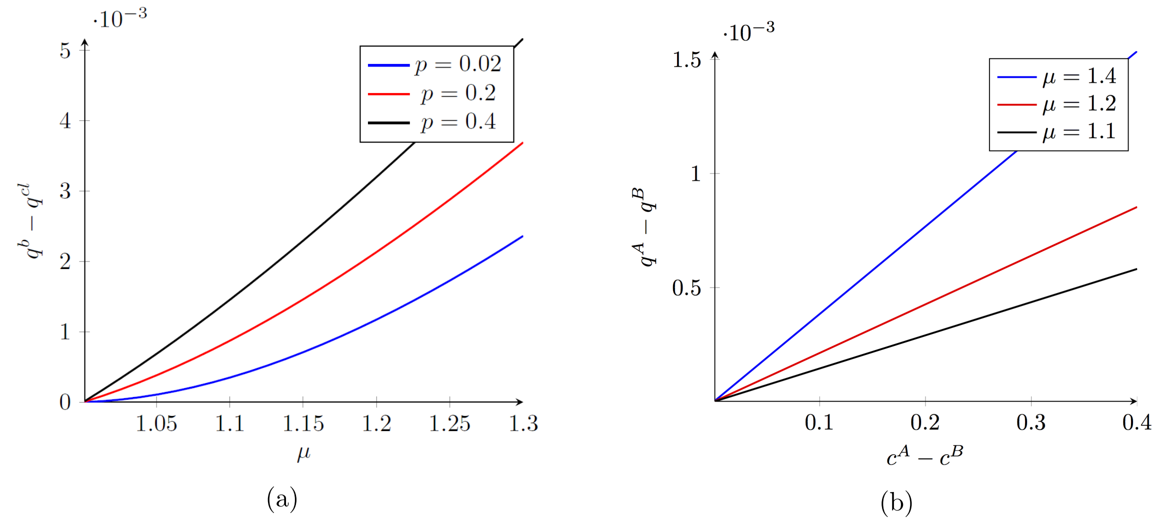


Figure 1.7: Difference in premium

I can use expression (1.7) in order to have a difference in premium as a function of different policies affecting collateralization. Thus, I have the following expression that explains the difference of premium between clearinghouses A and B with different collateralization policies:

$$q^A - q^B = (c^A - c^B)\Big[\mu - 1 + p\Big]\frac{(\mu - 1)}{\mu}\frac{z}{m}\omega_1$$

The closed-form expression derived above may be arranged to show the price difference among two different clearinghouses with same fraction of collateralization c.

$$q^A - q^B = c\Big[\mu - 1 + p\Big]\frac{\left(\varphi^A - \varphi^B\right)}{m}\omega_1$$

1.4 Calculation of the exposure in clearinghouses

In order to lay out a quantitative exercise, I closely follow Duffie and Zhu [47], Cont and Kokholm [40] and D'errico et al. [42]'s method for calculating bilateral and clearing exposures. I consider a finite N market participants which trade some derivatives. I allow for K classes of derivatives. These classes could be defined by the underlying asset classes, such as credit, interest rates, foreign exchange, commodities, or equities. Since multiples long- and short-positions may exist in any possible direction then these flows can be offset or netted across participants. Formally, netting as a measure of efficiency can be achieved through either a bilateral or clearing process. The latter extracts additional benefits by the usage of novation. For instance, if entities i and j have a CDS position by which i buys protection from j, then both i and j can novate to a clearinghouse, who is then the seller of protection to i and the buyer of protection from j.

Amid participants, let $X^k_{i,j}$ be the amount that j will owe i in some derivatives class k, before considering the benefits of netting across asset classes, collateral, and default recovery. Similarly, the exposure of participant i to j is $\max(X^k_{i,j}, 0)$ because, by definition $X^k_{i,j} = -X^k_{j,i}$.

The posting of collateral depends on the size of the exposure and therefore counter parties incur in pay-up front payments. The unit cost of posting these collateral requirement is $\mu - 1$ where $\mu \geq 1$. The fraction of collateral per unit of exposure is denoted by c as before.

Under bilateral netting, the exposure of participant i to any counter-party j, is netted across all K derivative classes, but exposures to different counter-parties cannot be netted (see Duffie and Zhu [47]). Formally, the total netting efficiency is:

$$\phi^b_{i,N,K} = \sum_{j \neq i} \left[\max \left\{ \sum_k^K X^k_{i,j}, 0 \right\} \right] \tag{1.9}$$

I consider the implications of a clearinghouse for all class of derivatives, this measure of efficiency has a broader definition in comparison to the one specified in Duffie and Zhu [47]. In this case, all positions across assets among counter-parties are novated to the same clearinghouse:

$$\phi^{cl,K}_{i,N,K} = \max \left\{ \sum_{j \neq i} \sum_k^K X^k_{i,j}, 0 \right\} \tag{1.10}$$

In equation (1.9) netting is done across all asset classes for each counter-party; and the total net exposure of dealer i is the sum of the individual exposure calculated with each counter-party j. When a CCP is introduced in the market, as in equation (1.10), the total net exposure is the exposure to the CCPs of party i which is calculated across assets and counterparties. As Cont and Kokholm [40] states, whether the introduction of a clearinghouse increases or decreases net exposures depends on the particular market, e.g. the notional sizes of the asset classes, riskyness of the asset classes, correlation between the asset classes, the number of asset classes, the number of participants etc. In the next section, I start deriving the size of the (variable) exposure (X) for each participant assuming that it is proportional to the notional values. Then, I show the analytical expectations of the net exposures specified in expressions (1.9) and (1.10).

The exposure ϕ^{cl,k_1} assumes that only asset class k_1 is cleared through a central counter-party;

$$\phi_{N,K}^{cl,k_1} = \sum_{j \neq i} \max\Big\{\sum_{K}(1-w_k)X_{ij}^k, 0\Big\} + \max\Big\{\sum_{j\neq i} w_{k_1} X_{i,j}^{k_1}, 0\Big\}$$

The exposure $\phi^{cl,k_{1,2}}$ assumes that two asset classes k_1 and k_2 are separately cleared through a central counter-party

$$\phi_{N,K}^{cl,k_{1,2}} = \sum_{j \neq i} \max\Big\{\sum_{K}(1-w_k)X_{ij}^k, 0\Big\} + \max\Big\{\sum_{j\neq i} w_{k_1} X_{i,j}^{k_1}, 0\Big\} + \max\Big\{\sum_{j\neq i} w_{k_2} X_{i,j}^{k_2}, 0\Big\}$$

1.4.1 Assumptions of the joint distribution among assets

Let's consider that for a specific class of asset k, I assume $X_{ij}^k \sim \mathcal{N}(0, \sigma_k^2)$ for all $i \neq j$ and allowed to be correlated across other assets. As in Duffie and Zhu [47] and Cont and Kokholm [40], I assume that the standard deviation of X^k is proportional to the credit exposure i.e. $\sigma_k = \alpha_k X$.

1.4.2 Assumption about heterogeneity

As in Cont and Kokholm [40], instead of credit exposures I use notional values to determine the size of the X_k and assume that they are proportional to the notional values according to the following expression:

$$X_{ij}^k = \theta_k Z_i^k \frac{Z_j^k}{\sum_{h\neq i} Z_h^k} Y_{ij}^k$$

Where Y_{ij}^k is distributed as $\mathcal{N}(0,1)$ and Z_i^k is the notional size of dealer i in asset k. In other words, the exposure of i to j for asset k is a fraction of the notional value of party i in derivative class k. This fraction is the notional value of counterparty j in comparison to the total amount of all other remaining notional values for h different of i. The parameter θ_k is related to the risk of asset k. Putting the former differently, different assets may differ in the valuation of the risk and therefore this will lead to different collateral requirements. As in Cont and Kokholm [40], I assume that this parameter θ is equal to $3.9e-3$ and $9.8e-3$ for interest rate and credit default swaps respectively[22].

1.4.3 Expectation of exposures

In the previous section the size of multilateral or total exposure is denoted by ϕ. In this section I actually calculate the exposure of the rest of the market to the CDS seller since collateral amounts are required. I denote the aforementioned exposure as φ[23]. Since Y_{ij}^k is distributed as a normal, then analytical expression for the expected (net) exposure is as follows;

$$\mathbb{E}(\varphi_i^b) = \frac{1}{\sqrt{2\pi}} \sum_{j\neq i} \sqrt{\sum_{k=1} \sum_{m=1} \rho_{km} \theta_k Z_i^k \frac{Z_j^k}{\sum_{h\neq i} Z_h^k} \theta_m Z_i^m \frac{Z_j^m}{\sum_{h\neq i} Z_h^m}} \tag{1.11}$$

$$\mathbb{E}(\varphi_i^{cl}) = \frac{1}{\sqrt{2\pi}} \sqrt{\sum_{j\neq i} \sum_{k=1} \sum_{m=1} \rho_{km} \theta_k Z_i^k \frac{Z_j^k}{\sum_{h\neq i} Z_h^k} \theta_m Z_i^m \frac{Z_j^m}{\sum_{h\neq i} Z_h^m}} \tag{1.12}$$

Take notice that $k, m \in \{K\}$ only for this section; later I will refer to m as a specific asset. On the other hand, in the case of CDS, the relevant expression that determines the swap difference between two clearinghouses in expression (1.8) is $\frac{\mathbb{E}\left(\varphi^b - \varphi^{cl}\right)}{Z^k}$ which can be calculated from above expressions. In the case of interest rate swaps, the ratio $\beta \equiv \frac{c\varphi_i}{Z_t^k}$ is

[22] Cont and Kokholm [40] states that for the CDS, θ_k is calculated as the mean of the standard deviation of the daily profit-loss of 5-year credit default swaps on the names constituting the CDX NA IG HVOL series 12 in the period July 1st, 2007 to July 1st, 2009 (page 13). In the case of interest rates, this parameter is calculated as the standard deviation of the historical daily profit-loss from holding a 5-year with notional of 1.

[23] In the case of the bilateral netting, this exposure is calculated as $\varphi_{N,K}^b = \sum_{j\neq i} \left[\max \left\{ \sum_k^K -X_{i,j}^k, 0 \right\} \right]$.

the expression that matter for the determination of the difference in swaps as expression (1.6) suggests. Here, the foregoing fraction will affect the discount rate and would produce a correlation with the forward rate; thus the swap rate is affected.

I also consider the calculation of exposures when a fraction w_k of a contingent asset k is cleared in a clearinghouse; this approach is the same as in Cont and Kokholm [40]. I intend to replicate the results in Duffie and Zhu [47] and quantitatively show the size of exposure between a bilateral and "full" clearing strategies. Also, I consider the size of the exposure when there are at least two clearinghouses. The idea is to show how different variation of market structure would impact in the size of the exposures and consequently on price of assets.

The following expression gives the expected exposure when there is a fraction of one contingent claim cleared in one clearinghouse.

$$\begin{aligned}\mathbb{E}(\varphi_i^{cl,K}) =& \frac{1}{\sqrt{2\pi}} \sum_{j \neq i} \sqrt{\sum_{k=1} \sum_{m=1} (1-w_k)(1-w_m)\rho_{km}\theta_k Z_i^k \frac{Z_j^k}{\sum_{h \neq i} Z_h^k} \theta_m Z_i^m \frac{Z_j^m}{\sum_{h \neq i} Z_h^m}} \\ &+ \frac{1}{\sqrt{2\pi}} \theta_K w_k Z_i^K \frac{\sqrt{\sum_{j \neq i} (Z_j^K)^2}}{\sum_{h \neq i} Z_h^K}\end{aligned} \tag{1.13}$$

Parameter $w_x = 0$ unless $x = \{K\}$ since the contingent claim K is the only one cleared in the clearinghouse.The following expression gives the expected exposure when there is a fraction of two contingent claim (denoted by K and $K-1$) which are cleared in separated clearinghouses.

$$\begin{aligned}\mathbb{E}(\varphi_i^{cl,K,K-1}) =& \frac{1}{\sqrt{2\pi}} \sum_{j \neq i} \sqrt{\sum_{k=1} \sum_{m=1} (1-w_k)(1-w_m)\rho_{km}\theta_k Z_i^k \frac{Z_j^k}{\sum_{h \neq i} Z_h^k} \theta_m Z_i^m \frac{Z_j^m}{\sum_{h \neq i} Z_h^m}} \\ &+ \frac{1}{\sqrt{2\pi}} \theta_K w_k Z_i^K \frac{\sqrt{\sum_{j \neq i} (Z_j^K)^2}}{\sum_s h \neq i Z_h^K} \\ &+ \frac{1}{\sqrt{2\pi}} \theta_{K-1} w_{k-1} Z_i^{K-1} \frac{\sqrt{\sum_{j \neq i} (Z_j^{K-1})^2}}{\sum_{h \neq i} Z_h^{K-1}}\end{aligned} \tag{1.14}$$

Also above parameter $w_x = 0$ unless $x = \{K, K-1\}$.

1.5 Analysis and discussion

In this section, I present discussion and implications of the analytical expressions (1.6) and (1.8) those related to the swap-rate difference between clearinghouses. At the end of this section I will succinctly discuss the data that could be used in order to find evidence of the effect of clearing methods on swap valuation. The full empirical strategy for the underlying model is pushed into the chapter III in my dissertation. In this section I will describe assumptions and possible scenarios where the theoretical model may explain some particular events in the range of data. This approach has certainly the advantage of freely playing with assumptions over the set of parameters; thus, below discussion is clearly simple and offers escenarios that support the results of the underlying theoretical model more likely.

1.5.1 The difference in CDS premiums

The expression in (1.8) shows that the sign of the swap rate is given by the difference between sizes of exposures relative to the amount of CDS trading. In order to evaluate the sign of this expression, I construct the ratio $\frac{\mathbb{E}(\varphi^{i,A})}{m^{i,A}}$ for clearinghouse A and participant i, m is the notional amount of CDS traded in that clearinghouse. The expected measure of exposure (φ) is specified in section (1.4.3) and the exercise requires data of notional values; I follow Cont and Kokholm [40] and use data of top 10 companies in USA from Office-of-the Comptroller of the Currency (OCC) for calculation of exposures. The amounts and market participation of 10 top companies are shown in table (1.4).

For sake of explanation and intuition I can start with a simple example; assuming the following: i) there are only two participants in the clearinghouse, ii) two contingent claims k and m (for instance m stands for CDS and k for an interest swap contract); iii) correlation between assets (ρ) is zero, and (iv) same risk parameter (θ) amid assets, then expression (1.12) is as follows:

$$\varphi^A(m,k) \equiv \frac{1}{\sqrt{2\pi}}\theta\sqrt{(S_i^k)^2 + (S_i^m)^2}$$

Where S^k and S^m is the notional value of k and m. Thus, the expression for fraction $\frac{\varphi^i}{m^i}$ in

Holding	Total derivatives	Swaps	Credit
CITIGROUP INC.	47092.6	25141.0	1761.9
JPMORGAN CHASE & CO.	46992.3	25670.8	2028.4
GOLDMAN SACHS GROUP, INC., THE	41227.9	20837.7	1424.3
BANK OF AMERICA CORPORATION	33132.6	19044.2	1264.9
MORGAN STANLEY	28569.6	15660.9	904.3
WELLS FARGO & COMPANY	7099.0	4496.8	30.9
HSBC NORTH AMERICA HOLDINGS INC.	6342.5	4012.4	125.0
MIZUHO AMERICAS LLC	4755.2	4364.7	4.1
STATE STREET CORPORATION	1445.8	12.1	0
CREDIT SUISSE HOLDINGS (USA), INC.	989.4	82.2	45.6

Table 1.4: Notional amounts of derivative contracts (in US billions)

terms of notionals is:

$$\frac{\varphi^A(m,k)}{m^{i,A}} \equiv \frac{1}{\sqrt{2\pi}}\theta\sqrt{1+\left(\frac{S_i^k}{S_i^m}\right)^2}$$

Thus, expression (1.13) for the above case is denoted as;

$$\frac{\varphi^B(m,k)}{m^{i,B}} \equiv \frac{1}{\sqrt{2\pi}}\theta\sqrt{1-w_m+\left(\frac{S_i^k}{S_i^m}\right)^2}+\frac{1}{\sqrt{2\pi}}w_m$$

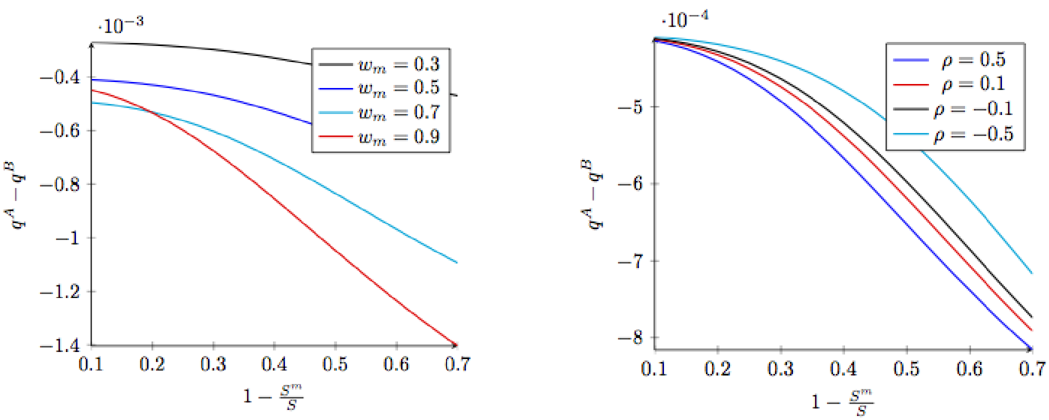
where $S_i^k + S_i^m = S_i$ is the total notional of derivatives. Since there are two participants, the clearinghouse which is not specialized is actually representing a bilateral arrangement; thus the exercise resembles a comparison of price difference between a bilateral arrangement (clearinghouse A) and a specialized clearing arrangement i.e only clearing CDS (clearinghouse B). The results discussed in the next lines are mostly driven by the number of participants as Duffie and Zhou [50]'s findings suggest. Figure (1.8) shows the size of the difference between rates under different sizes of the notional values for interest rate swaps respect to the total value of derivatives market for agent i and also different fraction sizes (ω_m) of the value of CDS that are cleared. I provide a benchmark (red line) in figure (1.8) that resembles a high market participation of LCH in credit derivatives. In the following table 1.5 I show four more scenarios for the quantitative exercise.

Given the scenarios I can calculate the premium basis under different sizes of exposures that hinge on the fraction of notional cleared and number of participants. For the scenarios

Scenario	participants	Risk parameters	Correlation
0	2	$\theta_m = \theta_k$	$\rho = 0$; Other sizes of ρ
1	10	$\theta_m = \theta_k$	$\rho \in (-0.8, 0.8)$
2	10	$0.5\theta_m = \theta_k$	$\rho \in (-0.8, 0.8)$
3	10	$0.3\theta_m = \theta_k$	$\rho \in (-0.8, 0.8)$
4	10	$0.1\theta_m = \theta_k$	$\rho \in (-0.8, 0.8)$

Table 1.5: Scenarios for CDS premium determination

1 to 4, I use expressions (1.12), (1.13) and (1.14) for calculation of exposures. I use (1.11) as a comparative case.



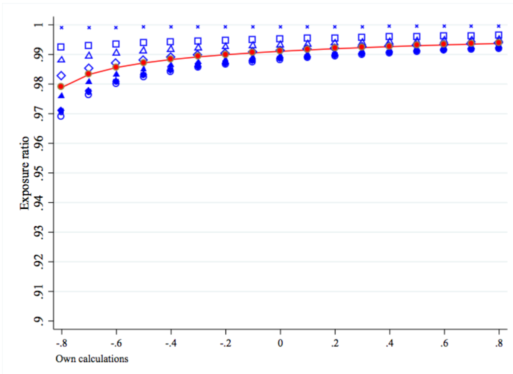
(a) Different CDS Market-size under clearing

(b) Different correlation amid assets

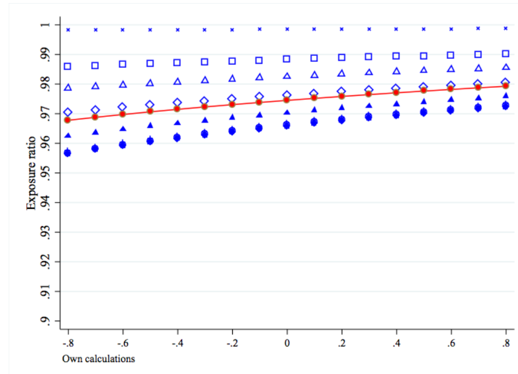
Figure 1.8: Difference in premium between clearinghouses

Figure (1.8) shows two participants that trade CDS and interest rate swaps. In the panel (1.8a) the difference in premium declines as long the market share of interest rate swaps ($\frac{S^k}{S} \equiv 1 - \frac{S^m}{S}$) increases. In other words, for any market share, the seller that clears all assets in one clearinghouse offers a price (q^A) lower than the seller that clears CDS in a separate clearinghouse. As a higher percentage of the notional goes to the specialized clearinghouse, i.e. a small ratio $1 - \frac{S^m}{S}$, the exposure and the premium are higher. In the panel (1.8b) an increasing higher negative correlation amid these two assets increase the difference in premium between these two sellers.

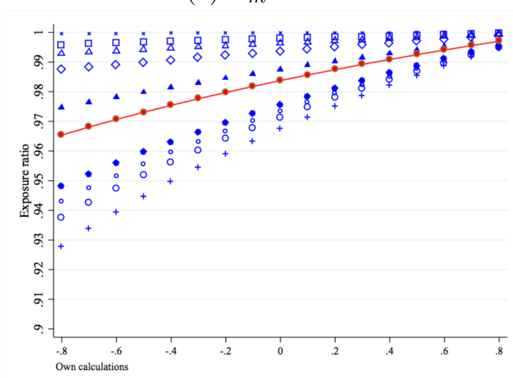
The following figure (1.9) shows the exposure ratio of an agents that choose to clear some fraction of the assets in a clearinghouse respect to clear same assets separately. Each symbol in that figure represents a holding as shown in table (1.4). The effect of netting is significant when the correlation between positions is negative; as long the correlation goes to positive the gains are not significantly large for clearing in just one clearinghouse.



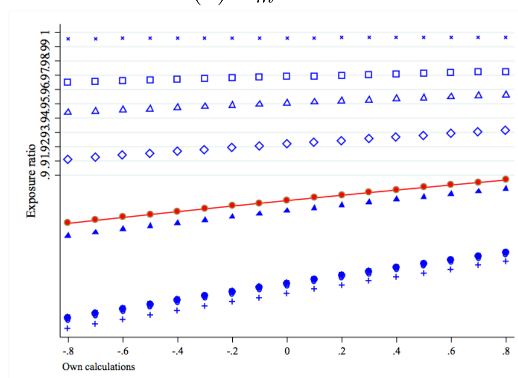
(a) $w_m = 0.3$



(b) $w_m = 0.5$



(c) $w_m = 0.7$



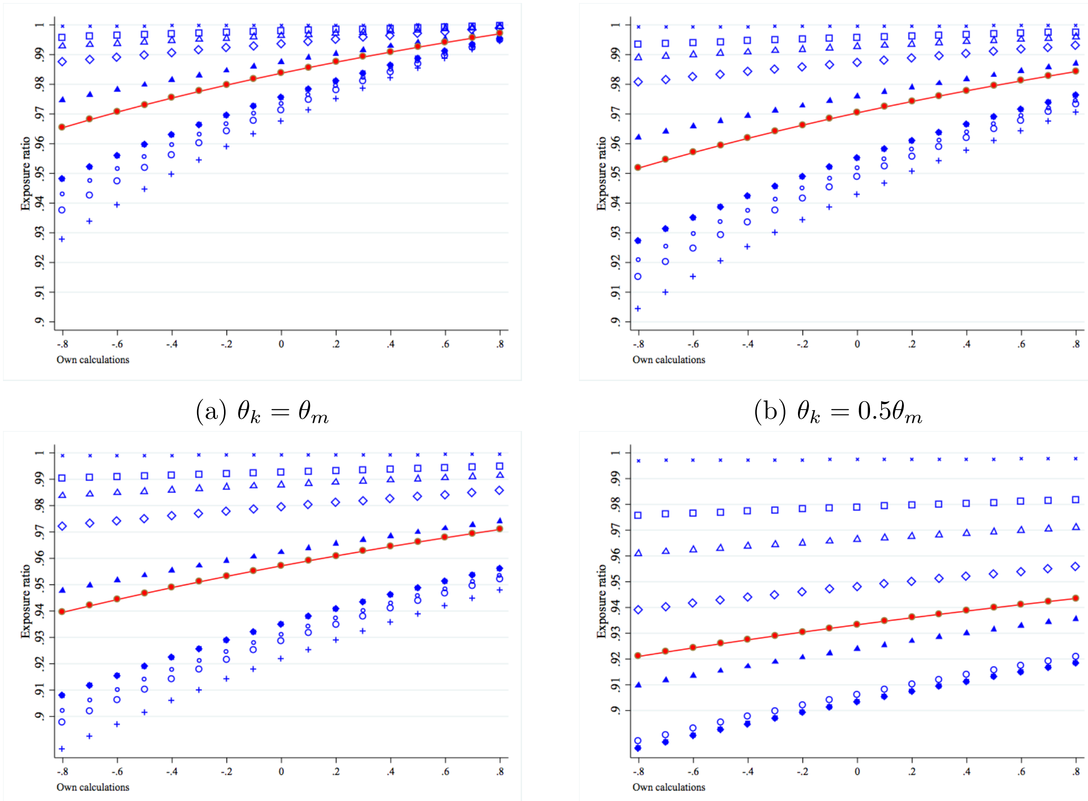
(d) $w_m = 0.9$

Figure 1.9: Exposure ratio between one versus two clearinghouses

Figure (1.10) shows the exposure ratio under different assumptions regarding the relative size of the valuation of risk (θ) for the CDS and IR. The ratio of exposures decreases, i.e. there are gains of having just one clearinghouse, when the asset risk (θ_m) increases for CDS; that can be seen in the change of the aforementioned ratio through figures (1.10a) to (1.10d).

1.5.2 The basis between LCH and CME

As described in expression (1.6) the differences in swap rates hinge on the covariance between the default-risk adjustment (R) and the LIBOR. In order to sign the difference between $s^{w,A}$ and $s^{w,B}$ I undertook a first-approximation to the exponential $e^x \approx 1 + x$ this implies for



(a) $\theta_k = \theta_m$ (b) $\theta_k = 0.5\theta_m$

(c) $\theta_k = 0.3\theta_m$ (d) $\theta_k = 0.1\theta_m$

Figure 1.10: Exposure ratio between one versus two clearinghouses

$s^{w,A} > s^{w,B}$ the following;

$$cov_0^Q\Big[1-\int_t^T (r_s+h(1-\beta_s^A)-y_s\beta_s^A)ds, L(T)\Big] > cov_0^Q\Big[1-\int_t^T (r_s+h(1-\beta_s^B)-y_s\beta_s^B)ds, L(T)\Big]$$

Assuming that benefits of collateral are constant i.e. $y_s = y$, above expression is equivalent to:

$$cov_0^Q\Big[1-\int_t^T (r_s+h(1-\beta_s^A))ds, L(T)\Big] > cov_0^Q\Big[1-\int_t^T (r_s+h(1-\beta_s^B))ds, L(T)\Big]$$

Finally, if I assume that clearinghouse B keeps deepening any clearing "strategy" β_s^B across time and term structure; then the swap rate in aforementioned clearinghouse is less than other swap rate -*traded in another clearinghouse.* If I assume that $\beta_s^A \equiv \beta_s^B = 1$, $y_s^B = 0$ and any $y_s^A > 0$ then the result in Johannes and Sundaresan [64] arises which states that swap rates in the presence of costly collateral (whose contracts are traded in clearinghouse A) are higher than those assuming costless collateral (whose ones are traded in clearinghouse B). I formally define the concept of "strategy" as the one pursued by clearinghouse that reduces the amount of collateralization required in the contract. I formally show these results and the usage of concepts in the following proposition and a corollary,

Proposition 1 *The basis between clearinghouses A and B, $s^{w,A} - s^{w,B}$, where only clearinghouse B keeps a strategy of netting across time and term structure, is non-strictly positive under the following condition,*

$$0 \geq cov_0^Q\Big[\int_t^T h\beta_s^B ds, L(T)\Big] \tag{1.15}$$

Proof. The result is easily obtained from above discussion ■.

Corollary 2 *If $\beta_s^A \equiv \beta_s^B = 1$, $y_s^B = 0$ and any $y_s^A > 0$ then $cov_0^Q\Big[\int_t^T \beta_s^A(h+y_s^A)ds, L(T)\Big] > 0$; the swap rate in the presence of costly collateral is higher than that one which assumes costless collateral i.e. $s^{w,A} > s^{w,B}$.*

Proof. The result follows from discussion in Johannes and Sundaresan [64] ■. The following proposition shows the *basis* in terms of the change of parameter β;

Proposition 2 *The basis between clearinghouses A and B, $s^{w,A} - s^{w,B}$, is calculated as follows,*

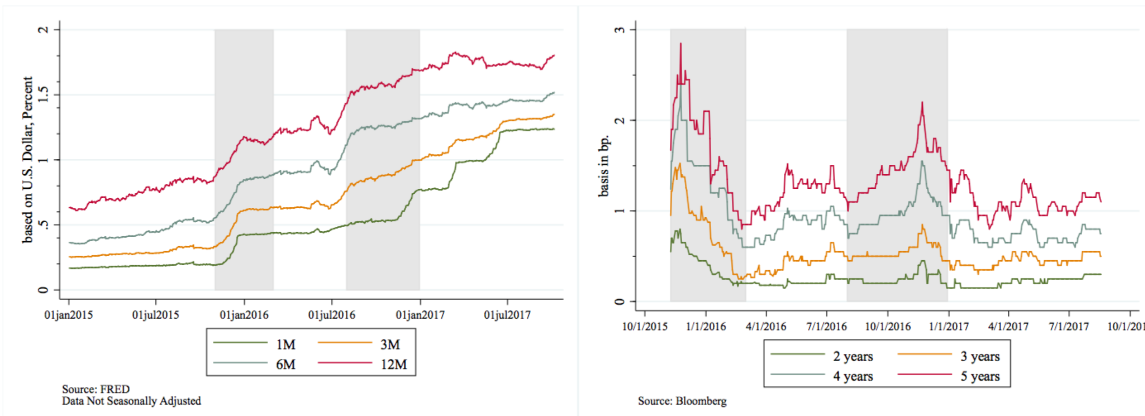
$$\begin{aligned} s^{w,A} - s^{w,B} &= cov_0^Q\Big[r_t + h(1-\beta_t^A) - y_t^A\beta_t^A, L(T)\Big](\dot{\beta}_t^A - 1) \\ &\quad - cov_0^Q\Big[r_t + h(1-\beta_t^B) - y_t^B\beta_t^B, L(T)\Big](\dot{\beta}_t^B - 1) \end{aligned}$$

Proof. It can be proved by using Stein's lemma ■. The following corollary follows the proposition (2) above and shows the sign of the basis when there is an strategy of reducing the collateral requirements i.e. netting across time keeping constant this requirement across term structure.

Corollary 3 *Considering a strategy $\beta^B(t,s) = a_0 - a_1 t$ where t denotes time and it is not affected by the term structure defined by s; if expression (1.15) holds then $s^{w,A} \geq s^{w,B}$.*

Proof. Expression $\int_{t=0}^{T} h\beta_s^B ds$ is equivalent to $h\beta_t^B T$. Assuming that exposure (φ_t) shrinks across time but term structure i.e. $\beta^B(t,s) = a_0 - a_1 t$, then the sign of the basis hinge on correlation of these lessening exposure with Libor rate i.e. $cov_0^Q\Big[hT(a_0 - a_1 t), L(T)\Big]$ $\blacksquare$.

Above proposition concludes that the basis would depend of the linear association between the netting strategy of the clearinghouse and LIBOR. Is there empirical support for aforementioned result? Let's see the data. Figure (1.11) shows the behavior of six months Libor and the LCH-CME basis from the end of 2015 to October 2017.



(a) Libor rate

(b) Basis

Figure 1.11: Daily Libor and Basis

Above figure shows that Libor trend was reversed starting 2015; before this year the Libor rate had a long-run persistent negative trend. The libor was completely flat starting the financial crisis up to 2014. Since 2016 the libor rate shows a persistent positive trend.

Back at figure (1.2), it shows that LCH started gaining market participation in clearing at a significant pace; whether assuming that this clearinghouse's risk management strategy were accompanied by reducing exposures through netting, then the covariance between β_t and libor would be more likely negative. As a consequence and according to proposition (3) the basis would be positive then i.e. $s^{w,CME} - s^{w,LCH} > 0$.

Spikes in basis data are also puzzling. Panel figure (1.11b) shows that basis is wide immediately before the end of 2015 and after July 2016 to the end of that year (this range of data is shaded in above figure). The basis for claims with a long-term maturity is visibly more affected in quantitative terms. This may be associated to significant increase of the libor rate under these ranges of data, see panel figure (1.11a). In those periods the covariance between β_t and libor more likely would be increasing and as a consequence widening the basis. I do not discard either the effects of reducing exposures by the other clearinghouse and collateralization across term structure in order to explain the wide of the basis over this period in analysis; this for sure would be clarified in a proper empirical strategy.

1.6 Conclusions

I showed how the exposures are related to the swap rates in a theoretical framework. I analyzed this relationship in a financial structure that allows clearing of positions. Clearing is potentially a tool that reduces significantly exposures and thus lessen the amount of collateral requirements. The impact on swap rates of these financial structure has not been broadly discussed in the literature. The simple approach presented in this chapter is not intended to capture every movement in swap rates, and more likely changes not captured by the theoretical model are due to model misspecification, market segmentation, or temporary miss-pricing as fairly suggested by Johannes and Sundaresan [64].

I showed in section (1.3) that swap rates have a closed functional from hinging on the exposure size. Sellers of these contingent claims may choose to clear these ones in clearinghouses and taking further advantage of netting through novation. In the case of interest rate swaps, I adjusted the standard valuation expression by incorporating the effect of collateral requirements in a clearing setup. In a full recovery assumption, interest rate swaps can be seen as short contracts with terminal date at default. If only a fraction of the value of the contract is recovered, then the swap would be increasing as collateral requirements are higher. Practices as netting or compression that save collateral costs would reduce the swap rate. In section (1.4) I discussed the calculation of the exposures and how they are affected by clearing through assets and participants. I also consider the case where participants can clear their claims in separated or specialized clearinghouses. The analytical expression for swap rates needs of information about notional values, percentage of volume that is cleared, risk of the claim and relative size of the market for each derivative.

I quantitatively showed in section (1.5) that relative size of the CDS market and the percentage of claim that is cleared affects the exposure and thus the CDS premium. I started with a simple example of two participants and two assets with the purpose of showing the benefits of netting. An increasing fraction of CDS earmarked to clearing as long as the CDS market size shrinks would increase the exposure in the structure with a CCP that clear only CDS claims; thus the premium determined in a CCP which clears CDS and additional claims will be relatively cheaper. Additionally, a higher and positive linear association between positions of different claims makes the premium competitive when participants choose to clear both claims.

In a second exercise I use data from ten top holdings that handle derivatives in their portfolio. I compare the premium between structures with one and two specialized CCP's. There is a significant difference in exposures between these structures when the fraction of CDS earmarked to clearing is high and also when the correlation amid positions is highly negative. Additionally, a lower risk of default for other claims rather than CDS would reduce the size of the exposure in the structure with one CCP, this reduction will be important at negative values of correlation amid positions.

In the case of interest rate swaps I could establish a relationship between netting strategy through the time and the Libor rate that is connected with the *basis*. The negative linear association between above variables shown in the years 2015 and 2016 seems to validate the appearance of a widening *basis* between LCH and CME. The basis for claims with a long-term maturity is visibly more affected and precisely are more likely associated to significant increase of the Libor rate.

The results of this research has the following implications in terms of policy. First, netting through novation has significant gains in reducing exposures, further benefits may relies on correlation between asset positions as theory of portfolio predicts. I assess these gains using data from OCC, these gains are large when comparing a financial structure of one clearinghouse respect to other with two specialized clearinghouses. A financial structure with a clearinghouse can be competitive in terms of prices and collateral requirements thus turning out to be appealing to more participants. Second, a macro prudential policy such as capital requirement is becoming a central feature in financial structures in the aftermath of the recent financial crisis and more clearly after Dodd-Frank act. Clearing of a fraction of portfolio of derivatives of banks could offer a feasible way to reduce pressure on these requirements since counter-party risk can be reduced effectively inside clearinghouses. Furthermore, other strategies as mutualization (sharing losses amid participants) and further risk management strategies can potentially be part of the regulation in the next years.

Chapter 2

The Impact of Collateralization on Swap Rates Under Clearing: What Data Say?

2.1 Introduction

This chapter makes a quantitative assessment of the impact of clearing practices on price of derivatives. By using an empirical approach I found a negative and significant impact of clearing practices on price of derivatives. This finding supports the theoretical model discussed in Cama [26]. In practice, netting and compression procedures inside clearinghouses may significantly affect the size of exposure in contracts; thus, these clearing practices enables to see a lower (competitive) price of these contracts in comparison to the ones negotiated in standard markets. I use data of interest-rate and credit-default swaps traded in clearing and non-clearing markets.

The theoretical framework that explains the relationship between swaps and clearing method lays out in the same mechanism that show the effects of risk management and bilateral netting on contracts. In Cama [26], the autor explains in a simple theoretical framework how much the swap rate is affected by clearing practices; interest rate swaps decrease with strategies that encourage the reduction of exposures while keeping constant counter-party risk. Also, Cama [26] found that sudden changes in the exposure amount affects the covariance of zero-coupon adjusted rate and Libor and thus it potentially may affect the differential of swaps (*basis*) traded in CME and LCH. The empirical strategy closely follows Cama [26]; I show the empirical representation of Cama [26]'s theoretical model in section (2.3) of this document. The empirical approach gathers econometric exercises that finds significant determinants for the interest rate and credit default swaps differentials. These differentials are calculated between a cleared and non-cleared market

(OTC).

This chapter contributes with identifying changes in swaps due to clearing practices beyond other factors found in the standard price-discovery literature. Since clearing of derivatives has recently became central to the modern financial system, it is necessary to have an assessment of the effect of clearing practices on the mechanism of pricing. The Dodd-Frank act is a comprehensive set of rule for regulation of financial markets that will be a key player in the future of economic growth and it ultimately represents the institutional driver dodging local shocks and guiding financial markets on the path of stability and resilience; this intended rhetoric does really make sense, now more than ever when literature on economic growth realizes an increasing cost of crises (see Cerra and Saxena [30]). Furthermore, austere estimations from IMF suggest that had capital requirements been set 15% of weight assets the 2008-09 financial crisis would have been avoided. The aforementioned assessment demands a too high requirement that could undermine banking sector broadly. Clearing practices arise as an alternative whereby lower requirements of collateral can be offered with a competitive price whereas keeping constant the risk of default. In that sense, this chapter empirically shows a connection between clearing practices and changes in prices; the relevance of my discussion arises for example when low prices are observed in data and literature explain these levels can be embroiled to price competition.

The chapter is organized as follows. The following section presents the literature related to empirical findings for the case of interest-rate and credit default swaps. The third section examines the data and sample. The fourth section setups the methodology for the empirical assessment; I revisit the theoretical formulation and I further explain the respective assumptions behind the formulas. The fifth section leads to the quantitative exercise in order to provide insights regarding what drives the difference of swap rates between clearinghouses. The last section gathers the conclusion of this research and provide further questions to pursuing in a future work.

2.2 Literature review

In literature, clearing has been associated to reduction of positions, less requirements of collateral and dissemination of information. In theoretical terms, recent literature has shown how price of swaps is relate to clearing. For instance, in a broader sense for any asset, Koeppl [68] studies the effects of demand of assets and collateralization on asset pricing. In an original modelistic setup, Acharya and Bisin [1] studies the impact of informational features on CDS premium; however, this result can easily be extrapolated to the impact of other clearing strategies as mutualization and proper collateralization. On the foregoing, Cama [25] analyzes the equivalence of different levels of collateralization and mutualization in terms of a higher premium. On the other hand, Stephens and Thompson [99] analyze price competition on premium; that paper explains lower premiums with higher levels of counter-party risk. Cama [25] also shows lower premium but with no price competition assumption, however this feature hinges on a moderate counter-party risk. In summary, the theoretical contribution hitherto is mainly built up on the framework developed by Koeppl and Monnet [71], Koeppl [68], Acharya and Bisin [1], Cama [25, 26] and Stephens and Thompson [99] for standardized derivatives transactions.

Clearing do not guarantee less exposure though. Literature mostly agrees that a reduction of counter party risk is due to multilateral netting. Initial and margin requirements also help to prevent further the excessive stack-up of risk exposures. However, Duffie and Zhu [47] show that size of exposures may actually rise with clearing; they explain that depends on the number of cleared assets and number of market participants. Cont and Kokholm [40] show that conditions for observing a decreasing exposure after clearing -stated in Duffie and Zhu [47]- are highly important whether correlation amid different asset positions are omitted. According to authors' calculations, reduction of exposures can be observed as least in a market with only 12 participants.

In the empirical side, literature has found mix results. For instance, Loon and Zhong [79] examines the impact of clearing on the CDS premium using a comprehensive DTCC sample of cleared single-name contracts. The authors found that CDS premium is higher under clearing. The factors explaining this difference seems to arising from either demand side or costs that inherently arose in a possible clearing framework (see Duffie and Zhu [47]). The foregoing actually appeals to the ambiguous effect of the increased value of credit protection as the driving mechanism to explain differences in premiums. This actually raises the question whether a better term of the credit protection is a costly feature and easily to be transferred to the buyers rather than being considered as a purely demand shock. On the other hand, on the contrary to Loon and Zhong [79], Du et al. [43] found that premiums on centrally cleared trades are significantly lower relative to spreads on uncleared transactions. Finally, Du et al. [43] state that their findings are consistent with the view that counterparty risk has minimal effect on pricing[1].

2.3 The data and sample

In this section I comment over the data and sample for the empirical approach. One of the variables of interest is the *basis* or price differential between LCH and CME. Specifically, the basis is constructed as the difference between the fixed-rate payer at LCH and the fixed-rate receiver at CME. In some periods, the basis for the same USD Swap Cleared at LCH or CME has increased significantly exhibiting a term structure with values up to 2bps; much larger than the typical bid-offer spread of 0.25 bps. According to Clarus[2] a basis of 0.15bps is to be seen as insignificant for the daily-range under analysis. The data source of the basis is Bloomberg and the frequency is daily since November 9th 2015.

[1]That assertion is also tested by Du et al. [43], authors found statistically significant effects of counterparty credit spreads on premiums but small.

[2]See cme-lch-basis-spreads.

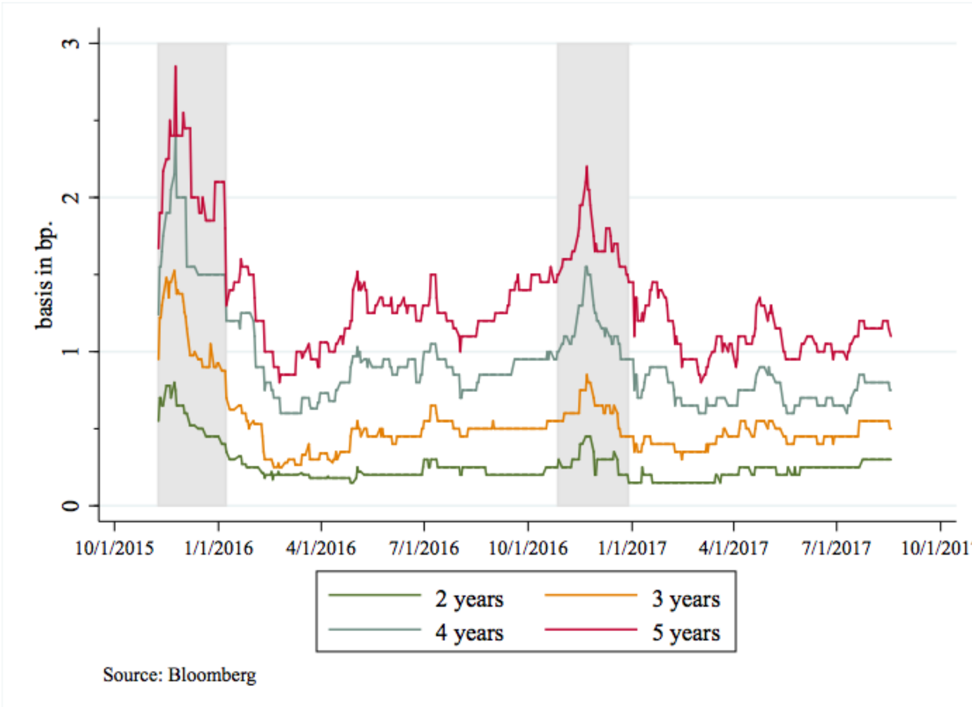


Figure 2.1: Basis, different maturities. Shaded area for 5Y values greater than 1.5 bps.

In the case of CDS, the database is made of reports of credit derivatives available between December 30th, 2012 and February 28th, 2018 which are publicly disseminated by Bloomberg using a truncated set of reports from Depository Trust & Clearing Corporation (DTCC). The database has information of the four most actively traded index CDS; these are CDX.NA.IG (*Investment Grade*) and CDX.NB.HY (*High Yield*) for North America and itraxx.Europe and itraxx.Xover for the case of Europe. CDX indices are a family of tradable CDS indices covering multiple sectors with classification as higher as investment grade with high volatility[3] or yield and also covering sectors with moderate diversification. These indices are made up of some of the most liquid entities in the relevant single-name CDS market. The indices roll on a semi-annual basis[4], and the composition of each new series (a new index) is established based on a transparent set of rules designed to enable the current series to track the most relevant instruments in the credit market.

[3] CDX.NB.HY.HVOL (High volatility) series was dropped from our sample.

[4] For instance each CDX Index that has a roll date of September 20th shall be issued with the maturity date of December 20th occurring 5 years and 10 years following the roll date.

Transaction	Number of Obs.	Relative frequency
Amendment	14854	0.028671
Novation	13886	0.026802
Partial Termination	39368	0.075987
Trade	449983	0.86854

Table 2.1: Credit Default Swaps transactions

The data report has information of maturity, premium in basis points, notional value, currency terms under the contract, usage of swap execution facility, identification of new trades, and trading of cleared/non-cleared transactions. A report can have amendments and cancellations those mainly refered to previous trades. According to Loon and Zhong [80] the reporting entity files a cancellation report that pinpoints the original report. As in Loon and Zhong [80] I also emove canceled reports by using a search of one or two days around the cancellation report that match same characteristics of the transaction. This is an alternative and quick procedure -in comparison to Loon and Zhong [80]'s protocol- due to the missing information of identifiers in the retrieved data. Same procedure for the amendments reports; in this case I keep only recent transactions. I remove transactions labeled as novated[5]. In the case of CDS, the cleaning process reduces the sample from 519 426 to 518 091 reports of which 449 983 are new trades and the remaining ones are corrected reports. Tables (2.1) and (2.2) describe the data. The sample covers 305 099 cleared reports (59%).

Type of transactions	Number of Obs.	Relative frequency
Cleared	305099	0.587383
Uncleared	214322	0.412617

Table 2.2: Cleared and uncleared transactions for CDS

In the case of interest-rate swaps, originally Bloomberg provides around 3.7 millions observations (see table 2.3), mostly contracts with fixed-floating legs. The regression analysis gathers only 1.4 millions of observations since I focus in transactions in USD currency. The percentage of clearing transactions is around 66% in the sample (see table 2.4 for details).

[5]This type of transaction is related to the compression of some contracts.

Transaction	Number of Obs.	Relative frequency
Amendment	229096	0.061583
Novation	126705	0.03406
Termination	338034	0.090867
Trade	3025293	0.81323

Table 2.3: Interest-rate swaps transactions

Type of transactions	Number of Obs.	Relative frequency
Cleared	2 447 945	0.6580
Uncleared	1 272 152	0.3419

Table 2.4: Cleared and uncleared transactions for IRS

I also present an additional specification for the interest-rate swaps model. I use a bivariate econometric model that jointly gathers the interaction between swaps rate and the Chicago Board Options Exchange (CBOE) Index of Volatility, henceforth VIX. According to Investopedia[6], VIX shows the market's forward-looking stance of 30-day volatility implied by a wide range of S&P 500 index options. In short, VIX is a widely used measure of market risk, often referred to as the "investor fear gauge". As a caveat -see details in the section of results- the theoretical model discussed in previous chapter assumes that market risk is constant, thus any change in the swaps may clearly be explained by clearing practices ultimately. The foregoing is enough motivation for undertaking additional econometric exercises taking into account the type-I error of presence of market volatility. I also juxtapose bivariate results for models that allows changing variance across time range. A model that allows a difference of levels of variance at some particular point in time may be another feasible alternative in terms of modelistic; this will be fully explained at the end of the following section.

2.4 The empirical model

In this section I derive the empirical model following Cama [26]. I will start with the theoretical equation that relates the basis and the size of exposure; then the empirical expression is obtained after introducing a clearinghouse and its practice over the maturity

[6]See more at VIX (CBOE Volatility Index).

period of the derivative.

2.4.1 The interest-rate swap model

As in Cama [26] the swap rate is calculated as

$$s^w = E_0^Q[L(T)] + cov_0^Q\Big[r_t + h(1-\beta(c,\varphi)_t), L(T)\Big](h\dot{\beta}(c,\varphi) - 1) \tag{2.1}$$

Whereby s^w represents the swap rate, $L(T)$ the libor rate with maturity T, r_t is the free-risk bond and $\beta(c,\varphi)_t$ is the collateralization -or amount of collateral in terms of the value of the contract- which depends on the size of exposure (φ) and collateral fraction (c).

The difference in swap rates or *basis* among clearinghouses A and B is as follows;

$$\begin{aligned}\Delta S \equiv s^{w,A} - s^{w,B} = cov_0^Q\Big[r_t + h(1-\beta_t^A), L(T)\Big](h\dot{\beta}^A - 1)\\ - cov_0^Q\Big[r_t + h(1-\beta_t^B), L(T)\Big](h\dot{\beta}^B - 1)\end{aligned} \tag{2.2}$$

Let's assume that β^A and β^B both have a decreasing trend i.e. $\beta^A = g^A(t) \equiv a + b\min(t,\bar{t})_{t>t_0} + \epsilon_{A,t}$ and $\beta^B = g^B(t) \equiv e + f\min(t,\bar{t})_{t>t_0} + \epsilon_{B,t}$ where $b < 0, f < 0$; t indexes time and $\bar{t} \in (t_0, T)$ and constants a and e are properly chosen to make $\beta^A \in (0,1)$ and $\beta^B \in (0,1)$ respectively, errors (ϵ) are distributed standard normal. Thus, the above expression (2.2) can be expressed as follows when including the terms of trend.

$$\begin{aligned}\Delta S = cov_0^Q\Big[r_{A,t}, L(T)\Big](hb - 1)\\ - cov_0^Q\Big[r_{B,t}, L(T)\Big](hf - 1) + \varepsilon\end{aligned} \tag{2.3}$$

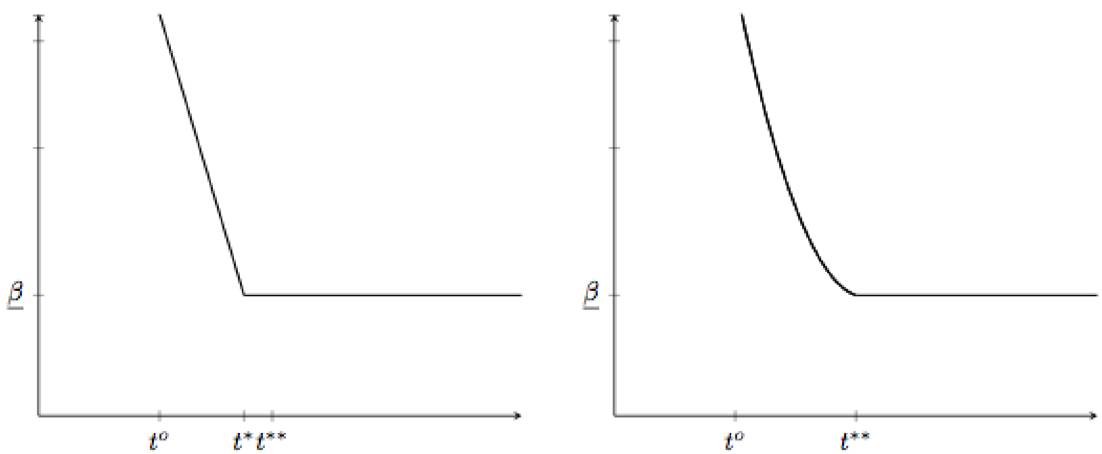
Whereby $r_{j,t} \equiv r_t + h(1-\beta_t^j)$ for $j = A, B$ and $\varepsilon \equiv \epsilon_A(hb-1) - \epsilon_B(hf-1) \sim \mathcal{N}(0, (hc-1)^2 + (hf-1)^2)$. When $t = \bar{t}$ then $cov_0^Q\Big[r_{A,\bar{t}}, L(T)\Big] = cov_0^Q\Big[r_{B,\bar{t}}, L(T)\Big]$. Thus, expression (2.3) can be arranged as:

$$\Delta S = h\ cov_0^Q\Big[r_t, L(T)\Big](b - f) + \varepsilon$$

Thus, if $f < b$ then $\Delta S > 0$ which proves that close to the boundary $\bar{t}$ the basis is still positive. In expression (2.3) covariances can be different since they are affected by the change in t. Thus, the basis (ΔS) can be expressed as a stochastic process with different drifts through the life of the contract. It must notice that for $t' < t_0$ β^A and β^B are constant and therefore expression for the basis would be represented by a random process. Figure (2.2a) shows β as a function of t; thus $\bar{t} \equiv t^*$ and $\underline{\beta} = a + b\bar{t}$.

In the case of a second-order polynomial for the size of the collateral i.e. $\beta^A \equiv \max\{a + bt + ct^2, \underline{\beta}\}_{t>t_0}$ and $\beta^B \equiv \max\{e + ft + dt^2, \underline{\beta}\}_{t>t_0}$, figure (2.2b) juxtaposes the shape of β for linear and quadratic assumptions. Hence, the basis can be expressed as;

$$\begin{aligned}\Delta S = &\, cov_0^Q\Big[r_{A,t}, L(T)\Big](h(b + 2ct) - 1)\\ &- cov_0^Q\Big[r_{B,t}, L(T)\Big](h(f + 2dt) - 1) + \varepsilon_t\end{aligned}$$



(a) Linear

(b) Quadratic

Figure 2.2: Change in β

Where the residual term can be re-written as follows,

$$\varepsilon_t \equiv \epsilon_A(h(b + 2ct) - 1) - \epsilon_B(h(f + 2dt) - 1) \tag{2.4}$$

Thus, the basis can be arranged as follows;

$$\Delta S = (\gamma_A - \gamma_B)t + \gamma + \varepsilon_t$$

where $\gamma_A \equiv 2cov_0^Q\Big[r_{A,t}, L(T)\Big]hc$; $\gamma_B \equiv 2cov_0^Q\Big[r_{B,t}, L(T)\Big]hd$ and $\gamma \equiv cov_0^Q\Big[r_{A,t}, L(T)\Big](hb-1) + cov_0^Q\Big[r_{B,t}, L(T)\Big](hf-1)$. Taking into account that $e^{x-1} = x$ when x is small enough, I can express the basis as:

$$\Delta S_t = \tilde{\gamma} + (1 + \gamma_A - \gamma_B)\Delta S_{t-1} + g(\varepsilon_t, \varepsilon_{t-1}) \tag{2.5}$$

$\tilde{\gamma}$ is equivalent to $(\gamma_A - \gamma_B)(1-\gamma)$ and $g(\varepsilon_t, \varepsilon_{t-1}) \equiv \varepsilon_t - (1 + \gamma_A - \gamma_B)\varepsilon_{t-1}$. Above expression holds when $1 + \gamma_A - \gamma_B > 0$. Thus, the basis can be represented as a AR(1) process with correlated errors and changing parameters. For sake of comparison with data from Bloomberg, I express (2.5) in terms of $\Delta S_t^d \equiv -\Delta S_t$,

$$\Delta S_t^d = -\tilde{\gamma} + (1 + \gamma_A - \gamma_B)\Delta S_{t-1}^d - g(\varepsilon_t, \varepsilon_{t-1}) \tag{2.6}$$

The threshold model. Expression in (2.6) shows a specification with a changing dynamic for the basis. The change in the size of parameter hinges on the parameter β which represents the relative size of the exposure level. Assuming for instance that clearinghouse A's reduction of exposures becomes more intense and thus this intensity reinforces the sign of covariance between r_t and $L(T)$ then the persistence would be increasing i.e. a higher value for $1 + \gamma_A - \gamma_B$. Also, the sign of the constant denoted by $-\tilde{\gamma}$ is ambiguous. In order to pinpoint these changes I propose a threshold model using a proxy for detecting the change of β in each clearinghouse. I mentioned a proxy for the key variable since data of collateralization and exposures is either not accurate or limited for only some contracts. The usual approach intended in literature lays on either calibration or estimation of exposures from notional values (see Duffie et al. [49], Cama [26] and Cont and Kokholm [40]). I consider a time measure that may be used as a proxy of β. This is the relative share market participation in derivatives market among clearinghouses, LCH has the lion's share and the changes of its market participation relative to the CME clearinghouse may lead a signal for detecting a change in parameters. I reproduce the figure shown in Cama [26] here below,

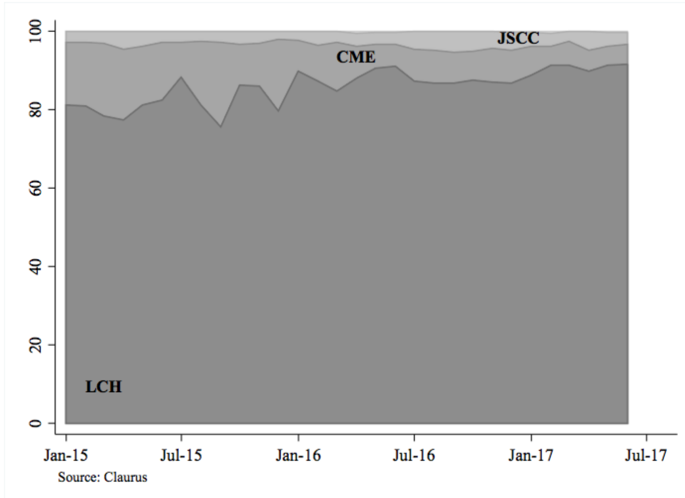


Figure 2.3: Derivatives market participation by clearinghouse

2.4.2 The Credit-default swap model

Cama [26] shows the premium hinges on the size of the exposure. The reduction of this exposure has effects on the collateral amount provided by the seller[7]; thus, keeping constant the counter-party risk and assuming perfect competition, the premium will decrease accordingly. In this section, I specify the empirical model based in the theoretical model shown in Cama [26]. The setup shows that premium is determined by equalizing the protection and premium leg for this asset; thus the premium and the exposure have a simple linear relationship that may be easily identified by standard linear econometric methods.

The relationship of interest in this chapter is the one between exposure and premium. Literature has emphasized in the effects of liquidity on the premium; this certainly gives a point of discussion between number of contracts sold and premium. In terms of utils for buyer, a contract with a low premium is related to a high exposure[8]. Similarly for the seller, low premium is related to low exposure as Cama [26] shows; as discussed this can be

[7]The collateral amount is determined by the collateral fraction -given by any risk management- and the amount of exposure.

[8]It can be related to additional costs when the exposure of her contract is significant high i.e. monitoring and legal fees, additional hedging, counter-party risk and so on.

a simple model constructed under the key assumption of perfect competition; however, the size of the effect of having less exposure on premium is a empirical question.

Data in Swaps Data Repository (SDR) through commercial data platforms or terminals still lacks of important information details[9]. The empirical model requires size of the exposure in any contract; regrettably, a comprehensive detail in data of this class of derivatives is clearly a limitation currently. However, the approach -I will present in next lines- requires only the identification of contracts that are cleared and non-cleared in data. Thus, the impact of collateralization under clearing is summarized in regressions that account for difference in premiums due to contracts traded in OTC versus clearing markets. Formally, data are stack taking into account year effects and the pooled-regression produce an estimate of treatment effect i.e. difference between treatment and control groups. In Cama [26] the difference of premium amid two clearinghouses is given by the following equivalent linear expression:

$$q^A - q^B = \alpha(\varphi^A - \varphi^B)$$

Where A and B stands for the market; q is the respective premium and φ is the collateralized fraction of the exposure as size of the notional value. The parameter α is positive[10]. The data discussed in section (2.3) can be separated in two groups: cleared and uncleared transactions. Thus, a pooled-regression with time-effects is the strategy to follow. In the terms of the aforementioned model, let's be A the clearinghouse, and B any market that do not offer market clearing services, thus keeping a constant relative collateral size equal to $\varphi^B \equiv \overline{\varphi}$;

$$\begin{aligned} q_s &= (\nu + \alpha\overline{\varphi}) + \alpha(\varphi^A - \overline{\varphi})\mathbb{1}_{s\in A} \\ &\equiv \tilde{\nu} + \alpha(\varphi^A - \overline{\varphi})\mathbb{1}_{s\in A} \\ &\equiv \tilde{\nu} + \tilde{\alpha}\mathbb{1}_{s\in A} \end{aligned}$$

[9] For example Bloomberg and CLARUS have a limited access to data.

[10] Actually $\alpha = c(\mu - 1 + p)w > 0$, where c is the fraction of the exposure being collateralized; μ is the cost of posting collateral per unit of notional, p is the probability of counter-party default and $1 - w$ is the subsidized-fraction received for paying out collateral costs. See Cama [26] for details.

Thus if transaction s belongs to A then $\mathbb{1} = 1$ and 0 otherwise. $\tilde{\alpha}$ represents the impact of clearing on the premium. Re-arranging above term and including an index for time series[11], the symbol (XB) for controls and η standing for error, finally the empirical model is,

$$q_{s,t} = \tilde{\nu} + \tilde{\alpha}\mathbb{1}_{s,t} + XB_{s,t} + \eta_{s,t}$$

The econometric identification of the relationship between premium and exposure (or collateral size ultimately) is standard. In order to identify the expression that determines the premium by the seller I consider the method of two-stage-least-squares (2SLS); thus, this procedure by construction would avoid to take into account demand factors effecting the premium.

2.4.3 Additional issues

In this section I explore two caveats in the theoretical model explained in previous sections that makes to undertake the addition of a new variable in the analysis and consequently a new specification under analysis. In expression (2.1) the parameter h *-the hazard rate for default-* is assumed constant. According to Duffie and Singleton [46] the term $h_t(1 - \beta_t)$ is the risk-neutral mean-loss rate of the asset due to default. Thus, Duffie and Singleton [46] states that discounting at the previous adjusted-short rate both the probability and timing of default and effect of losses on default are took into account. In this matter, the empirical approach includes the lineal parameterization of h by using the VIX series.

In section (2.4.1) I show the model behind data conceptually. However, time-series literature advises about significant bias when data suggest a unit root in the process[12]. I revise the high persistence of the basis serie in section (2.5) and I propose a estimation of the serie I(1) i.e estimation using same serie but in difference. I use a flexible model to take into account the heteroskedasticity property of the process according to expression (2.4). It is worth mentioning that the constant has ex-ante unknown sign as intensity in clearing practices increases; additionally, misspecification may bias the constant significantly. The

[11] Regarding this variable, the data provides information in hours and minutes.

[12] Literature revision about the unit-root bias is conclusive; in those terms the bias in the threshold parameter can be extensive as well.

former is not harmful in identification sense of course.

2.5 Results

In below section (2.5.1) I show the results from estimations using a simple threshold model for the basis. In section (2.5.2) I examine bivariate threshold estimations in order to overcome caveats to assumptions described in section (2.4.3). In section (2.5.3) I use a bayesian bivariate model for the serie in differences; I take advantage of model flexibility to showing a changing variance and circumventing some bias rising from unit-root processes. All these alternative models were considered for the case of the basis. Finally, in section (2.5.4) I run regressions to show that in average contracts are priced differently in clearinghouses in comparison to OTC markets after controlling for notional value, maturity and other significant variables. I do not intend other time-series analysis since the constrained data do not have information of reference entity or dealer. Although the former strategy is risky results suggest that bias size is not significantly large.

2.5.1 The threshold model

In this section I show results from threshold auto-regressive (TAR) or regime-change specifications. The estimation is very simple; the objective is to minimize the mean square error by using a grid-search on the domain of the variable that is candidate (*or threshold*) to break away the linear relationship. Then, the difference between the non-linear' and linear model's mean-squared error must be statistically different in order to conclude that there is enough evidence against linearity. I use a LM test to perform the statistical test of non-linearity and I also consider a bootstrap method of 20 000 repetitions for calculating the probability of null-hypothesis rejection. As discussed before, the threshold variable is the difference in derivatives market participation between LCH and CME, henceforth Δw. Furthermore, the methodology demands a trimming sample, this fraction is fixed to 18 %.

Formally, the model is as follows,

$$\textit{Regime 1}: \Delta S_t^d = \alpha_1 + \rho_1 \Delta S_{t-1}^d + \sigma\nu_t \qquad \text{if } q_{t^m-j} < \tau$$
$$\textit{Regime 2}: \Delta S_t^d = \alpha_2 + \rho_2 \Delta S_{t-1}^d + \sigma\nu_t \qquad \text{if } q_{t^m-j} \geq \tau$$

q is the threshold variable to look at to finding τ, τ is the value of the threshold and j is the number of periods in the past where the methodology detects a current regime change. In the estimation, I consider $j = 0, 1, 2$ that represent the current month (t^m), one and two previous months respectively.

Table (2.5) shows the methodology detects a difference in the mean-square error around the value $\tau = 0.82$; however the test of non-linearity does not found overwhelming evidence in favor of non-linearity at conventional significance levels.

	$q_t^m = \Delta$ w; $\tau = 0.842$	
	Regime 1	*Regime 2*
α	.0454573	.0616278
	[-.0229801 .1138947]	[-.0002358 .1234914]
ρ	.9683966	.9398102
	[.9154133 1.02138]	[.8831881 .9964323]

LM test for no threshold: 5.916. Boostrap pvalue: 0.18.

Table 2.5: Threshold estimation

In table (2.6) I show the results of a significance regime change for $j = 1$. The value of τ is around 0.80. The regime 1 shows less persistence than regime 2, this finding supports my specification shown in section 2.4.1. The LM test rejects linearity at 10 % only.

	$q_{t^m-1} = \Delta$ w; $h = .801$	
	Regime 1	*Regime 2*
α	.0768056	.0196317
	[.0060039 .1476072]	[-.0307401 .0700035]
ρ	.9431885	.9794700
	[.8881315 .9982455]	[.9350661 1.023874]

LM test for no threshold: 7.826. Boostrap pvalue: 0.0657.

Table 2.6: Threshold estimation

More lags for the threshold variable do not significantly reduce the mean-square error in statistical terms. Table (2.7) shows the methodology detects a difference in the mean-square error around the value $\tau = 0.75$; however the test of non-linearity fails to report evidence in favor of non-linearity at conventional significance levels. The addition of more lags have a detrimental effect since the domain of the threshold variable is reduced. Furthermore, each lagging throws away multiples of 30 observation days. This would eventually affects the accuracy of estimations[13].

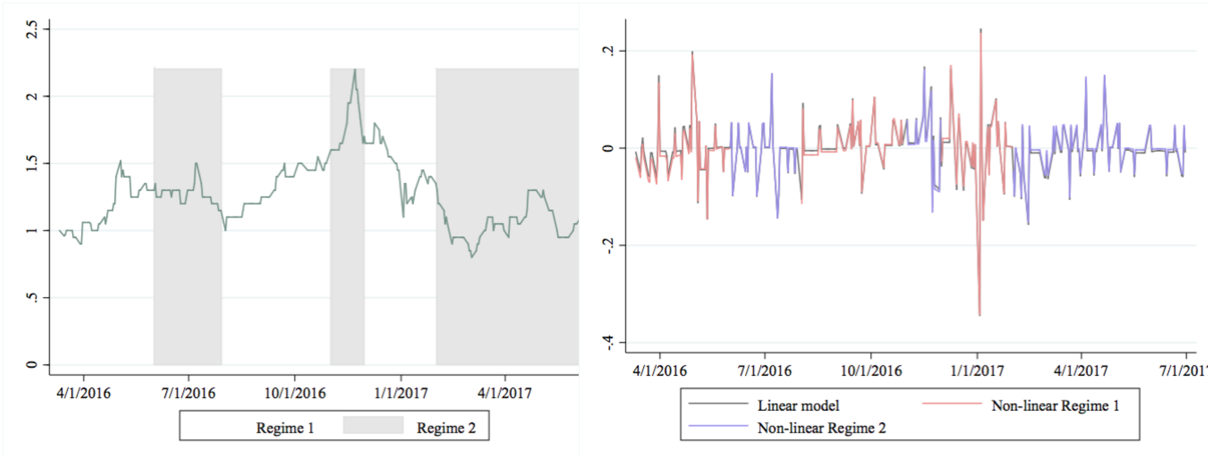
	$q_{t^m-2} = \Delta$ w; $\tau = 0.7494$	
	Regime 1	*Regime 2*
α	.088084	.038101
	[-.0690012 .2451692]	[-.000027 .0762289]
ρ	.9117851	.9708091
	[.7844919 1.039078]	[.9387484 1.00287]

LM test for no threshold: 5.1158. Boostrap pvalue: 0.29825.

Table 2.7: Threshold estimation

The regimes which were previously pinpointed by the TAR method are shown for the basis in figure (2.4a). The regime 2 appears for the first time in data from June 1st 2016 until July 29th 2016; then this regime covers exactly each day of November 2016; afterwards, the presence of regime 2 re-appears from February 1st 2017 to the end of the sample. The appearance of regime 2 represents periods where LHC has a significant more market participation in derivatives market. Figure (2.4b) shows the improvement of the goodness-of-fit of the non-linear model. As previously shown, the methodology detects a higher persistence of the series (see table 2.6); however this difference is not significant, actually the method only show a rejection of linearity only at 10%.

[13] Furthermore, the trimming for performing the grid-search reduces sample further.



(a) Regimes (b) Residuals

Figure 2.4: TAR model for the basis

In this following paragraph I assess the TAR model after statistical evidence shown above. The evidence in favor of a TAR model is not overwhelming in statistical terms. This univariate model and the lack of other covariates -that could be important for explaining the changing of the basis- arises the discussion of estimating alternative models. For instance, in expression (2.1) the symbol h -that denotes the probability of default of one of the counterparties- is assumed constant. In the next section, I incorporate the VIX as a measure of risk perception by the market into the analysis. I specifically use a bivariate model in order to find evidence of a non-linear relationship in the sample.

2.5.2 The Threshold-VAR model

In this section I show results for the bivariate model. Formally, the specification is as follows;

$$\textit{Regime 1}: y_t = \Theta_{1,t} x_t + \epsilon_t \quad \text{if } q_{t^m - 1} < \tau$$

$$\textit{Regime 2}: y_t = \Theta_{2,t} x_t + \epsilon_t \quad \text{if } q_{t^m - 1} \geq \tau$$

where the parameter Θ gathers the linear effects of the lags of the system on y_t as in a typical VAR method setup. In this bivariate specification I use the VIX and the basis as endogenous variables. For the sake of ordering issues that arise in VAR models, I assume that VIX error has an exogenous impact on the basis but the opposite.

The estimation uses bayesian tools. The threshold coefficient is around 0.7661 with an upper and lower values of 0.7792 and 0.7514 respectively. Table (2.8) shows the size and significance of parameters in the two-regimes VAR system. The basis has a high persistence in the regime where the market-rate participation is above the threshold. This finding is equivalent to the result shown in the previous section for the univariate case. However, the magnitude of this parameter can be debatable in statistical terms and the discussion may end up with the acceptance of a linear model ultimately. The table (2.8) also shows that coefficient associated to the lag of VIX in the basis equation is practically zero in the statistical sense. Likewise, according to the method, there is not enough evidence that previous values for the basis significantly impact on the VIX.

	$q_{t^m-1} = \Delta$ w; $\tau = 0.7661$			
	Regime 1		Regime 2	
	VIX_t	$basis_t$	VIX_t	$basis_t$
VIX_{t-1}	0.9268	-0.0008	0.8903	0.0025
	[0.8591 0.9899]	[-0.0052 0.0038]	[0.8331 0.9426]	[-0.0004 0.0052]
$basis_{t-1}$	1.4024	0.8804	0.2124	0.9655
	[-0.1045 2.8726]	[0.7849 0.9558]	[-0.3207 0.8206]	[0.9393 0.9878]

Repetitions in the MCMC chain: 4500.

Table 2.8: Threshold VAR estimation

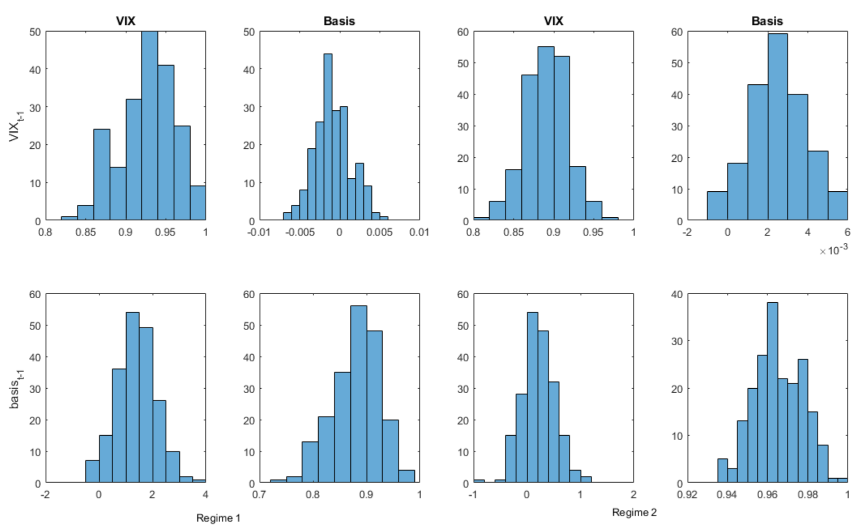


Figure 2.5: TVAR coefficients

Figure (2.5) shows the shape of the empirical distribution for each parameter in the estimation; the bayesian approach relies on flexibility thus its usage has enormous advantage when circumventing strong initial assumptions given by normality. Figure (2.6) shows the regimes for the series in the VAR system. Regime 2 prevalence in data since June 2016 is a result that contrast with the one shown in the univariate case. Theoretically, the method should correlates non-stop drops of the basis with a low relative market participation such as the one identified at the beginning of the sample[14]. However, there are not many episodes that would strongly shape this conjecture in sample. Regime 2 can be pinpointed in data showing sudden and short increases of the basis; this behavior can be conceptually assigned to a unit-root series ultimately.

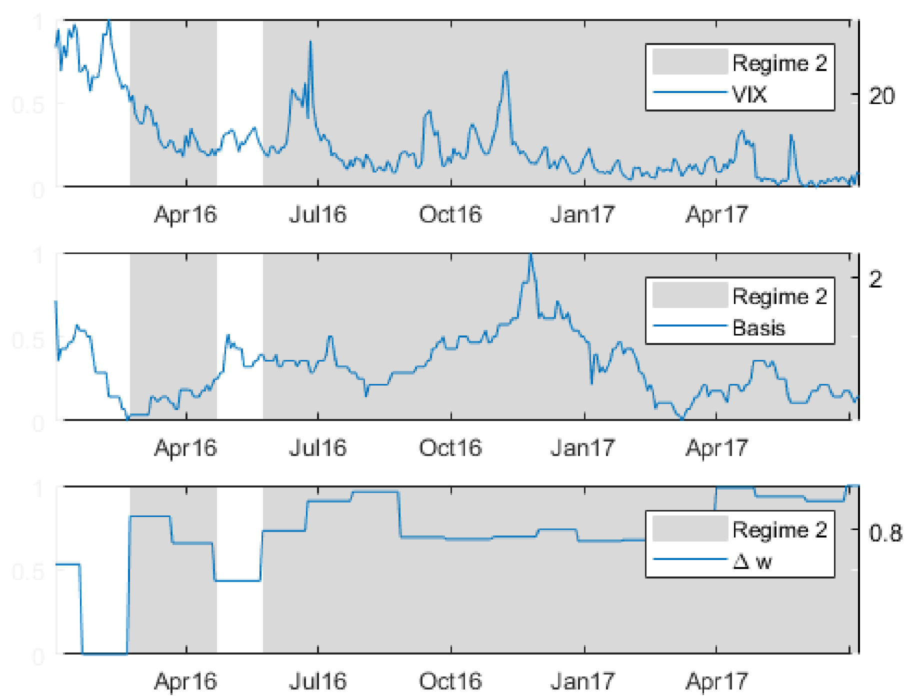


Figure 2.6: Regimes for a TVAR system

[14]The estimation sample starts after 30 periods since the threshold variable lag was fixed to be one month.

2.5.3 Alternative specification

In this section I show results from a bayesian estimation. The bayesian VAR estimates are mostly preferred because of they respect the likelihood principle and deal with misspecified models, as well as they have a good small sample behaviour and asymptotic properties. As previously discussed, I assume a unit-root for the *basis* serie and lay out the explanation of sharp increases of the *basis* on the bayesian estimation. The main idea is to find the shape of the variance depicted in expression (2.4).

The model to estimate is as follows;

$$y_t = \Theta_t x_t + \epsilon_t$$

where y_t is a vector of observed endogenous variables, in terms of Cogley and Sargent [36], x_t is used to built matrix X_t thus it is equal to $I_n \otimes x_t$ and x_t includes all the regressors (i.e, the lags of y_t as well the constant). The bunch of parameters gathered in $\theta \equiv vec\,(\Theta_t') \sim \mathcal{N}(0, Q)$ is governed by the nature of hyper-parameters. Since $\epsilon_t = A^{-1}\varepsilon_t$ then variance of ε_t is equal to $H_t = AR_tA'$ where A is a lower triangular matrix of correlations and R_t is the variance of ϵ_t. In the setup I consider a differenced-serie for both the basis and VIX.

In the bayesian setup, the continuous stylized stochastic volatility model can be described as $\dot{S}_\tau = \lambda d\tau + h_\tau dW_{S_\tau}$, the discrete version is approximately as follows;

$$\ln h_{it}^{\varepsilon} = \alpha + \delta \ln h_{it-1}^{\varepsilon} + \sigma_{iv} v_{it}$$

The volatility of innovations v_{it} are mutually independent. The variance of unconditional process $\ln h_t^{\varepsilon}$ hinges on the associated free parameter σ_v and δ which describe the variance of the errors and the persistence of the process for h^{ε} respectively. The priors are set up as in Cogley and Sargent [36]. In the cases whereby the density does not have standard form, literature handles that with an accepted-rejected sampling procedure (Metropolis-Hasting sampling). Details in the appendix section (C).

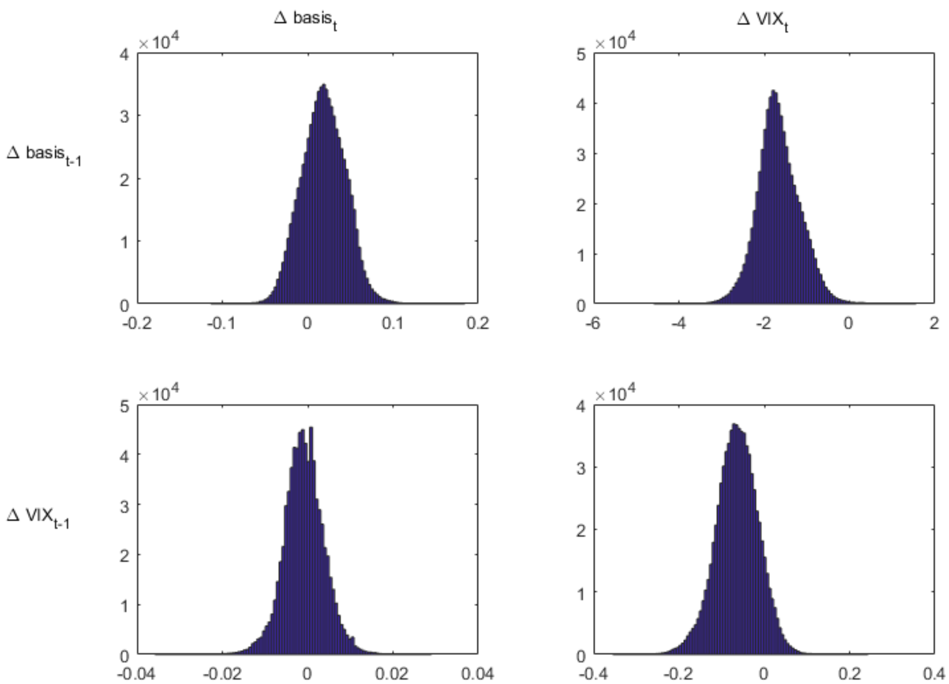


Figure 2.7: BVAR coefficients

In figure (2.7) the coefficients of the BVAR estimation are shown. The analysis by using (standard-size) confidence intervals reveals a time-series effects mostly for the VIX in difference. The coefficient related to the persistence of the differenced-basis is practically null in statistical terms[15]. Also the reader must take notice that there is no significance effect arising from VIX on the dynamic of the basis. The coefficient related to the persistence of the differenced-VIX shows a negative value. The effect of the differenced-basis is negative for any confidence interval constructed at some loose significance levels. The above analysis concludes that dynamic of basis does not rely significantly on the auto-regressive component of the model. Hence, the variance -that evolves through time- of the error component may explain mostly of the dynamics.

[15]The confidence interval under a bayesian estimation may be interpreted in other way though.

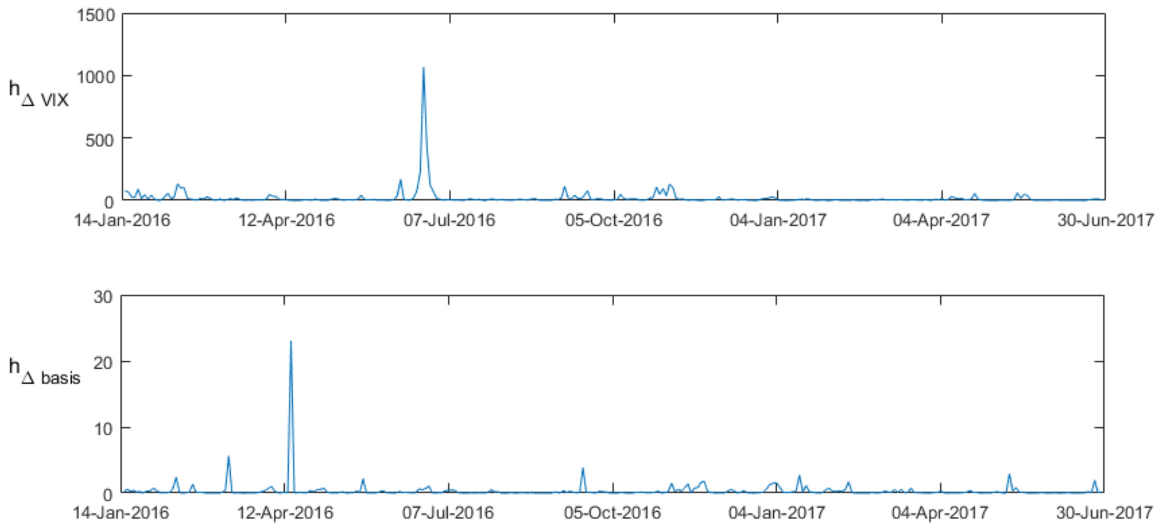


Figure 2.8: Stochastic volatility (h^{ε})

In figure (2.8) the variances (h^{ε}) of the innovations are shown for both differenced series. In the case of the differenced-series of VIX, the methodology detects a higher variance around July 2016. The size of this variance also has effects on the differenced-series of the *basis* due to the ordering of variables previously assumed upon the VAR model setting. The estimation suggests that errors between series are correlated positively; therefore any shock on one (exogenous) variable affects to the other in the same direction. Moreover, the sudden appearance and vanish of unusual values of shock realization enables to see changes in the same direction of the series under analysis for a significant period of time. Thus, differenced-series of the *basis* was affected by a shock with an unusual high variance around April 2016, the series "*climb up*" from 1 to 1.5 points. This lingering effect is explained by the presence of a unit-root with parameter of persistence greater than 1; the distribution of aforementioned parameter in the upper-left panel of figure (2.7) suggests that may be the case actually. Henceforth, the variance of the shock on the *basis* series would explain why the *basis* was relatively high (above 1.25 bp.) through April to the end of June 2016. The model also can explain other sudden change for the basis; as figure (2.8) suggests, around July 2016, the estimation shows VIX series was affected by shocks with a variance of significant size! These may explain the high and persistent change of the basis on its way to the mark close to 2 basis points at the end of year 2016. Also, starting 2017, the analysis suggests that both series had experienced shocks with moderate variance. However, it is worth mentioning that the method generalizes pervasive large positive shocks as evidence of large variance. In other words, mostly of the above argument is explained by using examples of large positive shocks but negative ones; particularly at low levels of the basis. The presence of further low levels of basis may produce arbitrage with contracts of maturity less than five years inside same clearinghouse, these gaps could be registered in data but ephemeral enough. Finally, values greater than 1.5 bps. for the basis are recorded when the market participation rate is high for LCH. In conclusion, significant changes in the variance of both series have had impact on the variable of interest. Also, sequential changes in the basis may potentially be produced by unit-root dynamics with a changing variance, particularly in periods where the market participation rate of LCH is relatively high. It is worth mentioning that methodology of estimation suggests a heteroskedasticity pattern more complicated than the one given by expression (2.4); however, as the reader may know, this is innocuous to the identification of parameters in the VAR system.

2.5.4 Regression analysis

In this section I show regression by index. Tables (D.3-D.10) report regressions of transaction-level premium for the following indexes: CDX NA IG (IG), CDX NA HY (HY), iTraxx Asia (AS), and CDX Emerging (EM). The dependent variable is transaction-level relative effective spread. The regressions employ a large amount of trading contracts executed between December 31, 2012 and February 28th, 2018, publicly disseminated by DTCC Data Repository (DDR), and for which the premium is reported. Explanatory variables are constructed from DDR trade reports and capture the Dodd-Frank reform, and the effects of segments, trading activity, and other product characteristics.

I consider the following regressors: *vclear* equals one if the trade is centrally cleared and zero otherwise. *vSEF* equals one if the trade is executed on a swap execution facility or designated contract market and zero otherwise. *Sefdt* equals one if the trade date occurs on or after October 2, 2013, and zero otherwise as suggested in Loon and Zhong [80].

vSEFSefdt is the interaction of *vSEF* and *Sefdt*. *Blkszdt* equals one on or after July 30, 2013 and zero otherwise. Regarding these dummies, Loon and Zhong [80] explains that SEFs required to comply with Commodities Future Trading Comission (CFTC) rules on registration and operation by October 2, 2013; while CFTC's minimum block size definitions became effective on July 30, 2013. *Tenor5* equals one if the index tenor is 5 years, and equals zero otherwise. *lsize* is natural log of notional size and *lmonthNot* is the notional amount traded during the current month. *difM* is the time in years between index expiration day and trade execution day. I control for eventual endogeneity using the method of two-stage least squares (2SLS); the setup requires an auxiliary regression for the size of transactions taking as exogenous variables possible determinants. In this case the total notional amount of transactions during the current month was specified as the suitable variable that would isolate endogeneity.

Regressions results are shown in appendix. In table (D.4) the regression analysis for series CDS.NA.HY shows a significant and negative effect of clearing. However, after controlling for the new reference entities that adjust the CDS index each semester, the wedge between cleared and non-cleared prices are smaller; the parameter related to the variable *vclear-seriesHYn* is positive statistically and produces an increase in the premium when the contracts are cleared. The series take the value of an increase index; thus recent contracts would offset the negative impact of clearing at some extent. Year-effects are significant and the significance of the effect of tenor of five years on prices just verifies the compensation for this class of assets in comparison to other short maturities. The trade in swaps execution facilities has a positive impact on prices. The remaining distance to the date of maturity is found to be small for specifications that do not include the VIX and 5-year tenor series. The reforms that started in October 2nd and July 30th in year 2013 (indicated by *Sefdt* and *Blkszdt*) have a positive impact overall. The interaction considering the placement of reforms and trading taking place in SEF -measured by variable *vSEFSefdt*- indicates that reforms had a negative impact on prices specially for trades happening in those SEF venues. Returning to the discussion of the effect of clearing, it seems that the impact of clearing is between -33 and -41% on prices; after controlling for external volatility and maturity, that effect falls to around -0.143 and -0.137%. For sake of comparison, Loon and Zhong [80] found the impact around -10.3% (see table 8 in Loon and Zhong [80]).

In the case of the index iTraxx Asia (AS) and CDX Emerging (EM), clearing has a negative effect on premium after controlling for same variables used in the previous analysis for CDS.NA.HY. The time effects are important for all mostly specifications shown in tables (D.8) and (D.10). The premium seems to be unaffected by the size of the notional value for these both indexes. Also, at least a reform have significant effects on the premium of AS. In the case of index EM, the late reform considered in regressions had a negative effect on premium for clearing transactions. Additionally, early reform had an overall positive impact on premiums. The VIX variable has a positive effect on the premium for the index AS only. In the case of CDS.NA.IG, clearing has a puzzling positive effect on premium (see table D.6); however, specifications taking into account reform effects show that new series within CDS.NA.IG index have a lower premium than the old ones for clearing contracts. Also, year effects are negligible in statistical terms and VIX variable has a positive effect on premium. On the side of effects of reforms different specifications show modest positive effects on premium. The variable *tenor5* for this index has a negative effect; since 5-year contracts are mostly traded in the derivatives market, this could be seen as evidence of economies-of-scale for this particular index.

The restricted data issue arose earlier in section (2.4.3) is not quantitatively harmful besides the right sign of the parameter that represents clearing effects; the additional variables found in literature that are omitted in regression analysis accrue to five to seven percentage for the total explanation-power of the model. Thus, my specification makes around the half of the total goodness-of-fit of the regression model overall in comparison to empirical findings in literature.

2.6 Conclusions

The theoretical model in Johannes and Sundaresan [64]-*that explains the effect of collateralization on swap rates*- is modified by Cama [26] in order to describe the existence of at least two regimes with heteroskedastic errors. I carefully setup the empirical side looking for statistical evidence that supports the aforementioned structure. Since information of the size of exposure and respective collateralization are limited, I circumvented this problem by using a proxy for this variable. Thus, I propose the derivatives-market participation as the variable closely connected to clearing practices that eventually reduce the size of exposures. If this participation increases relatively for some clearinghouse, the exposure and its collateralization would be compressed due to more participants and assets. Thus, the derivative-market participation indirectly provides evidence of a significant difference of swap rates that may be found either amid clearinghouses or bunch of markets that specially compromise in clearing practices.

A TAR model is implemented to explain the dynamic of the *basis*; the evidence against linearity is supported at conventional confidence levels. A TVAR was also implemented in order to overcome the absence of risk and volatility effects in swap contracts arising from external variables. The persistence of the *basis* was found to be significant large in both univariate and bivariate models and the dynamic of a closely unit-root process may explain sudden and sharp increases in the *basis*.

The aforementioned results suggests that basis does have two separated regimes for the auto-regressive component in the statistical sense. Additionally, assuming series are integrated of order one - as threshold methodology suggests after June 2016- and setting up a flexible model that supports a time-changing variance, I detect unusual changes in the variance of the bivariate error around April and July 2016. These dates are associated to high market participation rates for LCH, this share is at least above 0.75 mark. The former suggests that methodology shows a higher variance when market participation rate is high but the size of these variances are not the same amid these aforementioned dates. In conclusion, significant changes in the variance of both series have had impact on the *basis*. Also, sequential changes in the basis may potentially be produced by unit-root dynamics with a changing variance, particularly in periods where the market participation rate of LCH against CME's one is relatively high.

In the regression analysis for both interest-rate and credit-default swaps, there is statistical evidence supporting that clearing has a negative and significant effect on swap rates.

Literature has found the same result using a short period of analysis. A proper caveat was addressed earlier due to limitations of data sources; literature on this topic suggests additional variables than the ones presented in the final results. These variables measure important liquidity and micro-structure effects. However, the omitted-variable bias is not large according to my regression analysis; the sign of the parameter measuring the effect of clearing on premium prevails. In quantitative terms, the impact of clearing in derivatives contracts is between -33 and -41% on premiums; additionally after controlling for external volatility and maturity that effect falls to around -0.143 and -0.137%.

Regarding future work. Since information about collateral amounts and exposures is limited, my research implicitly calculates changes in collateralization of exposures by using the changes in the derivatives-market participation; the direct estimation needs to inputs as correlation size amid assets and collateral policy. As an alternative, structural models can help to estimate the deep parameters associated to the implicit model. Also, it would be interesting to incorporate in data characteristics of receivers and payers of derivatives instruments and further market characteristics, this would help to increase the explanatory power of the empirical model.

Chapter 3

The Effect of Mutualization and Collateralization on Credit Default Swaps Premium

3.1 Introduction

This chapter investigates how particular clearing procedures affect credit default swaps premium and further implications concerning the minimization of counterparty risk. I embedded a regulatory-agent or clearinghouse into a standard financial market that trades credit default swaps (CDS). I setup the insurance market as one characterized by a lower premium and higher exposure to counterparty risk in equilibrium as a result of opacity of over-the-counter markets. In general, if a CDS seller defaults, premium is lower when mutualization takes place as clearing policy and capital requirements are not too low. The allocation is characterized by a higher recovery rate and also by a large number of non-defaulting contracts relative to a bilateral agreement. Clearinghouses may offer incentive contract when collateralization takes place as clearing policy. The premium is higher for this practice relative to bilateral agreements. In equilibrium there is not default for this particular contract. The premium increases since the value of the position (the recovery rate) increases. This chapter has implications for the interaction of derivatives markets and regulation.

The most predominant feature in the recent financial-crisis aftermath was the shortage of liquidity and the worsening of the trading standstill over the asset market. It was also notorious that real sector and the rest of financial markets dreaded contagion after the collapse of the shadow banking sector[1] where finally the massive defaults on CDS were identified

[1]A collection of investment banks, hedge funds, insurers, and other non-bank financial institutions that share some activities of regulated banks, but differently supervised.

as one of major culprit in the financial crisis[2] Comm. [39]. CDS is a financial derivative contract whereby the buyer attempts to eliminate any possible loss arising from a default event. The seller (typically a financial institution) seeks a compensation for absorbing the future risk of having to make the conditional payment. Literature has pinpointed these CDS as leaky boats or destabilizing-and-contagion triggers. Thus, since great recession, participants have requested market reform and regulation, particularly on derivatives instruments. Dodd-Frank[3] act in 2010 was an immediate response to last crisis and this initiative surely continues to be in the spotlight of discussion[4]. Other recent initiatives -such as Volcker rule, Lincoln Amendment and Basel III- intend to bring secure provisions and thus ending the concept of "too big to fail" ultimately. In other areas, proposed regulation has made some progress, but did not go far enough in others, specially in derivatives market[5]. Credit derivatives have currently had a significant growth since great recession aftermath. Last year, Financial Times[6] informed that a record of US$15.7bn in gross notional outstanding positions of single name CDS was cleared by investors in one of the largest credit derivative clearinghouse (Inter Continental Exchange ICE). The activity of derivatives fell hardly in 2008 and since 2010 consequently asset managers and hedge funds are attempting to bolster liquidity in clearinghouses even if the cost of clearing is higher than over-the-counter markets. According to Depository Trust and Clearing Corporation, the current outstanding gross notional for single CDS is around US$6.8tn compared with US$14.8tn at the end of 2008.

Dissecting price changes for CDS is the main subject of this chapter. I particularly focus in asset pricing determination or price discovery after specific policies (regulation) on

[2]The run on repo is also cited as an important factor behind the collapse of the shadow banking; however, Krishnamurthy et al. [73] suggests that run akin to the bank runs was confined to a small portion of the repo market.

[3]The reform and its impact is 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 role of supervision.

[4]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 [17]). According to CLARUS -a financial advisor company- this regulation will help with implementation of public disclosure requirements; and thus allowing for calibration/comparison and a smooth transition by banks prior to regulatory implementation in 2018/19.

[5]See Baily et al. [9] for a general assessment of the regulation-related steps still on progress.

[6]February 4, 2016 "Credit Default Swaps activity heats up?"

financial markets take place[7]. The current paradigm describes how to do the pricing of the CDS taking into consideration not only the risk of the event but also the risk of default of seller and buyer. More important, the impact of regulation on premium has not been studied yet from a theoretical perspective for a specific market. The interplay between price discovery and regulation is not really new in a broader or aggregate framework and the objective of my research resembles the ones in quantitative assessments, those typically found in general equilibrium analysis. For instance, in a banking environment, by easing credit conditions an ad-hoc regulation policy may impact on the real interest rate, even in the absence of any direct change in the interest rate of reference. The ultimate objective is to construct a framework of asset-pricing determination that may be embedded in a general equilibrium model, this extension certainly will be useful in hot and popular topics of regulation nowadays (e.g. macroprudential policies) and others not akin that require the usage of insurance models with extensions to an endogenous-price setup[8].

Price discovery is an important concept for surveillance of risks. For instance, monitoring of rampant prices are important since supervisors and monetary policy makers may able to interpret them according to fundamentals as liquidity changes, business cycle and credit risk arises. For instance, in the euro zone (see Annaert et al. [5]) and during the recent financial crisis, there was evidence that CDS spreads rose notoriously and mainly due to increased credit risk with a particular role of both individual and market liquidity. Thus, it is worth taking a dissection of price changes when regulation takes place over the market. In fact, optimal regulatory policy in the presence of limited liability is scarce even when takes to evaluate long-standing discussion of loss-sharing package program (see Keister [66] for a discussion about bailouts). Thus, derivatives market may have a "too big to fail" feature and a proper extrapolation of bailouts analysis will be certainly useful. Limited liability is another factor to take into account in the pricing of CDS. This has a significant impact in the pricing since not only matters to know the seller positions but also the size of those.

[7]Recent mainstream of discussion discourage the usage of large economic model; instead surveillance and understanding of specific markets in partial equilibrium would provide useful insights; for example, Smith [98] suggests that instead of focusing on consumption or other aggregates, economists might try thinking more about long-term buildups of problems in financial markets.

[8]See Borensztein et al. [22] for details of the impact of natural disasters using a sovereign insurance model. The setup keeps the premium constant.

Therefore, I study the interplay of above variables and CDS premium in Acharya and Bisin [1]'s model modified to analyze some of the functions that a clearinghouse performs.

The presence of clearinghouses seems to be critical for the structure of financial markets in the upcoming years[9][10]; clearinghouses hitherto arise as the device that would make the market more transparent, secure, stable and free of contagion (Acharya and Bisin [1]; Pirrong [92]). Immediately after the recent financial crisis, literature started evaluating the introduction of central counterparties. Central-clearing or clearinghouse practices is ultimately a risk-sharing arrangement; by applying netting, collateralization and mutualization, a clearinghouse prevents to build-up excessive risk and consequently ameliorates allocation of resources. The concept is not really new and mostly applied to other markets e.g. futures; thus, literature points out significant advantages from this arrangement (see Pirrong [92, 90, 91]), however, some requirements in the structure are demanding at the initial setup[11][12]. This certainly behooves us to examine policy practices through the glass of a microstructure model. Few approaches cope with collateral policies of clearinghouses whereas their financial structures are limited in terms of market completeness (see Koeppl and Monnet [71, 69])[13].

In contrast to transactions taking place in Over-The-Counter (OTC) markets, the original counterparties' contracts are replaced having a central counterparty or clearinghouse as a new partner. Thus, the clearinghouse becomes the buyer to the original seller and the seller to the original buyer, this formally is called novation. A clearinghouse has the potential to reduce systemic risk through i) multilateral netting of exposures through novation, ii)

[9]First clearinghouses can be tracked to 18th century Japan (Schaede [95], Kroszner [74]), evolution of operation range from controlling quality to delivery; thus reducing risk and improving the channel of distribution.

[10]Since the crisis has subsided, a series of initiatives have been arisen to better contain and mitigate systemic risks (see Fund [52]). 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.

[11]On the other hand, research questions the nature of clearinghouses; this side of literature finds that clearinghouses can hasty impose inefficient outcomes in trading volume, collateralization levels (Koeppl and Monnet [71, 69, 70], and other matters arising even from asymmetric information (Pirrong [91]).

[12]Fund [52] 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.

[13]Most microstructures are related to futures market (see Koeppl and Monnet [71]) showing the work of incentives.

enforcement of robust risk management standards, and iii) mutualization of losses resulting from clearing member failures. The clearinghouse can adjust the frequency of settlement, impose certain trading limits, or vary collateral requirements (Koeppl et al. [72]). Initial margin should be in the form of cash, government securities, and possibly other high-quality liquid securities (Fund [52])[14].

Mutualization, netting and collateralization are standard risk-sharing practices. As for mutualization, the clearinghouse earmarks funds from all participants and distribute them among members which experience the loss or default. Hence, mutualization guarantees a fixed payment to whoever long the asset; thus they could be perfectly insured against the risk. Netting current liabilities with value of incoming assets reduces the exposure of contracts at risk of default, offsetting different contracts may reduce the dollar amounts at risk upon default significantly. Collateral reduces the amount of credit implicit in derivatives trades. It is expected that clearing practices bring an efficient market structure for standardized financial contracts. It is clear that clearing practices do not make risk disappear: they reallocate it from those who bear risk at a high cost to those that bear it at a lower cost. Collateralization or margin calls paid by members only cover a portion of the risk and do not take into consideration large swings of losses; calibrating margin parameters in order to covering these changes would cost non-negligible additional margin to each clearing member if implemented. Thus, mutualization may provide cheaper resources to hedging actual market risks. Notwithstanding all these clearing practices have costs arising from information and incentive problems; moreover, the interplay between incentives and clearing policies may affect other variables as liquidity, choice of dealer or price determination. This chapter separately analyzes the effect of posting default funds and collateral on premium since as in Du et al. [43] buyers may face either dealer or non-dealer transactions; this properly requires to consider different strategies for hedging risk.

Trade opacity is a fundamental characteristic of the OTC structure; no trading party

[14] Fund [52] states that in order to satisfy the obligations of a defaulting credit members, clearinghouses use the following layers of protection: i) participants' margin; ii) margin posted by the defaulting clearing member; iii) Defaulting clearing member's contribution to the clearinghouse's guarantee fund; iv) CCP's first-loss pool; v) non-defaulting clearing member contributions to the CCP guarantee fund; vi) clearinghouse's claims or capital calls on non-defaulting clearing members and vii) the own clearinghouse's capital or equity (tier 1 and 2).

has full knowledge of short or long positions of others. A.I.G's inadequate liquidity position and other potentially unstable insurers as Citigroup and Merrill Lynch[15] produced large costs on the financial system; recent financial crisis showed that opacity was responsible for allowing the stack-up of such large exposures and thus marked the beginning of the consensus on reforms by the G20 in 2009. Since then, the reform led a mandate requiring that standardized OTC contracts to be cleared at a central counterparty. Standardized CDS contracts must trade on regulated exchange-like platforms called swap execution facilities (SEFs). Also, all trade information on CDSs is required to be reported to a central data repository and CDS market participants must hold cash in margin accounts as a buffer against changes in CDS valuations. Due to these changes, a stream of recent literature suggests the need to disclose information of all trades to agents in current opacity markets. Acharya and Bisin [1] state that enabling transparency of positions and trades, by creating a clearinghouse to all transactions, can ameliorate the quality of counterparty risk affected by taking on excessive leverage. This has become critical in the agenda of reforms for the financial sector immediately after the great recession. As pointed out by Acharya and Bisin [1], for instance, Acharya et al. [3] assort reforms proposals into either requiring or not the fully disclosure in a clearing framework; even some proposals consider full public disclosure of prices and volumes. Interestingly, the research agenda on clearing trades in opacity markets is still on its beginnings and in continuous progress.

Recent criticism about aggregate models and their predictions make researchers to turn into specific markets[16]. My research compresses the asset price dynamics theory into a material that would be critical as input in large and general macroeconomic models. A rich model with exogenous shocks and the consequent feedback from asset markets would give us better forecasting models and strong policy proposals; this has been a concern from the deeply and worrisome dearth of ability to predict last recession. [17]. The model developed in next sections will be certainly helpful for appraising next stream of reforms; Trump's plan to reduce regulations has received a scathing debate and it still certainly provides a

[15] See Thompson [101].

[16] See Blanchard [19] and [18].

[17] Rajan [94] expressed concerns regarding CDS trading back to 2005; the author argues that changes in the financial sector had altered incentives and risk consequently, with potential for distortions.

spotlight for discuss and hold tightly the benefits of mutualization and collateralization in opacity markets. How agents respond to policy is a research study that entails to review mandates that are widespread and profound, and obviously source of important systemic implications. Hence, policymakers should be acutely conscious of the potential for such effects from clearing, and be prepared to respond actively or passively to change in asset prices. Formally, this chapter uses a theoretical approach to test the following hypotheses that are ubiquitously found in empirical research[18]: i) central clearing causes an increase in premium through its impact on counterparty risk; ii) premium under central clearing is higher than one in a bilateral agreement; and iii) lower premium is associated with low mitigation of risk. These hypothesis will be tested conditionally to two clearing policies: fully collateralization and mutualization of losses. I also indirectly test the hypothesis of the presence of a lower premium when trading exclusively takes place in a price-competition market; it seems that competition for itself has a role in explaining lower premiums, see Stephens and Thompson [99] for details. I assess this hypothesis in my setup straight forward assuming random matches among participants when trading.

The endogenous recovery rate and premium is a remarkable feature of the model that will be shown in the section (3.3). This means that not only price is affected by clearinghouse policies also the notional amount of insurance. In other words, the terms of transaction in contracts are affected and it clearly marks a difference with trendy literature which is ubiquitously focused more in exchanges assuming constant prices. Also, it is worth noticing that the model delivers a partial equilibrium solution which has the potential to produce endogenous results in a extended general framework; questions - in the same line as directed by Yellen [107][19]- arising from the interplay of macro-prudential policies and the financial sector can be addressed with the usage of a model of insurance.

[18] See Loon and Zhong [79] and Du et al. [43].

[19] According to Yellen [107] 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 to 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.

3.2 Literature Review

This chapter studies how a particular clearing procedures affect credit default swaps premium and further implications concerned with minimizing counterparty risk. Early contribution by Koeppl and Monnet [71] shows that price for futures transactions might be affected by mutualization; instead, my chapter jointly takes on endogenous default and determination of prices. Earlier work has focused in additional earlier contributions have considered what benefits central clearing offers, such as netting (see Duffie and Zhu [47]), information dissemination (see Acharya and Bisin [1]) or the segregation of collateral as a commitment device (see Monnet and Nellen [85]). My analysis here is mainly built on the framework of Koeppl and Monnet [71]; Koeppl [68] and Acharya and Bisin [1] and Stephens and Thompson [99] that exhibits effects of novation, information and mutualization of risk for standardized derivatives transactions and an improved risk allocation for customized derivatives.

Significant progress in the literature has emerged regarding insurance provision and moral hazard since eighties (Stiglitz and Weiss [100] Duffie and Zhu [47], Acharya and Johnson [2], Parlour and Rajan [89], Acharya and Bisin [1] and Leitner [76]). However, mostly literature has still focused on moral hazard on part of the insured due to the existence of imperfect information. Recently, important contributions have been made by Acharya and Bisin [1], Stephens and Thompson [99], Thompson [101] and Koeppl [68] by studying the effects of moral hazard on part of the insurer on contracts instead. Acharya and Bisin [1] show that 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" to the foregoing and emphasize that social cost is not fully priced into CDS. Stephens and Thompson [99] study price competition when type of insurers are unknown in a model of insurance provision with limited liability in seller obligations. Clearing practices, specifically mutualization, is explored in Stephens and Thompson [99] suggesting that a high increase in counterparty risk and a prevalence of bad insurers would result in equilibrium. Other contribution for price determination is found in Koeppl [68] 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 not involves fulfillment of promises. Although above cited works achieve explicitly a price determination, they have different features that makes appealing to explore them in a general and concise setup that could resemble some stylized facts immediately before the recent financial crisis.

Literature mostly offers valuation or pricing of securities with exogenous hazard rates of defaulting[20]. Important extensions were made studying pricing under a joint default of both buyer and seller and specially when default occurs prior to the maturity i.e failure of no-jump condition (see Collin-Dufresne et al. [37]; Duffie and Singleton [46]; Duffie et al. [48]). For example, Leung and Kwok [77] and Jarrow and Yu [62] analyze the effects of a change in the probability of CDS's default on spreads jointly with other possible parties' probability default. A structural model that incorporates effects of collateral on CDS premium into a financial model is scarce in the literature so far; however, the existing literature is producing an important paradigm for determination of prices in a clearing framework. For example, Acharya and Bisin [1] study how to restore an efficient level of insurance by promoting transparent positions in insurers' balance sheet; the price and recovery rate are endogenous to the clearing policy. In a price equilibrium determined by competition, Stephens and Thompson [99]'s setup makes limited liability a key in explaining lower levels of CDS premium under clearing.

Certainly collateral is a fair demanding practice under clearing. Collateral requirement is the cornerstone in the lender-borrower relationship literature. Since borrower may become insolvent due to either exogenous (and intrinsic) factors or off-contract incentives that ponder on outcomes, 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

[20] Literature encompasses what is called structural and reduced-form models, the former explicitly define firm's value dynamics and some limited-commitment style compromise after default of reference entity or bond. In contrast approaches using reduced-form models abstract from valuation of firm; thus the default process is exogenous. According to Duffie and Lando [44] 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.

or reducing ex post incentive problems[21] [22]. Thus, collateral as signaling device arises to inducing loan applicants to reveal their default risk[23]. As for incentive contracts, theory points out that pledging collateral is optimal since potentially reduces effects coming from moral hazard[24]. Precisely, Koeppl [68] studies the effect of agency problems on the role of clearinghouse as a storage facility and a contract settlement agent that arises from novation. Koeppl [68] particularly analyzes an exchange market where asset pricing responds to contracts underlying no 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 price of transactions arises due to clearing. The effect of collateralization, specially in a derivative market, has not been studied deeply by construction. According to a recent global survey by ISDA, 22 percent of OTC derivative transactions are uncollateralized[25] Dealers and some other types of participants currently operating in OTC markets tend not to adhere to the idea of putting up collateral in a clearing framework. Fund [52] points out that without being mandatory there is some uncertainty whether enough multilateral netting and endowments can be achieved for daily operations, this is clearly discouraging beyond the collateral requirements. Fund [52] explicitly mentions that an approach that uses incentives based on capital charges or a levy tied to dealers's contribution to systemic risk could be used to encourage the transition.

Effects of clearing on CDS premium also may be evaluated looking at partial correlations between variables of interest. Literature delivers a fair amount of empirical evidence about premium changes due to counterparty risk and other interesting variables such as dealer

---

[21] The former represents the presence of adverse selection and credit rationing (see Stiglitz and Weiss [100] and Martin [81]).

[22] In addition, collateral also eases any limitation in contract enforceability (Cooley et al. [41]) and it still remains in some cases a feasible alternative to monitoring project outcomes at sufficiently low cost (Townsend [103]).

[23] See for details Bester [13, 14], Besanko and Thakor [11, 12], Chan and Thakor [32], Boot et al. [21], Mas-Collel et al. [82].

[24] See Boot et al. [21], Boot and Thakor [20], Aghion and Bolton [4], and Holmstrom and Tirole [58].

[25] According to this report, 78 percent of transactions (by notional amount) that are collateralized, 16 percent are unilateral, where only one side of the transaction is obliged to post collateral. In addition, where there is an agreement for bilateral collateral posting, such posting can be hindered by disputes between parties about the valuation of the underlying positions and collateral that result from diverse risk management systems and valuation models. Central clearing substantially reduces this problem, as it standardizes valuation models and data sources.

choice risk profile, liquidity and horizon of investment (Arora et al. [7], Arakelyan and Serrano [6]). However, empirical evidence on how CDS interact with regulatory policies is incipient. Loon and Zhong [79] examines the impact of clearing on the CDS market using a sample of voluntarily cleared single-name contracts. As expected, authors find a significant response of premiums to reduction of counter party risk from different factors; multilateral netting, initial and margin requirements also help to prevent further the excessive stack-up of risk exposures. Precisely, Loon and Zhong [79] found that CDS premium is higher under clearing. Du et al. [43] investigate whether central clearing has had an impact on how market price CDS contracts for different set of transactions involving dealers. Contrary to Loon and Zhong [79], Du et al. [43] found that premiums on centrally cleared trades are significantly lower relative to spreads on uncleared transactions. Loon and Zhong [79] appeals to the increased value of credit protection when clearing to explain the increase in the premium; instead, Du et al. [43] state that their findings are consistent with the view that counterparty risk has minimal effect on pricing[26]. Actually, the former could be not odd to find whether assuming collateralization and clearing practices fully eliminate counterparty risk. An interesting approach by Shan et al. [96] found that banks that actively use CDS had significantly low-risk ratings in comparison to CDS-inactive ones, this made possible that some banks produced more leverage. It was clear that CDS were not aligned by fundamentals and the hedge provided by CDS was not correctly priced.

Strategies under fully disclosure of positions such as netting and mutualization are a perfect companion for mitigating even further counterparty risk; however, in a framework that allows non-transparency markets, such strategies have not been fully studied at least in a theoretical framework. Specifically, Acharya and Bisin [1] state that constrained Pareto efficient allocation cannot be supported as equilibria in economies with non-transparent markets and netting.

The analysis in models of a possible change of terms of trade due to clearing procedures is still scarce in the literature; Augustin et al. [8] suggests that Dodd-Frank and Basel III effects are under-researched so far and these will certainly affect other dimensions of CDS

[26] That assertion is also tested by Du et al. [43], authors found statistically significant effects of counterparty credit spreads on premiums but small.

trading channel. The change of the premium to 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 the terms of trade ex-ante required by participants. Most of existing work focuses in showing the mutualization as well as the higher welfare achieved with a minimal cost of collateral (see Monnet and Nellen [85], Koeppl and Monnet; 2009; 2012) however prices are exogenously given. Koeppl [68] has an interesting approach that precludes some transactions from not defaulting and possibly, susceptible to observing higher trading prices in equilibrium. To the best of my knowledge, Stephens and Thompson [99] is the only paper that analyzes price determination of CDS prices so far. Stephens and Thompson [99] reckon that clearinghouses would produce some adverse affects and a declining price as result of price competition. I incorporate some Stephens and Thompson [99]'s features such as as limited commitment on the cost of insurance delivered to the seller in the model described in section (3.5); thus, the clearinghouse can use it as funds for mutualization.

Other features of the model are found in standard literature extensively. The model presented in section (3.5) mostly is based on Acharya and Bisin [1]; whereas that paper is concerned in the gains of disclosured information of positions in terms of allocation, my research emphasizes the setup of mutualization and its effect on CDS premium. The impact of clearing in opacity markets keep the spirit of Carapella and Mills [28]'s work that backstop an equilibrium with no release of information. I use definitions of type of contracts in Koeppl [68] that help to pinpointing contracts that make seller to do not consider make a default call. The optimal size of collateral or margin and guarantee-default also is quantitatively explored in Nahai-Williamson et al. [87]; however they do not consider the existence of recovery and also assume exogenous default with risk-neutral investors. In my model setup, participants have mean-variance utility preferences that potentially allows to use or include different risk-aversion attitudes; these preferences also make possible to compare default-fund and collateral sizes with optimal ones resulting from the application of a standard Value-at-Risk (VaR) procedure; actually they are equivalent conceptually[27]. VaR methodology has become a popular tool for risk management of financial institutions.

[27] See Berstein and Chumacero [10] for equivalences and construction of VaR measures.

Consequently, whether these preferences are used in a centralized or decentralized problem the result is optimal in financial terms since the resulting allocation is required for mitigating market risk by construction.

This remaining of the chapter is structured as follows. Section (3.3) describes a simple model of clearing that applies a mutualization arrangement in order to show the determination of CDS premium influenced only by limited liability; consequently, in this particular case, the policy i.e. mutualization does produce an unambiguous change in the CDS premium. Section (3.5) formally presents the agents and functions to maximize. Also, this section shows the equilibrium of the credit default swap market as well as the main characteristics and consequences of the trading in opacity markets. That section finishes discussing the collateral requirement under a bilateral clearing or arrangement. Section (3.6) discusses the determination of CDS premium due to collateralization and mutualization. Section (3.7) shows the results of the numerical exercise. Finally, section (3.8) presents conclusions and further research agenda. Appendix (E) contains proofs.

3.3 A Simple Model

In this section I setup a model that shows a basic structure of hedge with a constant premium for CDS. For the sake of connection to the rest of the chapter, I present this model as a preamble to discussing the change in the premium after clearing procedures. In next section (3.5) I relax the structure of this basic model and thus showing the determination of an endogenous premium after clearing. Particularly when the default is exogenous, I show in this section how the default structure between protection seller and the reference bond affect the valuation of CDS[28]. In other words, I introduce for this model an interdependence or correlation on default rates; this assumption allows to estimate the change of hedge as well as effects on marginal and default funds due to an increase in the premium.

[28]Literature is extensive on credit default swap valuation; see Leung and Kwok [77], Jarrow and Yu [62], Yarrow and Yildirim [106], Kim and Kim [67] and Collin-Dufresne et al. [37].

3.3.1 Default and Insurance

I assume a party goes long on a corporate bond and faces risk arising from default of the bond issuer. In order to get protection, this party or buyer enters a CDS contract in which he agrees to pay a premium payment to a CDS seller (S). In exchange this seller promises to compensate to the buyer for some amount of loss (L) in the event of default of the bond. Thus, the contract involves the CDS buyer, CDS seller and the reference party (R) or the issuer of the reference bond. The inter-dependent default risk structure between the CDS seller and the issuer of the bond may be characterized by the following correlated default intensities for a result on a rage of period split by threshold s^*.

$$\lambda_t^S = b_0 - b_1 \mathbf{1}_{\tau^C \geq s^*}$$
$$\lambda_t^C = c_0$$

τ^C defines the time when the reference entity defaults. I assume that default intensity λ_t^S reacts to default of the bond; a shrink in the default intensity pushes out a higher probability of default after threshold s^*. The parameters b_0, b_2 and c_0 are assumed to be constant. This structure closely follows the one in Leung and Kwok [77] for continuous time but I simplified to the case of two periods whose split is defined by threshold s^*. In order to find the joint probabilities I adopt the change of measure introduced by Collin-Dufresne et al. [37] in the valuation procedure of the premium (see appendix E for details). Thus, the following probabilities are defined;

$$P(\tau^C \geq s^*, \tau^S \geq s^*) = e^{-s^*(b_0 + c_0 - b_1)} \equiv p^C p^S$$
$$P(\tau^C < s^*, \tau^S \geq s^*) = e^{-s^* b_0}(1 - e^{s^* c_0})$$

p^S stands for the probability of observing the seller defaulting and p^C is the probability of occurrence of the credit event. The utility function of the CDS seller is given by the sum of three components: a protection and premium leg and other called "limited commitment" leg. These terms are defined as follows (see Morgan [86]);

$$
\begin{aligned}
\Pi^S = p^C(1-p^S)[-D(t_0,\tau)m + D(t_0,t_0)q + D(t_0,\tau)(\tau - t_1)qm] \quad & \Big\}\ \text{protection leg} \\
(1-p^C)[(D(t_0,t_1) + D(t_0,t_0))qm] \quad & \Big\}\ \text{premium leg} \\
p^C p^S[-D(t_0,\tau)\nu + D(t_0,t_0)qm + D(t_0,\tau)(\tau - t_1)qm] \quad & \Big\}\text{lim. comm. leg}
\end{aligned}
\tag{3.1}
$$

$D(t_0, t_1)$ is the continuous discount rate at period t_1 in terms of prices at t_0; $D(t_0, \tau)(\tau - t_1)$ is the accrued premium for the fraction of period between τ and the last payment date. The protection and premium leg are specified in the contract; however. the limited commitment leg represents the payment when both bond's issuer and CDS seller default; under this scenario a recovery amount R is less than the coverage m under contract. For sake of simplicity we assume values for parameters in the model: discount rates are equal to unity; any default is only realizable at last period i.e $\tau \equiv t_1$ and $m = 1$. The zero-profit condition on expression (3.1) gives the price or premium for the CDS;

$$q = p^C(1-p^S) + p^C p^S \frac{R}{m} \tag{3.2}$$

Lemma 2 *(Effect of limited commitment on premium). The premium unambiguously decreases due to a rise of CDS default probability or reduction of recovery amount (R). Formally,*

$$\frac{\partial q}{\partial b_1} = -e^{-s^*(b_0+c_0-b_1)}s^*(1-R) < 0$$

$$\frac{\partial^2 q}{\partial b_1 \partial R} = \frac{\partial q}{\partial R} = e^{-s^*(b_0+c_0-b_1)}s^* > 0$$

Proof. See appendix for details ■. Above lemma emphasizes the decrease of premium as a result of limited commitment. If either R shrinks or the CDS default probability increases with no penalty then premium decreases. On this section, the setup allows for correlation between probability of default of both assets: bond and CDS. This may be understood as a liquidity shock or any aggregate risk in nature. An exogenous shock on CDS default probability has the same effect on premium. In the next section, I closely follow the determination of the ratio $\frac{R}{q}$ as a measure of counterparty risk. In the following corollary I show the change of the ratio to an increase in the probability of CDS default.

Corollary 4 *Since R is exogenous, then $\frac{\partial(R/q)}{\partial b_1} > 0$ and $\frac{\partial(R/q)}{\partial R} > 0$*

The problem of the party is defined in the following expression as the one to choose the amount of insurance m:

$$\begin{aligned} \mathcal{L} = \max_{m} \;\; & (1-p^C)\mathcal{U}(w-qm) + p^C(1-p^S)\mathcal{U}(w-qm-L+m) + p^Cp^S\mathcal{U}(w-qm-L+R) \\ \text{subject to:} \quad & q = p^C(1-p^S) + p^Cp^S\frac{R}{m} \\ & L \geq R + m \end{aligned} \tag{3.3}$$

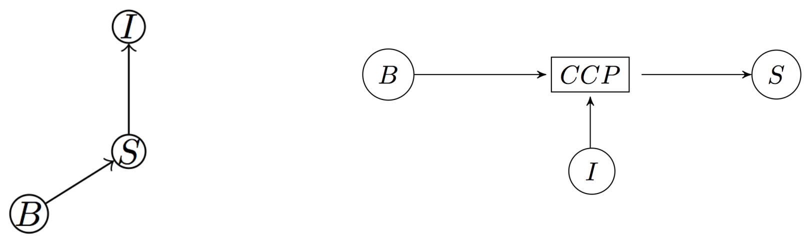
Then, solution to above problem results different from a fair pricing i.e. $L = m$. The following lemma summarizes the solution.

Lemma 3 *(Provision of insurance). Given $p^B > 0$ and the result due to limited commitment in Lemma 2 then there is a rationing provision of insurance i.e $-L + m + R < 0$.*

3.3.2 Central Counterparty Clearing

In this section a clearinghouse steps on the insurance market and perform mutualization and novation[29]. Figure (3.1) shows the process of novation when clearinghouse participates in the market.

[29]Since I assume that CDS seller only has one operation to reporting then netting is not an issue or procedure to claim.



(a) Bilateral Exposures (b) Clearing

Figure 3.1: Novation

The clearinghouse has a fixed number of participants that are homogenous, thus all insurance and premiums are identical across agents. In this particular example the premium is affected by mutualization but insurance[30], then the clearinghouse needs to choose default-funds from buyers (Φ_{df}), default-funds from sellers ($\Phi_{df,s}$) and marginal funds from "surviving" buyers (Φ_{mrg}) in order to maximizing the utility of the CDS buyer as follows;

$$\mathcal{L} = \max_{\Phi_{df}, \Phi_{mrg}} \quad (1-p^C)\mathcal{U}(c_1) + p^C(1-p^S)\mathcal{U}(c_2) + p^C p^S \mathcal{U}(c_3) \tag{3.4}$$

The clearinghouse has to satisfy the following constraints. First, the allocation has to be feasible,

$$\begin{aligned} (1-p^C)c_1 + p^C(1-p^S)c_2 + p^C p^S c_3 \ \leq \ (1-p^C)(w - qm - \Phi_{df}) + \\ p^C(1-p^S)(w - qm - L + m - \Phi_{df} - \Phi_{mrg}) + p^C p^S(w - qm - L - \Phi_{df} - \Phi_{mrg})) \\ +(1-p^C)\eta\Phi_{df} + p^C(1-p^S)\eta(\Phi_{df} + \Phi_{mrg}) + p^C p^S \eta(\Phi_{df} + \Phi_{mrg}) + \eta\Phi_{df,s} \end{aligned} \tag{3.5}$$

the feasibility constraint shows that at starting period the clearinghouse receives collateral Φ_{df} from agents in a "safe" group; this is they either do not experience default from the reference entity or they were able to collect the payment from CDS seller. Also, the clearinghouse receives funds Φ_{mrg} from a measure of agents facing the risk of bond default.

[30]Literature regarding clearing procedures emphasizes in keeping constant the terms of trade; see for a detail Monnet and Nellen [85], Koeppl [68].

The average value of the collateral posted by these agents is $p^C(1-p^S)\eta$ since collateral is costly (i.e $\eta < 1$). Hence, the RHS of the feasibility constraint in (3.5) represents the resources available to the clearinghouse. The LHS mirrors the clearinghouse's expenditure as a function of the possible realization of premium q and insurance m. The clearinghouse has to finance the consumption of a measure of agents in the safe group and a measure of agents in the risky group.

Second, the clearinghouse has to satisfy interim participation constraints for agents in the safe group as well as for agents in the risky group. These constraints define a limit for the marginal fund, they are as follows;

$$\begin{aligned} \mathcal{U}(c_1) &\geq \mathcal{U}(w - qm - \Phi_{df}) \\ \mathcal{U}(c_2) + \mathcal{U}(c_3) &\geq \mathcal{U}(w - qm - L - \Phi_{df}) + \mathcal{U}(w - q - L) \end{aligned} \tag{3.6}$$

Third, the clearinghouse has incentive compatibility constraints for each agent in the risky group:

$$\begin{aligned} c_2 &\geq w - qm - L + m - \Phi_{df} - \Phi_{mrg} \\ c_3 &\geq w - qm - L \end{aligned} \tag{3.7}$$

These constraints make sure that agents prefer the clearinghouse's allocation. Finally, a feasibility constraint on default and marginal call is formally required. However since $L > m$ the high state precisely is when the bond defaults but CDS seller, thus $\Phi_{mrg} < 0$.

$$\begin{aligned} \Phi_{df} &\geq 0 \\ \Phi_{mrg} &\leq 0 \\ \Phi_{df,s} &\geq 0 \end{aligned} \tag{3.8}$$

Thus, the program to solve requires to maximize expression (3.4) subject to (3.5), (3.6), (3.7) and (3.8). The premium is given by (3.2); m and R are chosen from result in lemma (2), and a logarithm function for $\mathcal{U}$ finally determines the size of L. The first order conditions are as follows;

$$
\begin{aligned}
c_1 : &\qquad (1-P^C)\mathcal{U}'(c_1)+\varphi_1\mathcal{U}'(c_1)-\varphi_0(1-p^R)=0\\
c_2 : &\qquad p^C(1-p^S))\mathcal{U}'(c_2)+\varphi_2)\mathcal{U}'(c_2)+\varphi_3-\varphi_0 p^C(1-p^S)=0\\
c_3 : &\qquad p^C p^S\mathcal{U}'(c_3)+\varphi_2\mathcal{U}'(c_3)+\varphi_4-\varphi_0 p^C p^S=0\\
\Phi_{df} : &\qquad \varphi_0(\eta-1)+\varphi_1\mathcal{U}'(w-qm-\Phi_{df})+\varphi_3+\varphi_5\\
&\qquad +\varphi_2\mathcal{U}'(w-qm-L-\varphi_{df})=0\\
\Phi_{mrg} : &\qquad \varphi_0 p^C(\eta-1)+\varphi_3-\varphi_6=0
\end{aligned}
$$

where $\varphi_0-\varphi_6$ are Lagrange multipliers associated to above constraints; non-binding constraints in (3.8) implies interior solution.

The following proposition shows the solution to the problem.

Proposition 3 *(Solution). There are some $\Phi^*_{df}>0$, $\Phi^*_{df,s}>0$ and $\Phi^*_{mrg}<0$, the unique solution is given by*

$$
\begin{aligned}
c_1^* &= w-qm-\Phi^*_{df}\\
c_2^* &= w-qm-L+m-\Phi^*_{df}-\Phi^*_{mrg}\\
c_3^* &= w-qm-L+\frac{\Phi^*_{df}(\eta-p^Cp^S)}{p^Cp^S}+\frac{\Phi^*_{mrg}(\eta-p^S)}{p^S}+\frac{\Phi^*_{df,s}\eta}{p^Cp^S}\\
\mathcal{U}'(c_1^*) &= \mathcal{U}'(c_3^*)\eta\\
\mathcal{U}'(c_2^*) &= \frac{1-p^S\eta^{-1}}{(1-p^S)\eta^{-1}}\mathcal{U}'(c_3^*)
\end{aligned}
$$

Proof. See annex for details ■. I compute the consumption equivalent σ of moving the allocation of resources to a clearing result Monnet and Nellen [85]. The value σ solves the following expression:

$$
\begin{aligned}
\mathcal{U}(c_1^*)+\frac{p^C(1-p^S)}{(1-p^C)}\mathcal{U}(c_2^*)+\frac{p^Cp^S}{(1-p^C)}\mathcal{U}(c_3^*) &= \mathcal{U}((w-qm)\sigma)+\frac{p^C(1-p^S)}{(1-p^C)}\mathcal{U}((w-qm-L+m)\sigma)\\
&\quad+\frac{p^Cp^S}{(1-p^C)}\mathcal{U}((w-qm-L+R)\sigma)
\end{aligned}
$$

The consumption equivalent shows the fraction $\sigma-1$ of agent consumption pulled off from moving to an economy with clearing. Under a specific parameterization, figure (3.2) shows σ (y-axis) as a function of the resources remaining after applying collateral costs for different levels of insurance amount m.

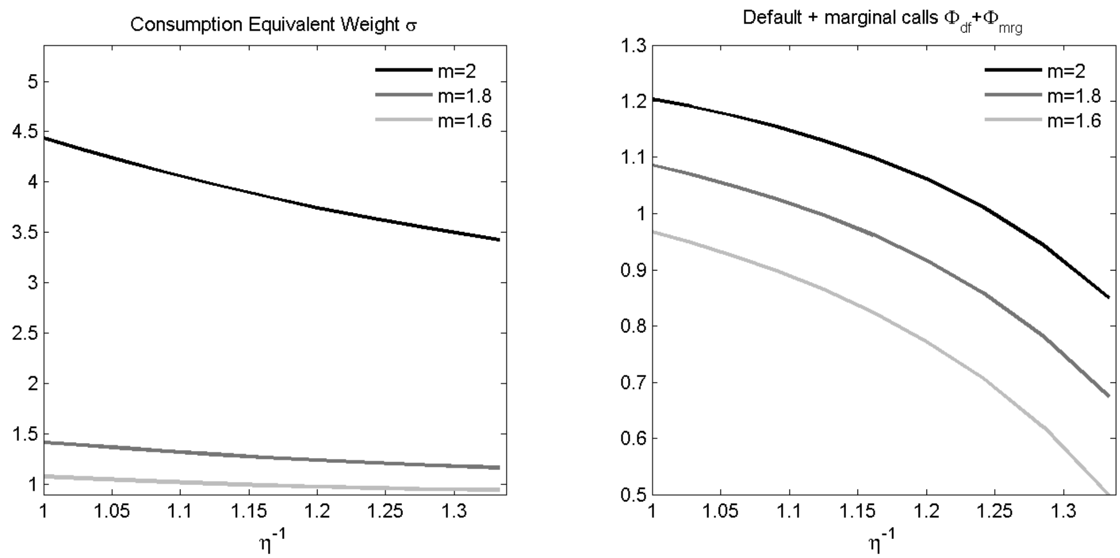


Figure 3.2: Parameterization: $R = 0.1$; $L = 2$; $w = 2.5$; $p^C = 0.6$; $p^S = 0.6$

Above figure suggests that mutualization practice improves social welfare by definition. However, the effectiveness of the former critically lies on the availability of funds that clearinghouse is able to collect from agents previously. The potential collectable dried up either the collateral costs increases (a higher η^{-1}) or available insurance (m) decreases; this definitely have significant impact in the new social welfare. Under extreme conditions of illiquidity, mutualization may worse initial welfare i.e $\sigma < 1$, figure (3.2) clearly shows the former.

I showed in this section benefits of mutualization and the impact of limited commitment on premium; premium always increases to clearing policy. Should it react differently to mutualization or any collateral policy that prevents default? The usage of a simple model as shown in this section will produce a trivial increase in the premium.

3.4 Current Regulation

3.4.1 Actual calculation of mutual-guarantee default fund and collateralization

In this section I make a short detail of how clearinghouses establish the size of collateralization and size of the mutual-gurantee default fund actually. This is important for calibration in the last section.

In the case of LCH, the first contribution to the mutual guarantee fund was April, 2002 for the securities and derivatives market and in March, 2013 for the bonds and repo market. CLH establishes same underpinning in the calculation of the default fund for both markets. Specifically, the fund needs to be sufficient to cover the potential failure of LCH's largest clearing member which is defined as the member whose risk exposure after deduction of collateral is the highest. The size of each member's contribution is based on the relative weight of each member's specific uncovered risk compared to the total sum of the uncovered risk of all the member's.

3.4.2 Basel III

As noticed by Augustin et al. [8], during the November 2010 Seoul Summit, leaders of the G-20 countries endorsed Basel III (the new bank capital and liquidity regulations). The foregoing as a response to a significant movements in banks' balance sheets which could not reflect a proper portfolio risk when operating CDS. In general, dealers are now subject to demanding capital requirements for derivatives trading; Basel rules requires top-quality capital equal to 6-7% of their risk weighted assets. These requirement is demanded in order to ensure that these institutions do not take on excess leverage and consequenty become insolvent. However, use of CDS can still create systematic risk because banks -usually major buyers and sellers of CDS- are a key piece in the financial network.

3.5 The Model

I closely follow model's setup in Acharya and Bisin [1] concerning the moral hazard on insurer side; this feature has recently received attention in literature (Stephens and Thompson [99], Thompson [101], Leitner [76]).

3.5.1 The Agents

In this section, I embed the provision of insurance in the model of two periods where a seller provides insurance to risk-averse buyers. The seller of insurance will provide insurance depending of the realization of the event of default of a third party; this can be generalized to the occurrence of a bond default. Thus, the probability of occurrence of this event is denoted by λ. The seller' endowment is denoted as ω_s, an additional subscript denotes the period. The insurance contract must be paid at starting period 0 and the price per unit of requested insurance is q, this known as the CDS price, henceforth premium. The promised payoff is Rm, where m is the amount or notional of insurance; CDS seller, henceforth seller, may go back on her word and only return Rm being $R < 1$. The seller maximizes a 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 Formally, sellers maximize the following function:

$$\Pi^S = \max_m \omega_{s,0} + mq + \lambda(\omega_{s,1} - Rm) - \frac{\gamma}{2}\lambda(1-\lambda)\left[\omega_1 - Rm\right]^2$$

The CDS buyers, henceforth buyers, have a short position that needs to cover by purchasing insurance. Specifically, each buyer previously engaged in lending the amount ω_b to a third party; with probability $1-\lambda$ the third party would be successful and it will deliver the return $r \geq 1$ on the loan, with probability λ the buyer gets nothing from the third party. The total size of these buyers is $\frac{1}{1-\lambda}$, same size for sellers. The matching when trading insurance is completely random; in last section I relax this assumption and I define an equilibrium with competition. Only sellers can default and this assumption is made by construction since the amount qm is payable up front[31]. In the case of defaulting, sellers undergo a non-pecuniary penalty or deadweight loss as a function of the short positions defaulted upon. Formally, I setup the timing and actions of participants in the insurance market as follows;

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

(T=1) Seller gets endowment ω_s and return θ from long-run portfolio. With probability λ the reference entity or bond defaults; seller makes a choice from set $\iota = \{ND, D\}$. Settlement and payoffs to each participants are made. Otherwise, with probability $1 - \lambda$ no transfers are made.

3.5.2 Equilibrium in the Credit Default Swaps Market

In this section I setup the CDS market into the remaining sections of the model. I closely follow the Acharya and Bisin [1]'s model for this insurance market; this one is particularly characterized by the excess of leverage recorded in balance sheets, this due to dearth of transparency in short positions. This opacity was a key feature during the financial crisis for this type of derivatives contract[32]. In the dawn of financial crisis, investors realized that protection was quite 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, clearing rises as a device that brings transparency in order to reduce the counter-party risk and achieve ultimately the efficient risk-sharing outcome. The need of protection against default risk makes a party to enter a contract of derivatives. The seller of this derivative (the short-position's holder) promises to compensate or pay out in the occurrence of an specific event that produce a loss to the buyer. This buyer (long-position's holder) agrees to make periodical payments to the seller of the protection, the price per quantity of purchased insurance is known as

[31]See Leung and Kwok [77] for the CDS pricing when buyers default with a exogenous hazard-rate environment.

[32]It follows discussion regarding AIG.

swap premium. Thus, the elements or parties involved in the CDS contract are: protection buyer, protection seller, swap premium and the reference liability which is triggered when the event materializes. The compensation payment is made at the end of some period known as settlement period. Formally, the contract for this derivative is as follows:

Definition 3 *(CDS contract). The CDS contract is formally denoted as $\mathcal{C}(R, q, m, \kappa, t)$ where R is the payoff, q is the price per unit of insurance, m is the amount of insurance, κ is the collateral size. t is the settlement period and it is equal to the last period. The amount $(q - \kappa)m$ must be payed at period 0.*

The sellers promise buyers the amount Rm if the event occurs (the default of a third party); otherwise, buyers do receive nothing from sellers; whatever state of nature happens buyers pay out the total (swap) premium denoted as qm. The settlement period is the last one, therefore CDs contract may be written shortly as $\mathcal{C}(R, q, m, \kappa)$.

3.5.3 The Trading in Opacity Markets

Sellers trade the CDS in non-transparent markets. As in Acharya and Bisin [1]'s setup, the determination of price's assumption is 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 the contract $\mathcal{C}$, this is by the payoff of the insurance, the cost of insurance or premium, the trading position and the posting of collateral. In order to determine the terms of this contract, the equilibrium must include the following: (i) buyers maximize an specific expected utility by choosing the amount of insurance (m), (ii) The market of insurance must clear, and (iii) In the case of default, seller honors his promise paying the recovery rate established in the contract. In a latter section I relax this incorporating the restriction that seller prorates her endowment (ω_s) amongst long positions holders. i.e $R = \frac{\omega_s}{m}$ if buyer defaults.

Seller may default (D) or non-default (ND) in her set of decision, i.e. $S = \{D, ND\}$. The collateral size (κ), as I will explain in the next section, has implications on the allocation achieved by the planner. On the other hand, buyers maximize their problem choosing m. In the next section I formally present the buyers' function to maximize.

3.5.4 The Strategic Default

In this section I show that in Acharya and Bisin [1]'s model, seller has incentives to default if the event occurs. In the case seller default, there is a linear penalty whose value depends upon short defaulted positions, this penalty per unit of amount of insurance is denoted as ϵ. Precisely, the deadweight cost level plays a role in sellers' decision when maximizing her utility function. In order to formally clarify the payments, I explicitly show the profit (Π^S_{ND}) when seller do not default,

$$\Pi^S_{ND} = \theta + qm + \lambda(\omega_s - m) - \frac{\gamma}{2}\lambda(1-\lambda)\big[\omega_2 - m\big]^2 \tag{3.9}$$

I replaced the initial endowment with a portfolio of size 1 that returns $\theta \in (-\overline{\theta}, \overline{\theta})$ at the end of last period; this modification only shows the benefits of novation and netting in order to achieve the highest benefits of collateralization and mutualization. The payoff when seller default (Π^S_D) is

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

As in Acharya and Bisin [1], above function shows that CDS sellers suffer a linear non-pecuniary penalty as a function of the positions defaulted upon, not only given by the term ϵm, but also by the size of collateral κ. As in Acharya and Bisin [1], I define the "risk premium" as $q = \big[\Delta\lambda + \lambda\big](R + \kappa)$. The buyer has the following function to maximize:

$$\Pi^B = \omega_0 - qm + (1-\lambda)\omega_b + \lambda(R+\kappa)m - \frac{\gamma}{2}\lambda(1-\lambda)\big[\omega_b - (R+\kappa)m\big]^2$$

I assume $r = 1$ for above function. I below formally define the equilibrium,

Definition 4 *(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

$\mathcal{C}(R, q, m, \kappa)$.

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

(c) Insurance market clears;

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

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

Thus, each agent chooses the amount of insurance (m) respectively; formally, the demand (b) and supply (s) of insurance are given by:

$$m^b = \frac{1}{R+\kappa}\left[\omega_b - \frac{q - \lambda(R+\kappa)}{\gamma\lambda(1-\lambda)(R+\kappa)}\right]$$

$$m^s_{ND} = \omega_s + \frac{q - \lambda}{\gamma\lambda(1-\lambda)}$$

$$m^s_D = \frac{q - \lambda(\epsilon+\kappa)}{\gamma\lambda(1-\lambda)(\epsilon+\kappa)} \tag{3.10}$$

Where premium q is as follows

$$q = (\Delta\lambda + \lambda)R \tag{3.11}$$

According to above problem to maximize, if ϵ is too low, then default shall prevail (see Acharya and Bisin [1]). Below I define the shape of risk premium and size of counterparty risk.

Proposition 4 *(Risk premium). The risk premium is constant and equal to* $\Delta\lambda = \frac{\gamma}{2+N}\lambda(1-\lambda)\left[\sum_{i=0}^{N}\omega_s^i - \omega_b\right]$.

Proof. Above proposition is a result of market clearing condition for a non-defaulting choice made by seller. N is the number of extra buyers per each buyer in the contract, at this stage $N = 0$ ■.

Proposition 5 *(Counterparty risk) When proposition (4) is evaluated at $N > 0$ and $\omega_s^i \equiv \omega$ for all $i = 0, ..., N$ then $\frac{R_0}{q_0} \geq \frac{R_N}{q_N}$. Being $\frac{R_0}{q_0}$ calculated when seller trades with just one buyer; and $\frac{R_N}{q_N}$ calculated when seller trades with N extra buyers.*

Proof. See appendix for details ■. Above proposition verifies Acharya and Bisin [1]'s claim of the existence of counterparty-risk externality. Given the definition of equilibrium (4), the market clear condition when a defaulting choice is made by seller produces a positive relation between the recovery rate and the deadweight loss. I formally define the recovery rate in the following lemma;

Lemma 4 *(The recovery rate determination). Since market clearing condition is part of definition (4), the recovery rate is;*

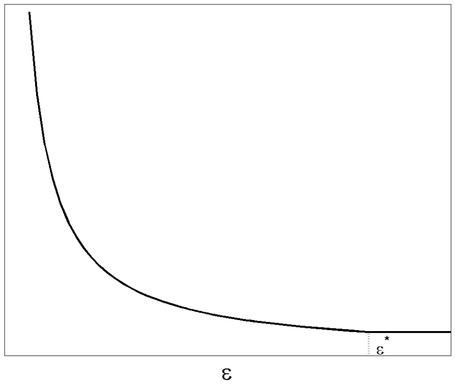
$$R \equiv R(\Delta\lambda, \epsilon, \kappa) = \beta(\Delta\lambda)(\epsilon + \kappa)$$

being $\beta(\Delta\lambda) \equiv \frac{\lambda \pm \sqrt{\lambda + 4(\omega_s \gamma \lambda (1-\lambda) + \Delta\lambda)[\Delta\lambda + \lambda]}}{2(\Delta\lambda + \lambda)}$

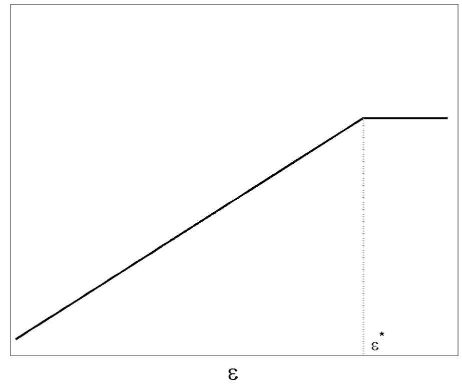
Proof. See appendix for details ■.

3.5.5 Inefficiency of Opacity Markets

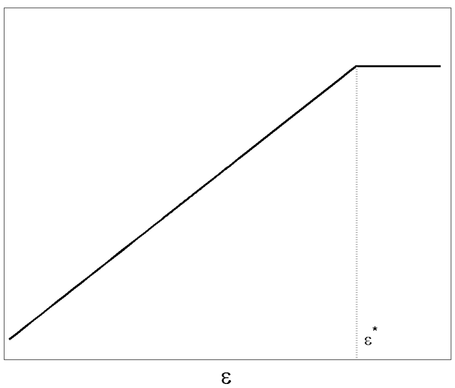
The inefficiency of equilibrium follows Acharya and Bisin [1]'s discussion. This rises from deadweight costs of insurer's bankruptcy; any strategy to increase these costs would recover the efficiency, for instance collateral. Since buyers are better off with some collateral size, planner can improve upon the non-transparent markets when deadweight costs are not negligible. Thus, as a result, the counter-party risk produces still too much demand for insurance in equilibrium, this gives incentives to default ex-post. Figure (3.3a) shows the quantity of insurance in equilibrium, buyers and seller utilities with a standard parametrization. Also, the realized payoff (R) and its price (q) are shown, all as a function of ϵ, the deadweight loss.



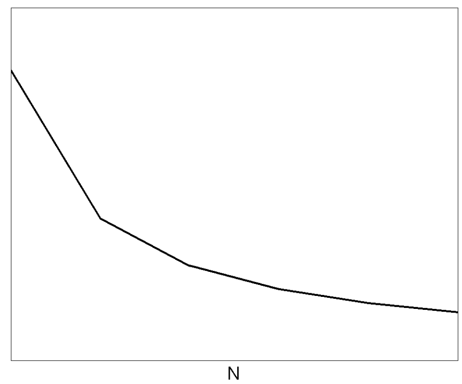
(a) Notional



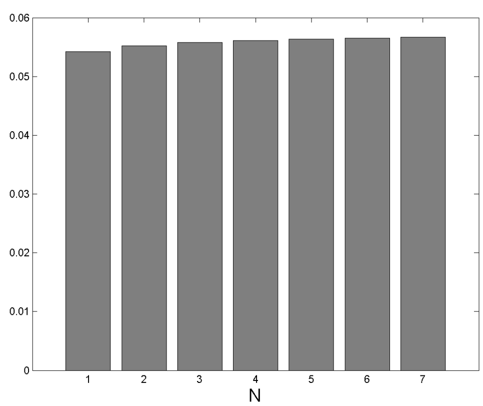
(b) Premium



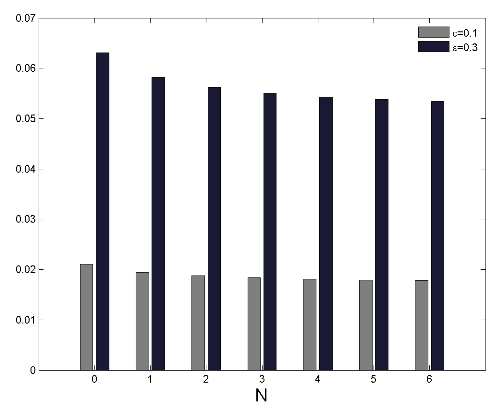
(c) Recovery Rate



(d) Ratio R/q



(e) Tier 1 ratio



(f) Tier 1 common ratio

Figure 3.3: Acharya and Bisin (2014) main results

It is surprising that Tier ratios do not show a sharp increase of risk as additional buyers take part of CDS trading (see figures 3.3e and 3.3f). In an empirical work, Chiaramonte and Casu [33] 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. Authors mentioned that international banks -including US banks- that ran into difficulty almost always had a tier 1 acceptable to regulatory standards. Thus, Chiaramonte and Casu [33] cast doubts in relation to the reliability of the capital index Tier 1 as a regulatory tool.

In the previous section I gave details of the solution with collateral bargaining; the collateral reduces the amount of trading insurance and it may reach a non-default solution (a default solution may exist when the deadweight loss is enough small). However, the solution provides an amount of insurance that is still far from an efficient one. The former is characterized by a low amount of insurance in equilibrium and non-default i.e $R = 1$. In the next section I include the clearinghouse that contributes with mutualization and novation upon trading of insurance.

3.5.6 Collateral requirements

In a bilateral arrangement, each buyer and seller sets the collateral requirements in the contract. Since collateral needs to be posted up front, seller needs to liquidate some fraction of its long-term portfolio. However, there is cost of η^{-1} units per each amount earmarked to fulfill collateral requirements. Below formally

Definition 5 *Collateral feasible set for seller. The set of feasible levels of collateral for the seller in a bilateral arrangement is given by the following,*

$$K^b = \Big\{\kappa \mid \theta\eta \geq \kappa m\Big\}$$

Since the buyer solves its problem choosing the notional amount of insurance and knowing rationally the recovery rate, then the function to maximize is flat respect to the collateral requirement. I formally state the former in the following lemma,

Lemma 5 *In the range $\kappa \in [0,1]$ then i) $\frac{\partial \Pi^b}{\partial \kappa} = 0$, ii) $\frac{\partial \Pi_D}{\partial \kappa} = -\eta^{-1} - \lambda - \gamma\lambda(1-\lambda) < 0$ and iii) $\frac{\partial \Pi_{ND}}{\partial \kappa} = -\eta^{-1} < 0$. The corner solution is $\kappa = 0$.*

Thus, the collateral size under a bilateral agreement is equal to $\kappa = 0$.

3.5.7 A digression: heterogeneous agents

Given that a particular deadweight loss $\epsilon < \epsilon^*$ makes seller to default, then the conditional fraction of defaulters is 100%. In other words, once the event occurs (default of the entity reference) all CDS sellers - who promise to cover the loss - default. The model still can generate a lower size of defaulters when it does include different deadweight losses across sellers. I formally show this in the following corollary;

Corollary 5 *(Heterogeneous agents). Let's assume that there is a fraction z of CDS sellers with $\epsilon \geq \epsilon^*$ and $1-z$ with $\epsilon < \epsilon^*$ and the probability of default (λ) is the same in both groups. Thus the conditional probability of default (given the default of the reference entity) is less than one, i.e. $(1-z) < 1$. The number of defaulters is $\frac{\lambda(1-z)}{1-\lambda}$.*

3.6 The Clearinghouse

The clearinghouse due to novation can observe the total size of trading; then, it can set a collateral policy affecting the amount of insurance. The clearinghouse can therefore require that seller posts collateral fraction κ and default fund ϕ in order to setup collateralization and mutualization respectively. The difference is that ϕm will be distributed among all buyers whose contract default; instead each κm is seized by the buyer in case the contract is under default. In the following section, I state the benchmark or first best for allocation;

3.6.1 The efficient allocation

I start characterizing a benchmark allocation that represents an efficient one amid participants in this fictional financial economy. I show this allocation involves a policy of transparency of trade positions. *Benchmark.* Acharya and Bisin [1] states that if the total amount of insurance and endowments were observable, a planner could impose a pricing rule on $q(m, \omega_1, \Delta\lambda)$ to be (i) $[\Delta\lambda + \lambda]$ whenever there is no default, and (ii) $[\Delta\lambda + \lambda]\frac{\omega_b}{m}$ when there is default. When substituting the price rule into CDS seller's maximization, the incentives 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-default insurance level.

Proposition 6 *(Efficient allocation). Under the following price rule (i)* $q = [\Delta\lambda + \lambda]$ *whenever there is no default, and (ii)* $q = [\Delta\lambda + \lambda]\frac{\omega_b}{m}$ *when there is default, the efficient allocation is achieved.*

Proof. An examination of first conditions on expression including the price rule shows the efficient level that resembles the insurance amount when there is no default. ■ However, this allocation would require information about the risk premium and possibly endowments. Therefore, any allocation under limited information represents a constrained Pareto optimum. Clearinghouse due to novation observes the size of trading and it 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; therefore let κ^* denote a minimal fraction of trading (collateral) which guarantees that seller has no incentive to default when holding the amount of insurance m^*.

Also, seller's decision on defaulting is based on the collateral size that buyer chose; the observation is that the payoff R and price q is affected by size of collateral; buyer knows that imposing a collateral may prompt seller to behave properly into 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 ϵ (see Acharya and Bisin [1]); however, if seller faces a low endowment, the provision of insurance will be affected and therefore ultimately affecting the payoffs. I will explore this possibility at the end of the next section.

Each CDS seller compromises in a two-period investment that pays θ which is uniformly distributed with mean equal to $\overline{\theta}$. I assume that 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 restriction, I have the following result $\phi(i) = \frac{\theta(i)-\overline{\theta}}{\lambda}$. Finally, the participation constraint is:

$$\alpha q(R)m(R) + \overline{\theta} \geq c \tag{3.12}$$

In the next two sections I present two clearing procedures: i) collateral storage and ii) mutualization. The first one shows the primitive role of clearinghouses as storage facility of collateral; mutualization involves loss-sharing among all participants in the clearinghouse. The latter entails to ask for default funds in order to financing expected losses due to defaulting.

3.6.2 Collateral Storage Facility

In this section I describe the collateral policy and market equilibrium when the clearinghouse's main role is to provide a facility for collateral storage[33]. 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 buyer and rest of settlement is enforced. As shown in a previous section, a bilateral arrangement sets collateral level equal to zero due to rising costs of collateral postings, and thus the equilibrium is characterized by a low recovery rate in equilibrium. In a clearing setup, since there is a limited commitment on seller side, clearinghouses have to pledge collateral to prevent strategic default. Therefore, the clearinghouse is able to collect collateral offering two contracts to buyers and sellers; one contract making possible a discourage to default but other setting an insurance when default. I follow closely Koeppl [68]'s characterization for these two contracts. Both contracts in the clearing setup deliver a weakly

[33] In the literature, as a storage facility. clearinghouse behaves as a third party that has a technology that prevents a defaulter from keeping the collateral while, at the same time, allowing the non-defaulter to keep the defaulting agent's collateral (see Monnet and Nellen [85]).

Pareto-improving equilibrium. Along this section I state some propositions that characterize the equilibrium under clearing; more significantly I show the effect of the implementation of the storage-facility framework on CDS premium.

The program (P1) is modified in order to show that collateralized fraction (κ) of the notional amount would be lost if seller defaults. Therefore, 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 if there is a default; the expression that defines the premium is also adjusted accordingly. The risk premium ($\Delta\lambda$) is determined as before with no change. The participation constraint for each seller (3.12) now includes the value of the collateral. The program is as follows,

$$\begin{aligned}
\mathcal{L} = \max_{\kappa} \quad & \left\{ \left(\max_{m^s} \ (\Pi^S_{ND} \ , \ \Pi^S_D) \right) \max_{m^b} \ (\Pi^B) \right\} \\
\text{subject to} \quad & m \equiv m^s = m^b \\
& \alpha q m + \overline{\theta} - \kappa m \geq c \\
& 1 \geq R + \kappa \\
& q = (\Delta\lambda + \lambda)(R + \kappa) \\
& 1 \geq \kappa \geq 0
\end{aligned} \tag{P1}$$

It must be noticed that clearinghouses choose collateral in relation to the size of notional, also they cannot control agents' actions to maximize their benefits. Both seller and buyer maximize their profit or utility functions choosing the level of insurance for trading; the equilibrium in definition 1 requires the market clearing condition. Functions Π^B, Π^S_D and Π^S_{ND} are as follows;

$$\Pi^S_D = \overline{\theta} + mq - \lambda(\epsilon + \kappa)m - \frac{\gamma}{2}\lambda(1 - \lambda)\left[(\epsilon + \kappa)m\right]^2 - c$$

$$\Pi^S_{ND} = \overline{\theta} + mq + \lambda(\omega_s - m) - \frac{\gamma}{2}\lambda(1 - \lambda)\left[\omega_s - m\right]^2 - c$$

$$\Pi^B = \theta_0 - mq + (1 - \lambda)\omega_b + \lambda(R + \kappa)m - \frac{\gamma}{2}\lambda(1 - \lambda)\left[\omega_b - (R + \kappa)m\right]^2$$

Below I define two contracts when clearinghouse's main role is to offer a storage facility of collateral.

Definition 6 *(The Incentive contract). The clearinghouse sets a collateral policy where* $R + \kappa = 1$ *and* $\overline{\theta} - c + (\alpha q - \kappa)m \geq 0$ *for some buyer and seller.*

Koeppl [68] defines an incentive contract aiming to reduce the probability of default in an exchange transaction; instead, the probability of default is equal to zero on above setup. The main role of collateral is a device that clearinghouses can use in order to reduce (at some extent in some cases) the probability of default. In the bilateral case, the seller would like to commit to not defaulting but cannot find an arrangement to do it since deadweight losses are badly low and counterparty risk externality is pervasive. Furthermore, collateral requirement is costly since it needs to be posted up-front, thus, $\kappa = 0$ as set forth by Lemma 5. The buyer may ask for collateral given its participation constraint, however the recovery rate is rationally anticipated in equilibrium (see Lemma 5) and therefore there is no incentive to push for a collateral level beyond $\kappa > 0$.

Definition 7 *(The Insurance contract). The clearinghouse sets a collateral policy where* $R + \kappa < 1$ *and* $\overline{\theta} - c + (\alpha q - \kappa)m \geq 0$ *for some buyer and seller.*

Also Koeppl [68] defines an insurance contract that extracts surplus from seller who defaults in an exchange market; instead, in this setup the ratio $\frac{R}{q}$ is constant and therefore, buyer cannot extract any surplus from seller. In conclusion, insurance contract results in a collateral level $\kappa = 0$

Corollary 6 *The risk premium is constant and given by expression in (Proposition 4) under a storage facility policy.*

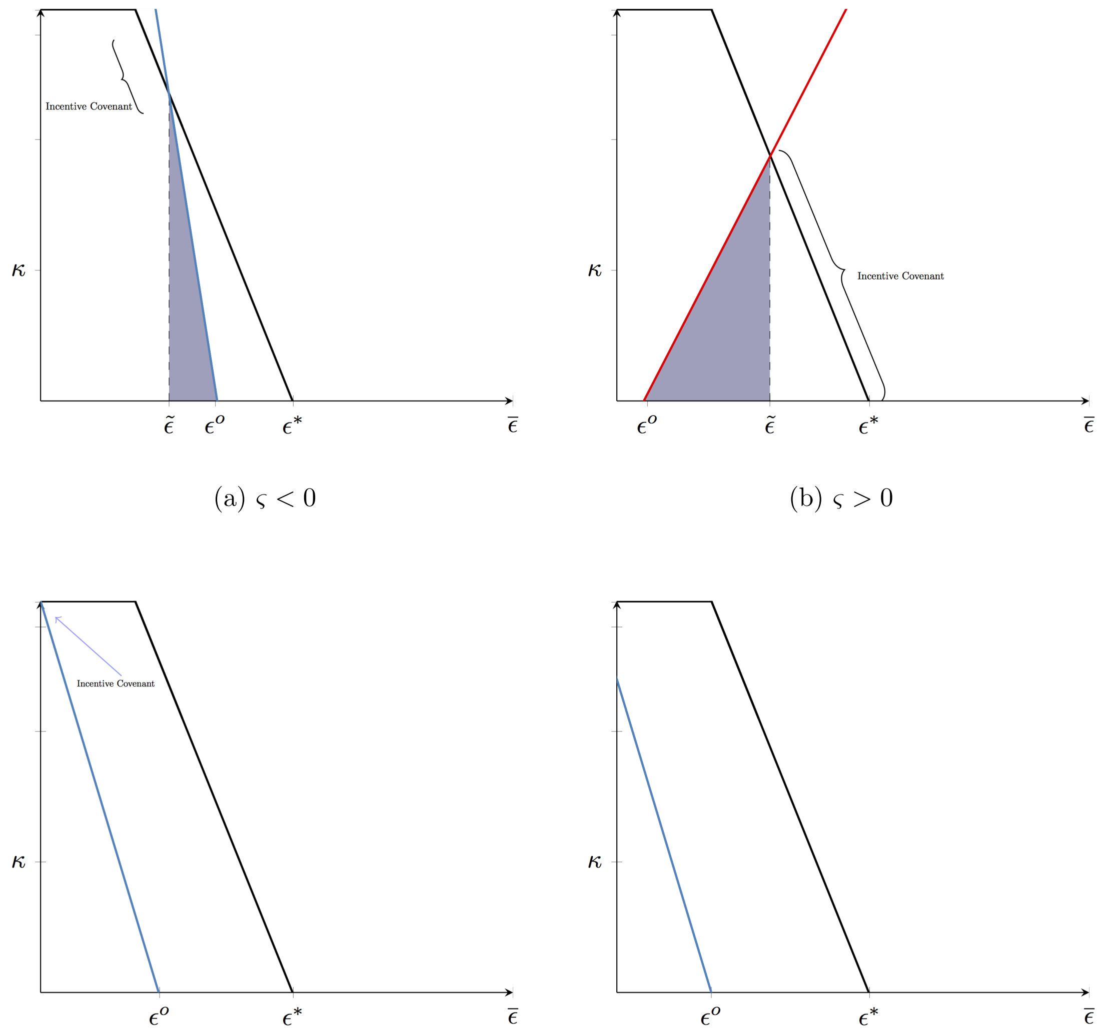
Proof. Since risk premium is a consequence of the risk that is aggregate in nature and cannot be fully diversified away then the risk premium is constant, see Acharya and Bisin [1] and appendix for details ■. In the proposition below I define the existence of two contracts in the range of deadweight losses values (ϵ) per notional amount of insurance.

Proposition 7 *(Existence of the Incentive contract). There are two contracts: Non-defaulting* *(henceforth Incentive) and defaulting contracts for $\epsilon \in [\underline{\epsilon}, \epsilon^*]$. Being ϵ^* the level of counterparty risk that makes CDS seller to do not default ex-ante. The collateral fraction (κ) is chosen from set $K = \{\kappa := \min\{k_1, k_2\}\}$ for all ϵ in the range, where $k_1 = \varsigma\epsilon$ and $k_2 = 1 - R(\epsilon)$. There is an range $[\epsilon^0, \epsilon^*]$ where both contracts exist. For deadweight losses less than ϵ^0, and low enough $(\theta - c)$ only an insurance contract exist.*

Proof. A positive correlation between deadweight loss and collateral ($\varsigma > 0$), when the participation constraint is binding, ensures the existence of an incentive contract; In figure (3.4b) there is an range $[\epsilon^0, \epsilon^*]$ where both contracts exist. The shaded areas in 3.4a and 3.4b represent insurance contracts that are constrained to reach a non-default result due to the participation constraint (see propositions 8 and 7). When $\epsilon \in [\underline{\epsilon}, \epsilon^0]$ an incentive contract does not exist for low values of $(\theta - c)$ (see figure 3.4d). See details in the appendix. ■.

Collateralization in this model has the same effect as an increase in the deadweight loss size. An increase of this parameter produces an increase in the premium and recovery rate. As I show in the bilateral case, unless collateral size does make the seller to not default then social utility does not increase. Thus, the clearinghouse should achieve a size of deadweight loss i.e. $\epsilon + \kappa$ that makes seller to not default; in other words the level of collateral must lay on the line $R + \kappa = 1$ and clearing budget must be slack as part of the solution. In the following lines I study cases when collateral is not enough to keep the seller off defaulting.

There is a condition that guarantee a corner solution for incentive contracts over the range for $\epsilon < \epsilon_0$; figures (3.4c) and (3.4d) depict the condition $\underline{\epsilon} \leq \varsigma^{-1}$ and the existence of incentive contracts. The clearing budget line (red) and the frontier $R + \kappa = 1$ (black) which implicitly sets the range for collateral i.e. $\kappa \in (0, 1)$. The gray area shows the set for collateralization in an insurance contract. The following proposition shows the determination of the collateral size under these two contracts.



(a) $\varsigma < 0$

(b) $\varsigma > 0$

(c) $\varsigma < 0; \underline{\epsilon} = \varsigma^{-1}$

(d) $\varsigma < 0; \underline{\epsilon} > \varsigma^{-1}$

Figure 3.4: Incentive and Insurance clearinghouse contracts

Corollary 7 *(Collateral level for insurance contract. For any ϵ that fulfills condition $k_1(\epsilon) < k_2(\epsilon)$ the collateral fraction for an insurance contract is in set $K_1(\epsilon) = \Big\{\kappa \in [0, \tilde{\kappa}) \mid \tilde{\kappa} = \varsigma\epsilon \;\&\; k_1(\epsilon) < k_2(\epsilon)\Big\}$*

The collateral in this contract is bounded by the clearing budget constraint when is binding. Given result in lemma (5), any collateral size do not change utility function under this contract; this could be understood as a range of collateral that gives same solution for the problem. However, particularly for this model, I assume $\kappa = 0$ as a unique solution for sake of simplicity. On the other hand, collateral size would be different from zero in a default region under an incentive contract.

Corollary 8 *(Collateral level for incentive contract). For any ϵ that fulfills condition $k_1(\epsilon) \geq k_2(\epsilon)$, the collateral fraction for an incentive contract is equal to the singleton $K_2 = \Big\{ \kappa = k_2 \mid k_1(\epsilon) \geq k_2(\epsilon) \Big\}$.*

The collateral in this contract fulfills the condition $R + \kappa = 1$. In other words, there are enough resources in the clearing budget constraint for implementing an incentive contract.

Proposition 8 *(Level of collateral in an incentive contract). The incentive contract may give different levels of collateral depending of the level of deadweight loss ϵ when $\underline{\epsilon} \leq \varsigma^{-1}$; if $\varsigma > 0$ the level of collateral shall be low, otherwise the level of collateral shall be large.*

Proof. Condition $\underline{\epsilon} \leq \varsigma^{-1}$; if $\varsigma > 0$ is sufficient to show that there is an incentive contract. Since $\varsigma < 0 \leftrightarrow \epsilon < \epsilon^0$ incentive to not default needs high collateralization. When $\varsigma > 0$ the recovery rate reaches the highest value through range of deadweight losses, this allows to have a lower level of collateralization (see details in the appendix) $\blacksquare$.

Corollary 9 *(Unobservable type of contract). If the deadweight loss level of CDS seller is unobservable, an outside observer cannot necessarily infer the type of the contract from the collateral level alone when $\epsilon \in [\epsilon^0, \epsilon^*]$. However, if $\epsilon \in [\underline{\epsilon}, \epsilon^0)$ low and high levels of collateral are related to insurance and incentive contracts respectively.*

Insurance and incentive contracts give different levels of collateral; small enough deadweight losses allows to associate incentive contracts with higher levels of collateral. For a low level $(\overline{\theta} - c)$ and small ϵ, collateral levels are low and related to insurance contracts. On the other hand, low level of $(\overline{\theta} - c)$ and higher $\epsilon < \epsilon^*$ are related to more insurance than incentives contracts. The following corollary shows equilibrium for a corner solution $\kappa = 1$; below conditions excludes the case for $\kappa = 0$ since by definition an incentive contract must be offered with $\kappa \in (0, 1]$.

Corollary 10 *(Corner equilibrium for incentive contracts). If $\varsigma < 0$ and $\underline{\epsilon} = \varsigma^{-1}$ there is* *an incentive contract with collateral level $\kappa = 1$. If $\varsigma < 0$ and $\underline{\epsilon} > \varsigma^{-1}$ there is no incentive contract.*

By definition, a incentive contract delivers the condition $R + \kappa = 1$. The binding clearing budget constraint for a corner solution is $1 = \varsigma\epsilon$. Thus, as explained in proof of proposition (8) the lowest possible level of deadweight loss in order to guarantee an incentive contract is $\underline{\epsilon} = \varsigma^{-1}$.

Below figure (3.5) shows the recovery rate and CDS premium affected by the collateral policy implemented by the clearinghouse. The incentive contract shows that for a not small level of deadweight loss, there is some collateral level κ^* that makes the seller to not default. The existence of κ^* is a possibility since the clearing budget constraint must be fulfilled. Depending of the level of deadweight loss, there would be different collateral requirements implemented by an incentive contract. Here two points to remark: i) collateral requirement makes recovery rate (R) and premium (q) increase; and ii) Ratio $(R + \kappa)/q$ is constant, this is a consequence of a constant risk premium ($\Delta\lambda$). Although risk is constant, there are more contracts under non-defaulting situation since collateral size works in the same way as an increase of deadweight losses.

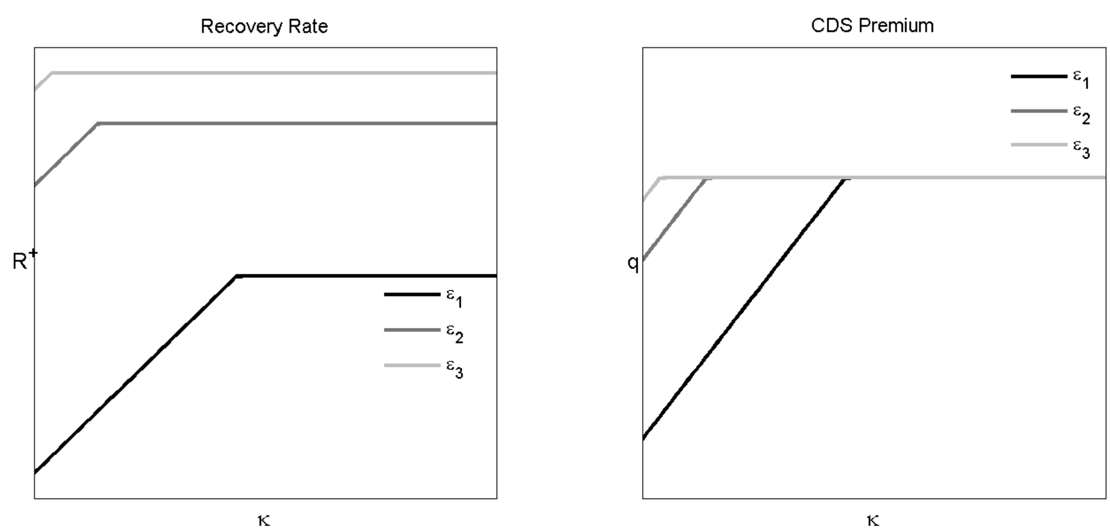


Figure 3.5: Recovery rate and CDS premium non-defaulting levels when $\epsilon_1 < \epsilon_2 < \epsilon_3 \approx \epsilon^*$

Also, figure (3.5) shows that collateral size is correlated to recovery rate levels; lower deadweight losses i.e. lower R requires higher amount of collateral for incentive contracts even for all values of deadweight losses. However, if type of contracts are pooled and even not observable yet, as corollary (9) claims, then collateral size is not informative about the amount of recovery rate.

Figure (3.6) shows that CDS notional is affected by the clearinghouse's collateral policy. Since R and q increases due to collateralization then notional amount of insurance decreases. Collateral requirements negatively affects the demand of insurance (m^b) through term $R + k \equiv \beta(\epsilon + \kappa)$; this term in particular offsets the effect of insurance shortage by seller and optimally isolate a detrimental in utils terms caused by the effect of the variance in the utility function. On the other hand, as I early noticed, collateral requirement for seller affects insurance supply in the same way as an increase in deadweight losses do.

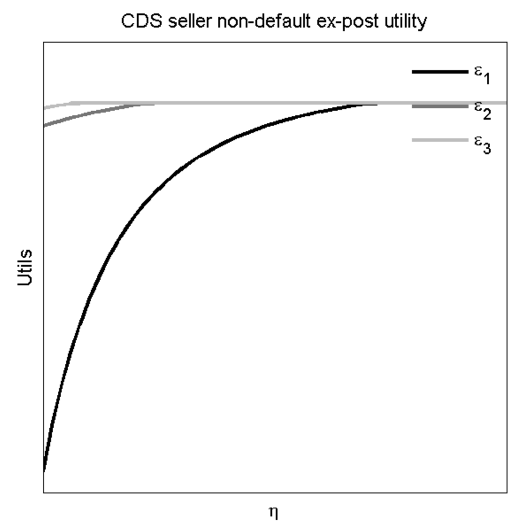


Figure 3.6: Notional and Non-defaulting ex-post utils when $\epsilon_1 < \epsilon_2 < \epsilon_3 \approx \epsilon^*$

Also, above figure shows the seller's ex-post utility as a function of collateral level. This function assess the ex-post decision of choosing non-defaulting and ex-ante determination of recovery rate (R). As long recovery rate is equal to $1 - \kappa$ then amount of insurance reaches the first best. Higher deadweight losses means higher recovery rates and therefore clearinghouse will require less collateral for delivering a non-defaulting choice.

Koeppl [68] states that insurance contract allows to extracts surplus from (a exchange) trade transaction and thus, in a moral hazard environment, seller can seize benefits from other activities that make the probability of default on the main event higher. The buyer can charge a higher price with a minimum collateral requirement even though allowing the counterparty risk to increase. In above setup, in a credit default swap market, a measure of surplus extraction is the ratio $\frac{R}{q}$; a seller can have a good deal if this ratio is higher after implementation of policies. However, in above setup the ratio is constant. I formalice this in the following proposition.

Proposition 9 *(Surplus extraction). In the credit-default-swap market allocation defined by equilibrium (4), the ratio $\frac{R}{q}$ is constant and equal to $\frac{R^{stge}+\kappa}{q^{stge}}$; being R^{stge} and q^{stge} the recovery rate and CDS premium when clearinghouse is acting as a collateral storage facility respectively.*

Proof. Since fraction $\frac{R}{q} \equiv \frac{1}{\delta\lambda+\lambda}$ then by proposition (4) $\Delta\lambda$ is constant ■. Above proposition clearly states that there is no gain in requesting collateral, this is not surprising due to lemma 5. However, there are less contracts that result in default. In Koeppl [68]'s terms: there are more significant gains in incentive than in insurance contracts. The new allocation proves to be weakly-Pareto improved. In the following lines, I closely study the effects of binding participation constraints on all variables, particularly on notional and CDS premium. This analysis is motivated by Acharya and Bisin [1] which makes an awareness of low levels of insurance even beyond the first best.

Proposition 10 *Solution There is unicity in the solution for the program (P1) when $R(\kappa)+\kappa = 1$ if $\beta\epsilon \leq 1$ and $(\beta - 1) > 0$ where $\beta \equiv \frac{\lambda+\sqrt{\lambda^2+4w(B)\gamma\lambda(1-\lambda)[\Delta\lambda+\lambda]}}{2[\Delta\lambda+\lambda]}$*

Proof. Since non-default choice is defined by definition (2) and $\Pi^S_{ND} > \Pi^S_D$ then the fixed point $R(\kappa) + \kappa = 1$ is the solution. ■

3.6.3 Mutualization

In this section, I setup the clearinghouse's problem. The clearinghouse needs to call for a default fund (ϕ^s) to sellers and a marginal fund (ϕ^b) to buyers[34]. In other words, each

[34] I assume for sake of simplicity that clearinghouse contribution is zero; thus the marginal is applied according to the waterfall tranche ordering and rules (see Fund [52], Exchange [51], LCHCLEARNET [75]).

participant must now contribute to a fund that is proportional to the total value of the liability. Thus, the amount of resources collected from sellers is $\frac{1}{1-\lambda}\phi^s$; instead, resources collected from buyers are equivalent to ϕ^b since the normalized unit of agents that do not see the event to occur is 1. Before stating the problem to maximize I define the equilibrium when the clearinghouse sets a mutualization policy.

Definition 8 *(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 $\mathcal{C}(R, q, m, \kappa)$ *as in 4*

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

(c) Insurance market clears;

(d) In the case of default, seller fulfill her promise and pay out the recovery rate times the amount of insurance. Thus, the function R *is defined as follows,*

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

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

$$\Phi(\varphi) = \begin{cases} R + \kappa + \varphi = 1 & \textit{full coverage} \\ R + \kappa + \varphi < 1 & \textit{Otherwise} \end{cases}$$

Here some points to discuss after definition of equilibrium. Seller always makes a default choice ex-ante comparing her utility to the case when $R+\kappa = 1$. When clearinghouse applies any mutualization policy for fully coverage, the seller responds providing $m = \frac{\omega s}{R+\kappa}$. Seller can realize a fully coverage scenario when clearinghouse is fully funded by either guarantee default funds or a visible own clearinghouse's equity. Whether resources are not enough for a fully coverage, then sellers provide $m_d(\epsilon)$ as defined before. In any case or scenario of clearinghouse's response to $R + \kappa < 1$, seller always will get Π_D as utility and insurance provided will be equal to $m(R+\kappa) = \omega_s$. The visible difference with the scenario without mutualization is that premium through risk premium $(\Delta\lambda)$ will be affected by resources coming from clearinghouse.

Formally, I setup the following clearinghouse's problem;

$$
\begin{aligned}
\mathcal{L} = \max_{\phi^s,\phi^b} \quad & \left\{ \left(\max_{m^s} \ (\Pi^S_{ND} \ , \ \Pi^S_D) \right) \max_{m^b} \ (\Pi^B) \right\} \\
\text{subject to} \quad & \frac{1}{1-\lambda}\phi^s + \phi^b = \frac{\lambda}{1-\lambda}\varphi \\
& m \equiv m^s = m^d \\
& \alpha q m + \overline{\theta} - \phi^s m \geq c \\
& 1 \geq R + \varphi \\
& q = (\Delta\lambda + \lambda)R \\
& 1 \geq \phi^s \geq 0 \\
& 1 \geq \phi^b \geq 0
\end{aligned}
\tag{P2}
$$

Where functions Π^B and Π^S_D are as follows;

$$\Pi^S_D = \overline{\theta} + mq - \lambda\epsilon m - \frac{\gamma}{2}\lambda(1-\lambda)\big[\epsilon m\big]^2 - \phi^s m - c$$

$$\Pi^B = \theta_0 - mq + (1-\lambda)(\omega_b - \phi^b m) + \lambda(R+\varphi)m - \frac{\gamma}{2}\lambda(1-\lambda)\big[\omega_b - (\phi^b + R + \varphi)m\big]^2$$

Expression Π^S_{ND} is the same as in (3.9). The first restriction in the program (P2) refers to the re-distribution of resources to buyers who see the CDS contract in default; $\phi_s m$ is the default fund posted by the seller, whereas ϕ_b comes from buyers who do not experienced the trigger of the event. The following restriction is the market clearing condition. The third restriction is the constraint of resources that are placed into the clearinghouse, as usual in clearing all calls must be collected in cash at period 0. The following constraints are related to non-negative and bounding conditions for any kind of corner solution. In order to solve the program (P2), the solution involves to fix values for ϕ_s, ϕ_b and φ and then finding the level of insurance m that maximizes the embedded function that appears on the objective function for the program (P2). Consequently, the optimal insurance level for buyers is as follows;

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

the optimal insurance level for sellers when default ($m^{s,d}$) and not default ($m^{s,nd}$) respectively are as follows,

$$m^{s,d} = \frac{q - \lambda\epsilon - \phi^s + \varrho(\alpha q - \phi^s)}{\gamma\lambda(1-\lambda)\epsilon^2}$$

$$m^{s,nd} = \left[\frac{q - \lambda R - \phi^s + \varrho(\alpha q - \phi^s)}{\gamma\lambda(1-\lambda)R} + \omega_s\right]\frac{1}{R}$$

Being ϱ the lagrange multiplier associated to the participation constraint.

$$\frac{\partial R}{\partial \phi^s} = \frac{\Omega_0(\epsilon) - 2(\phi^b + R + \varphi)\big[(\Delta\lambda + \lambda)R(1+\varrho\alpha) - \lambda\epsilon - \phi^s(1+\varrho)\big]\lambda^{-1} + (\phi^b + R + \varphi)^2(1+\varrho)}{\Omega_1(\epsilon) + 2(\phi^b + R + \varphi)\big[(\Delta\lambda + \lambda)R(1+\varrho\alpha) - \lambda\epsilon - \phi^s(1+\varrho)\big] + (\phi^b + R + \varphi)^2(\Delta\lambda + \lambda)(1+\varrho\alpha)}$$

Where $\Omega_0(\epsilon) = (1 + \omega_b\gamma(1-\lambda))\epsilon^2$ and $\Omega_1(\epsilon) = (\Delta\lambda - \omega_b\gamma\lambda(1-\lambda))\epsilon^2$. Since the premium depends on R I state a relation between R and ϕ^s in the clearing condition. I analyze this when both $\Omega_{0,1}(\epsilon) \xrightarrow[\epsilon\to 0]{} 0$. I will show in next lines a corner solution is part of the solution for the program (P2).

Proposition 11 *(Corner solution). Solution of program* (P2) *delivers the optimal result* $\phi^b = 0$ *when clearing budget constraint is slack.*

Proof. See appendix for details ■.

In order to show that recovery rate is higher in a mutualization policy than in a bilateral agreement; first at all, I show the condition that marginal change of recovery rate may be positive or negative. Then, I will show that response of default-fund has the same sign as the marginal change. This will prove that recovery rate is increasing in ϵ. Finally, it is sufficient to show that slope ($\beta(\Delta\lambda)$) is increasing after $\epsilon > \epsilon^0$.

Claim 1 *(Marginal Change of Recovery Rate). The marginal change to 1 unit of variation* *in default-fund call ϕ^s on the recovery rate R is positive when*

$$\frac{\Omega_0(\epsilon)}{\beta\epsilon + \frac{\phi^s}{\lambda}} + \beta\epsilon + \frac{\phi^s}{\lambda} - 2[(\Delta\lambda + \lambda)\beta\epsilon - \lambda\epsilon - \phi^s]\tilde{\lambda} > 0$$

being $\tilde{\lambda} \equiv \frac{1-2\lambda}{\lambda(1-\lambda)}$.

Notice the following result, Claim 1 shows that impact of default fund calls on recovery rate depends on the risk premium. In the following lemma I describe the determination of this variable:

Lemma 6 *(Risk Premium under clearinghouse policy). The risk premium is determined by the following expression*

$$\Delta\lambda = \frac{\lambda(\tilde{R}^2 - \tilde{R}^3) + ((N+1)\omega_s\tilde{R} - \omega_b)\gamma\lambda(1-\lambda)\tilde{R} + (1+\varrho)\phi^{s*}}{\tilde{R}^3 + \tilde{R}(1+\varrho\alpha)}$$

Where $R \geq \tilde{R} \equiv 1 - \varphi^*$

Proof. See appendix for details ■.

The following lemma shows the sign of $\frac{\partial R}{\partial \phi^s}$

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

In the following proposition I show that recovery rate is higher in mutualization.

Proposition 12 *(Recovery rate under mutualization). Given immediate above result and continuity of the function, then the recovery rate is higher in mutualization than in bilateral agreements under the sufficient condition:*

$$\frac{\partial \beta}{\partial \Delta\lambda} < 0$$

Proof. Above condition is hold for each $\epsilon > \epsilon^*$; see appendix for details ■.

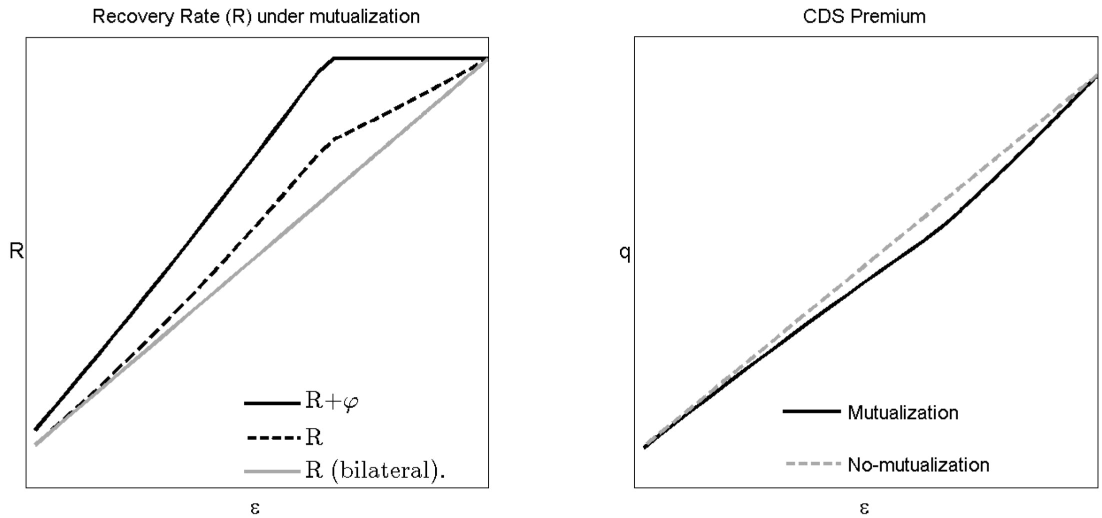


Figure 3.7: CDS premium and Recovery Rate

Figure (3.7) shows the effect of mutualization on recovery rate and premium. Low values of ϵ implies high levels of notional; this feature makes the clearing budget constraint to be tight. As notional values decreases, more resources are collected for mutualizing losses. These resources stem from all CDS sellers and equal to $(1-\lambda)^{-1}\phi_s m$. Notice that default-fund calls decrease for any case when $R+\varphi = 1$, an indication that full insurance is possible. Precisely, figure (3.8) shows that variable R/q increases in the range when $R+\varphi < 1$; 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 makes the premium decreases. Figure (3.7) shows that premium under mutualization is lower in comparison to the pricing in bilateral case; even the gap between them is larger when $R+\varphi \to 1$. Full insurance allows to dispense with resources since recovery rate increases. This have an immediate effect on risk premium and consequently on our variable of interest: the premium. Figure (3.7) also shows that under fully coverage the premium is not significantly lower than in a bilateral case. Literature agrees that clearing practices incentive agents to fulfill and improve to some extend the terms of contracts whenever default happens. This effect is measured by the increase of the recovery rate in the model. However, there is an effect that decreases the price and it is measured by the existence of resources collected by all participants from the market.

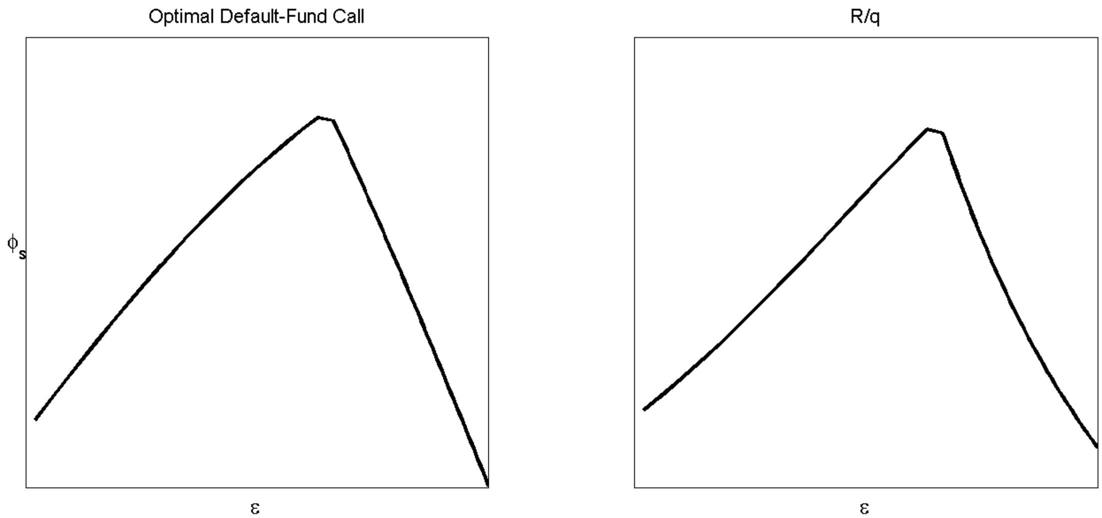


Figure 3.8: Default fund and ratio $\frac{R}{q}$

Figure (3.9) shows that notional amount of insurance drops when mutualization takes place as clearing policy. This effect is similar to the one with a collateralization policy. Mutualization improves the ex-ante social welfare. Once there are no need to collect more resources since fully coverage is achieved, welfare decreases. However, the welfare level is higher under mutualization than in a bilateral case.

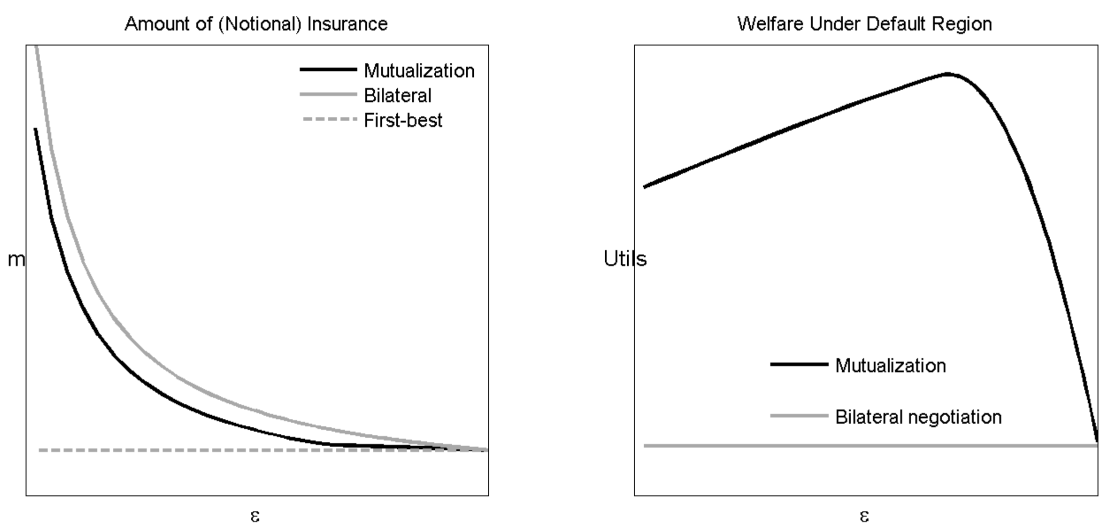


Figure 3.9: Notional and Social Welfare

Figure (3.10) shows that effective insurance, measured by $(R + \varphi)m$, increases in comparison to the bilateral case. Also, this amount of insurance gets smaller when full coverage is achieved.

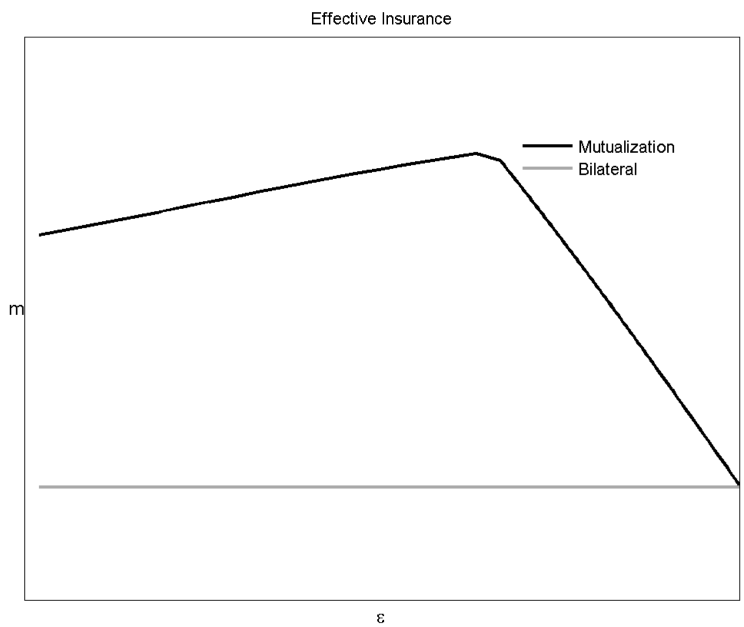


Figure 3.10: Effective insurance

3.7 Numerical exercise

Two illustrative exercises are performed in this section in order to show the effects of clearing policies. Figure (3.11) shows the financial structure for this exercise. The parameter N refers to extra buyers, this controls the leverage position of each seller. After the great recession, these positions are believed to be suitable due to regulation; thus $N = 0$. In the model there is I sellers; taking account the foregoing assumptions, there are equal number of sellers and buyers. As exposed before, a fraction λ of sellers default given a particular deadweight-loss parameter.

The first exercise shows the distribution of the premium produced by the effect of different endowments for sellers across clearinghouses. Size of endowments in the theoretical model reflects degree of limited liability since portfolio is kept with no variation. A quantitative measure of limited liabilities between sellers trading in different clearinghouses for the same instrument will open a gap in premiums. The exercise considers optimal collateral and mutualization policies.

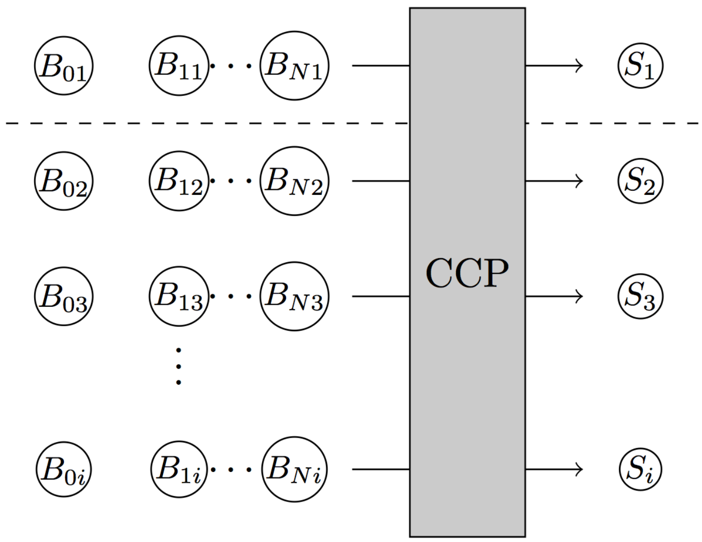


Figure 3.11: Clearing with $N \times I$ Buyers and I Sellers

The second exercise shows the size of default fund and collateral as fraction of notional when the probability of defaults increases. The third and four exercises shows the conditions for the existence of an interior solution when waterfall rules are applied or not. The fifth exercise focuses in matching the empirical difference of premiums between two clearinghouses (LCH versus CME) using default-fund calls. The last exercise analyzes the impact on premium when the total amount of guarantee-default fund increases significantly; a likely event that clearinghouses will take in the medium-run.

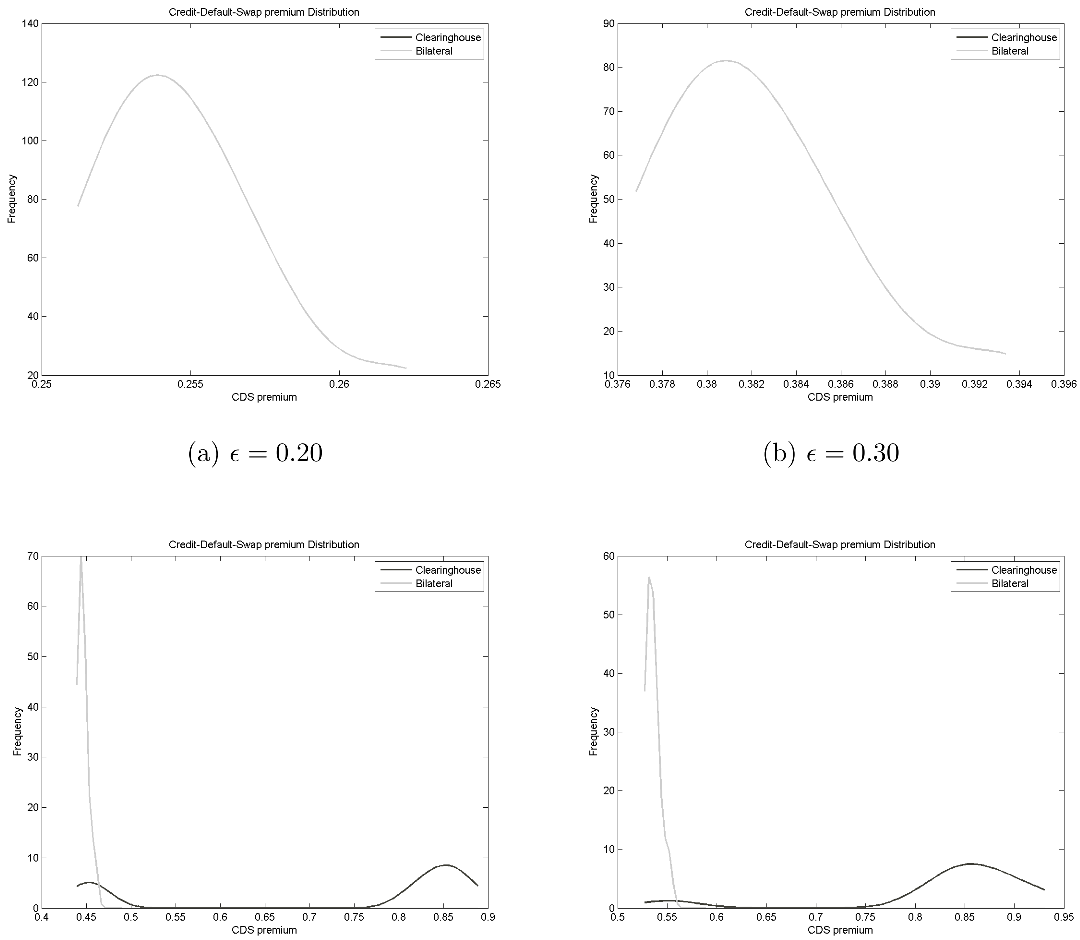
3.7.1 Clearing contracts with different endowments

In this section I use the model developed in past sections to simulate the impact of clearinghouse policy (collateralization and mutualization) on the premium. Table (3.1) shows the value of the parameters. The probability of occurrence of the event (λ) is fixed to 0.3. The risk aversion parameter (γ) is conservative and equal to one. The parameter α represents the fraction of the premium seized by clearinghouse; it is fixed to 0.2. The possible loss and endowment (ω_b) in the last period for the buyer is equal to 15. The average return of portfolio ($\overline{\theta}$) is equal to 0.88 whereas fixed costs of participation in clearing (c) is equal to 1. The endowment received in last period for seller ($\overline{\omega_s}$) is stochastic with average value equal to 10.

Parameters	Value	Definition
λ	0.3	Probability of the event
γ	1.0	Risk aversion parameter
$\overline{\omega_s}$	10	CDS seller's endowment average
σ_s^2	0.50	Variance of ω_s
ω_b	15	CDS buyer's loss
α	0.2	Limited liability parameter
$\overline{\theta}$	0.88	CDS seller's Portfolio
c	1.00	Participation costs
N	0.00	Extra buyers

Table 3.1: Parameterization

The only random variable in the model is the CDS seller's endowment ω_s; Thus, i.i.d $\omega_s \sim \mathcal{N}(\overline{\omega_s}, \sigma_s^2)$. I show the distribution of CDS premium (q) for clearing policies in comparison to bilateral ones for a given fixed value of deadweight loss (ϵ). Specifically, I analyze the CDS premium when seller has the incentive of defaulting; this choice is governed by the size of deadweight losses. Thus, the analysis is based on the range $\epsilon \in (\epsilon^0, \epsilon^*)$. Under the parameterization shows in table (3.1) the level of ϵ^* is 0.52. Figure (3.12a) shows that if deadweight loss is small there is no incentive contract and only an insurance contract which optimal collateral level (κ^*) is equal to zero. Figure (3.12b) shows a combination of insurance and incentive contracts; a higher CDS premium reveals an incentive contract that makes seller to not default. There is still a fraction of contracts that are constrained by funds and only an insurance contract is offered. Figures (3.12c) and (3.12d) show the prevalence of incentive contracts; all prices are higher than before and those levels represent the first best allocation.



(a) $\epsilon = 0.20$

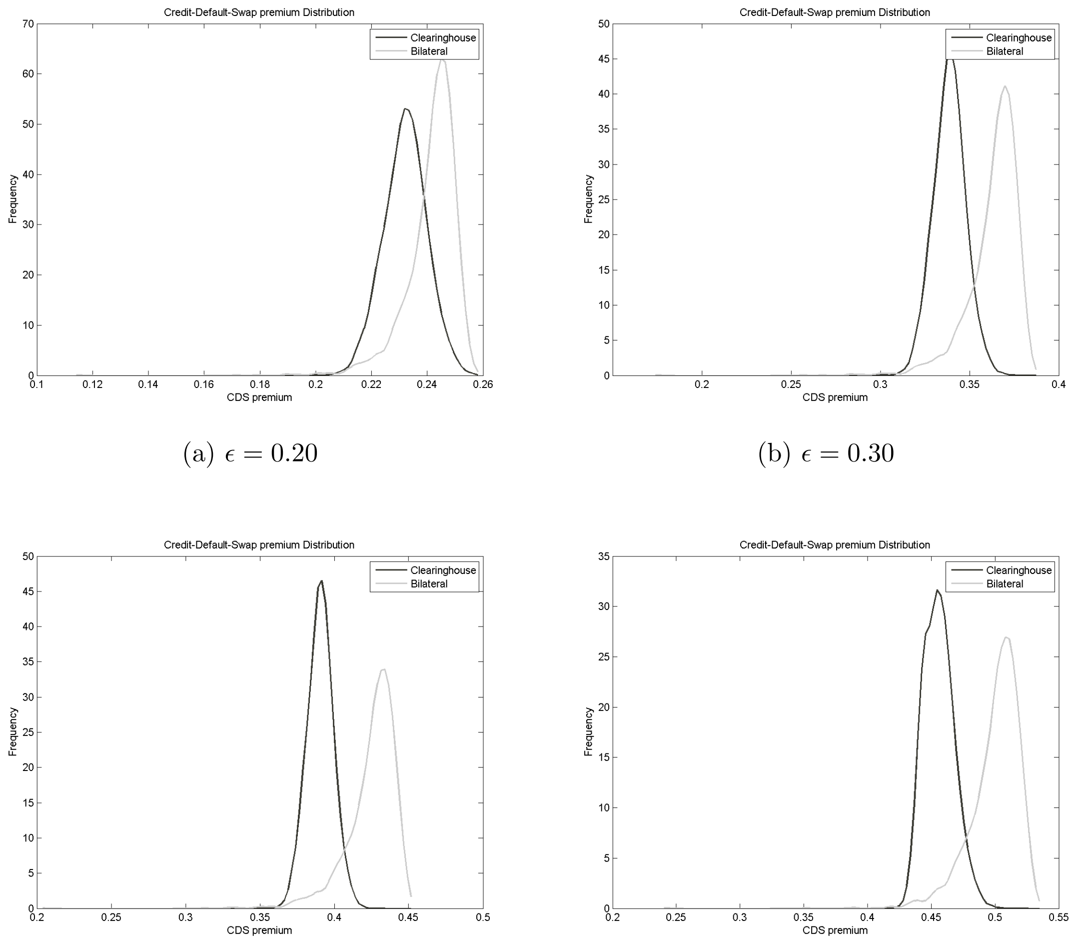
(b) $\epsilon = 0.30$

(c) $\epsilon = 0.35$

(d) $\epsilon = 0.42$

Figure 3.12: CDS premium distribution when clearinghouse performs as collateral storage facility

In the following figure I show the distribution of the CDS premium when mutualization is the policy implemented by clearinghouse when $\epsilon = 0.42$. As discussed in section (2), the CDS premium is lower under mutualization.



(a) $\epsilon = 0.20$

(b) $\epsilon = 0.30$

(c) $\epsilon = 0.35$

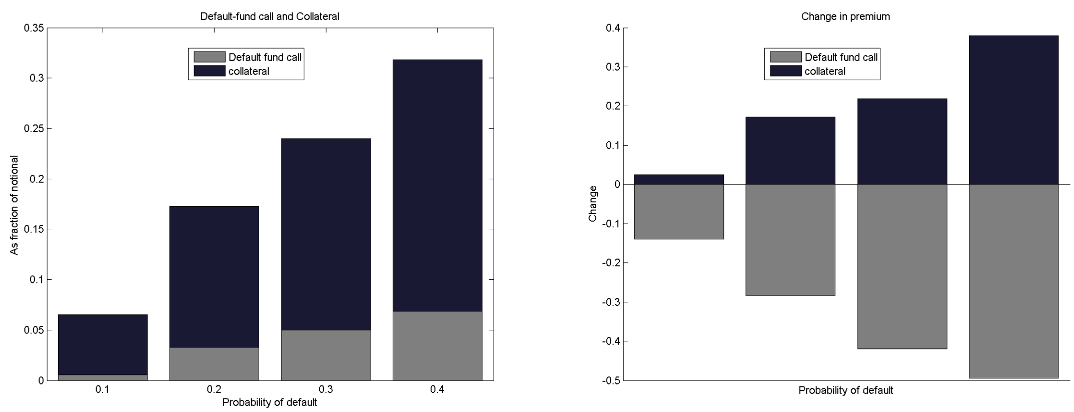
(d) $\epsilon = 0.42$

Figure 3.13: CDS premium distribution when clearinghouse performs mutualization

Thus, economies implementing collateralization are characterized by higher premium if the deadweight losses are high enough; the threshold $(\tilde{\epsilon})$, which indicates that a incentive contract is received, will be determined by the size of resources in the clearing budget. In contrast, economies implementing mutualization experience a lower premium over all range of deadweight losses.

3.7.2 Size of seller's default fund and collateral

Figure (3.14) depicts the effect of varying members' probability of default λ while maintaining other parameters constant on mutualization. The amount of resources is given 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. Figure (3.14b) shows the impact in the premium whether collateralization and mutualization practices are applied.



(a) Size of default fund

(b) Change in premium

Figure 3.14: Size of default fund and collateral

In quantitatively terms, figure (3.14b) shows that collateralization increases the premium; whereas mutualization decreases it. Given the parameterization shown in table (3.1) mutualization has a larger effect in absolute terms.

3.7.3 Optimal default-fund and marginal call

In this section I show the optimal default-fund and marginal call when the clearing budget is slack. Due to the characteristics of the problem I perform a grid search in order to find the solution to program (P2). According to waterfall rules, the resources coming form seller's guarantee default-fund must be the first shelter; once resources are not enough buyer's guarantee default funds (ϕ_s) and any marginal call (ϕ_b) should be used. However I analyze the change in the premium when rules do not exist. If the clearing budget or restriction is slack then a corner solution is achieved (see figure 3.15). A slack restriction is constructed appropriately increasing the portfolio size (θ_s).

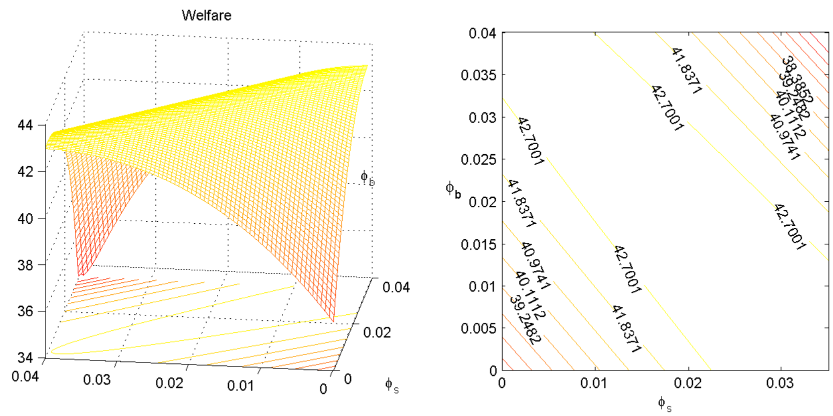


Figure 3.15: Welfare; clearing budget slack

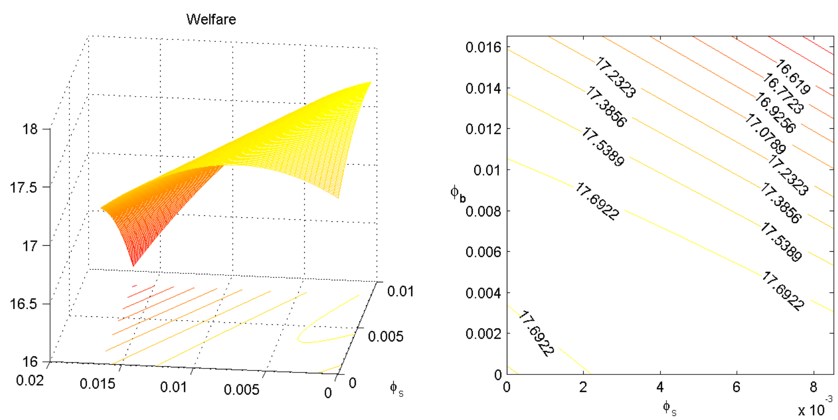


Figure 3.16: Welfare; clearing budget binds

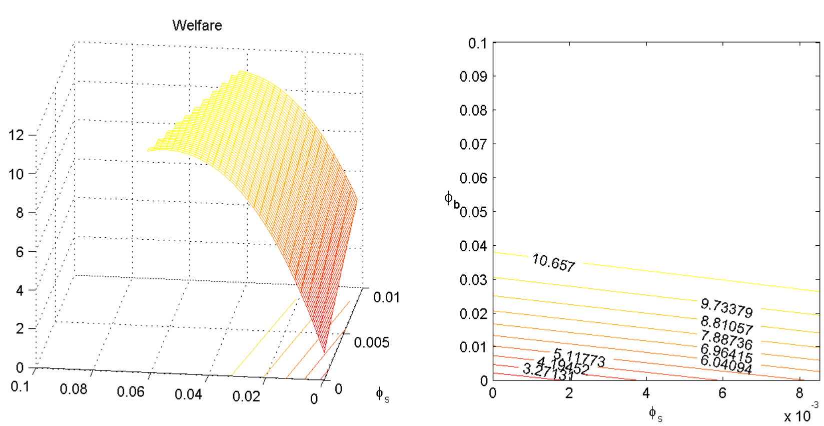


Figure 3.17: Welfare; clearing budget binds when $\lambda = 0.3$ and $\omega_b = 15$

If the clearing budget is almost tight still exists a corner solution (see figure 3.16); however, when the probability of default increases to $\lambda = 0.3$ and buyer endowment also increases to $\omega_b = 15$ an interior solution is achieved. Thus, more cases of default and resources to hedge demand more resources to collect from market participants. The table (3.2) shows the change in premium obtained between a mutualization policy (q^m) and a bilateral agreement (q^b) for cases depicted in figure (3.15), (3.16) and (3.17) respectively.

Clearing budget	Parameterization	Solution	$q^m - q^b$
Slack	$\lambda = 0.2$ $\omega_b = 14$	corner	-0.041
Almost binding	$\lambda = 0.2$ $\omega_b = 14$	corner	-0.006
Almost binding	$\lambda = 0.3$ $\omega_b = 15$	interior	-0.061

Table 3.2: Change in premium

The higher difference is 6 bsp. for the case when the clearing budget is almost binding, the probability of default is higher and the loss to hedge is large.

3.7.4 Waterfall Rules

Fund [52] states that clearinghouses must follows an ordering in the usage of resources when participants default (a.k.a. a waterfall rule). In this section, I consider that clearinghouse equity is zero and collateralization is not implemented; therefore, clearinghouse first layer of protection is the guarantee-default fund of sellers and the second is a marginal call to buyers for whom the event did not occur. Usually, there would be marginal calls to non-defaulting sellers, however, for sake of simplicity, I keep this call equal to zero. The waterfall rule says that when resources are exhausted after first-step collection on sellers the next layer is implemented, this layer is precisely the marginal call on buyers which is net-term defined. In other words, the guarantee-default fund is entirely offset for buyers who see their seller defaulting. These buyers will be covered with funds from sellers and remaining “survivors” buyers through clearinghouse.

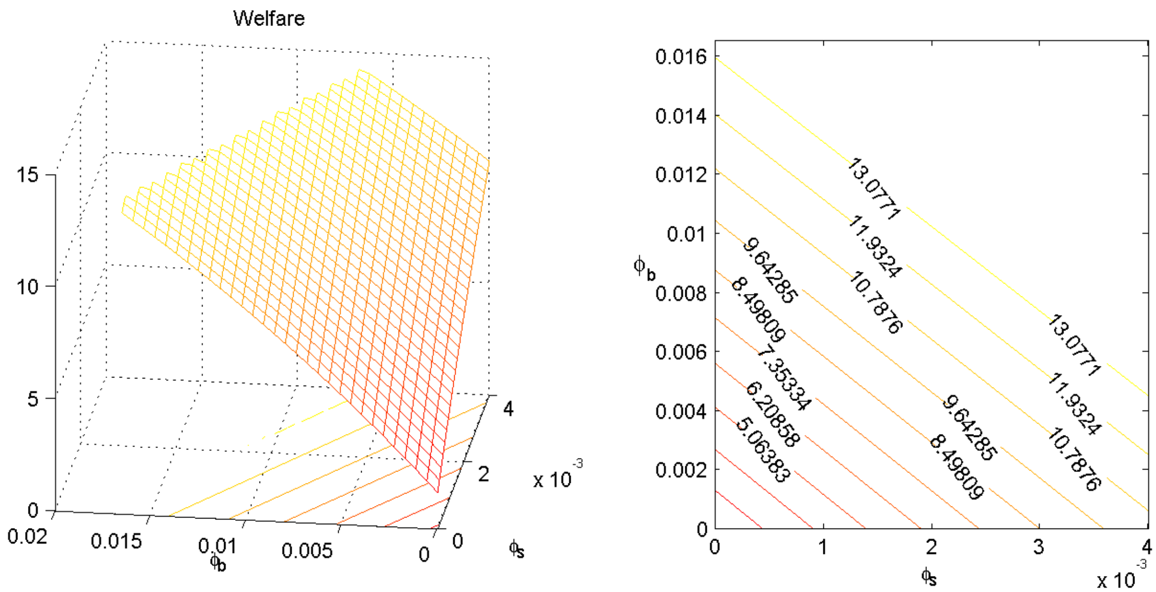


Figure 3.18: Welfare when clearing budget is binding

Figure 3.18 shows that when clearing budget is totally binding an interior solution is achieved.

3.7.5 Matching Data

I estimate the model in section (3.5) using a Method of Simulated Moments (MSM). The procedure requires a numerical simulation for shaping a theoretical premium distribution that will be then compared to its empirical one. The method is not cumbersome since only two endowments need to be simulated from a known distribution. The ad-hoc feature of the model then makes tractable the usage of this method[35]. I explained the procedure in the following lines.

The parameters of the model are denote by $\psi \in \Psi \subset \mathbb{R}^s$; the endowments are gathered in the vector $\chi \in \mathbb{R}^2$. The model described in section (3.5) produces a level of premium; this price is the result of the trading between sellers and buyers and clearinghouse policies

[35] See Gourinchas and Parker [54] for comparison with cases where the method faces enormous computational challenges.

given a set of parameters ψ. Thus, the unconditional expectation of log-premium is;

$$\ln q(\psi) \equiv \mathbb{E}\big[\ln q(\chi;\psi|\psi)\big] = \int \ln q(\chi,\psi) dF(\chi;\psi)$$

I approximate the theoretical unconditional expectation using a monte-carlo procedure; endowments are generated from a sequence of random variables $\{\hat{\chi}\}_{l=1}^{l=L}$ that are identically independently distributed. Then the unconditional expectation from the model $\ln q(\psi)$ is then simulated by

$$\ln \hat{q}(\psi) \equiv \frac{1}{L}\sum_{l=1}^{L} \ln \hat{q}(\chi_l,\psi)$$

where convergence occurs as $L \to \infty$. Thus, for any parameter vector $\psi \in \Psi$, the theoretical expectation can be replaced with its simulated part. Since I am interested in explain differences in premium across clearinghouses the following expression needs to be close to zero enough;

$$g\Big(\ln \frac{q^1(\hat{\psi}^1)}{q^2(\psi^2)}\Big) = \ln \frac{q^1}{q^2} - \ln \frac{\hat{q}^1(\hat{\psi}^1)}{\hat{q}^2(\psi^2)}$$

Finally, the MSM requires to minimize the following expression over ψ

$$G = g\Big(\ln \frac{q^1(\hat{\psi}^1)}{q^2(\psi^2)}\Big)' W_g g\Big(\ln \frac{q^1(\hat{\psi}^1)}{q^2(\psi^2)}\Big)$$

Since our simple approach requires to match only one moment (mean) and consequently the weighting matrix is equal to $W = 1$; the estimation procedure is equivalent to minimizing the sum of squared residuals;

$$G = \left(\ln \frac{q^1}{q^2} - \ln \frac{\hat{q}^1(\hat{\psi}^1)}{\hat{q}^2(\psi^2)}\right)^2 \tag{3.13}$$

The optimum is found by minimizing G iterating over ψ; then the gradient of the moment vector is evaluated numerically and the variance-covariance matrix is respectively estimated. The empirical counterpart is the mid price for a particular CDS index traded in a specific clearinghouse.

Since above procedure setups only one moment, I partition ψ into two subvectors ψ_1

and ψ_2. The first set ψ_1 gathers fixed parameters in a compact set; for instance, the risk aversion measure γ. Also, the subvector ψ_1 contains the size of collateralization (κ) in each clearinghouse. For this ad-hoc parameterization, I consider the work of Duffie et al. [49] that estimate the collateral demand of clearing practices. The subvector ψ_2 contains the default-fund parameter (ϕ_s).

The following table shows the choice of parameters for both clearinghouses.

Parameters	Value	Definition
κ	0.20	Collateral
ϵ	0.30	Deadweight loss
λ	0.30	Probability of default in clearinghouse
γ	1.00	Risk aversion parameter
α	0.20	Limited liability parameter
$\overline{\theta}$	3.00	CDS seller's Portfolio
c	1.00	Participation costs
N	0.00	Extra buyers

Table 3.3: Subvector ψ_1

The following table shows the variables to simulate and benchmark for each clearinghouse

Variable	CCP1	CCP2
$\frac{\omega_b}{\omega_s}$	0.81	$\sim \mathcal{U}(0.72,0.92)$
ω_s	12	$\sim \mathcal{N}(12,0.23)$
ϕ_s	0.0406[1]	arg min (3.13)

[1] Optimal value

Table 3.4: Variables in χ and ψ_2

A CDS whether cleared at LCH or CME is the same instrument and therefore there would be an insignificant difference in the price of these swaps (henceforth basis). Since regulation does not mandate clearing for CDS yet, changes of basis would be influenced by few observations for these instruments. However, basis for interest rate swaps, a deep trading market, is a good approximation for our exercise. Besides, interest rate swap resembles CDS closely. As discussed before, typically basis fluctuates small enough (0.15bps bid/offer) to be inconsequential to the market between clearinghouses. However, there are some dates where the basis increased 5 or 6 times this amount. Specifically, in May 2015, CME-LCH basis for USD IRS rose significantly exhibiting values up to 2bps; the following table shows the structure and basis of this instrument across clearinghouse.

Term	LCH mid	CME mid	Basis (bps)
1Y	0.45802	0.45952	+0.15
2Y	0.82319	0.82669	+0.35
5Y	1.65642	1.66842	+1.20

Table 3.5: LCH-CME basis

For sake of numerical analysis I take the basis for interest rate swaps with maturity of two years. The following table shows the SMM estimation for this case.

Parameter	Point estimate	Upper bound	Lower bound
$\hat{\phi}_s^2$	0.03128	0.03147	0.03109

Table 3.6: SMM estimation

Thus, the clearinghouse 2 collects funds on average equal to the fraction $\hat{\phi}_s^2 = 3.1\%$; this percentage is lower than the default fund fraction in the clearinghouse 1 (4.1%).

3.7.6 Reaching optimal guarantee-default levels

Last exercise shows the effect of increasing the total amount of the guarantee fund on premium. For this, I consider an amount that is feasible to observe in the financial market through the clearing. According to Depository Trust & Clearing Corp. a backstop on the repo market (a short-term lending) has risen to \$73.8 billion. This represents a significant increase in the fund comparing to roughly 50 billion two years ago. The total reflects an amount DTCC will seek in commitments from member firms to cover the cost of the credit facility. That facility can be invoked if any member defaults and the clearinghouse's other resources become exhausted; thus -according to DTCC-forcing its Fixed Income Clearing

Corp. subsidiary to step into the shoes of the defaulting firm and assume its obligations.

I consider for the exercise the following parameterization: low leverage (N=0), collateral around 20%, and same parameters as shown in table (3.1). I fixed the new amount as optimal and I calculate the difference in premium. According to the model, the premium should be decrease around 5.8%.

3.8 Conclusions

The credit derivative obligation has become a cornerstone after and before recent financial crisis. CDS helped protecting investor portfolios against default offering a transfer risk. Recent empirical literature shows that clearing practices have an ambiguous effect on premium; I offer a theoretical model that explains these findings. Also, size of premium arbitrage arises as a debate subject as multiple clearinghouses are operating across markets. I setup six quantitative exercises in order to show the effects of mutualization and collateralization on premium; two of them intend to match differences in real prices and relate them to changes in guarantee-default funds.

The model of CDS market taken from Acharya and Bisin [1] and Stephens and Thompson [99] is characterized by greater quantity of insurance sold and default. I modified the original model to include a clearinghouse that observes the size of trading and collect either defaul-funds or collateral from participants in the insurance market. If deadweight losses are high, an incentive contract can be offered by clearinghouse when collateralization takes place as clearing policy. The premium is higher for this practice relative to bilateral agreements. In equilibrium there is not default. The premium increases since the value of the position (the recovery rate) increases. If deadweight losses are not too high, an insurance contract is offered by clearinghouse when collateralization takes place as clearing policy. The premium is the same as before when parties set the contract bilaterally. In equilibrium there is default. In general, collateralization delivers a second best characterized as a weakly Pareto allocation relative to bilateral allocation. The first best is characterized as a constrained Pareto optimum. The ratio R/q, as measure of counterparty risk, is constant for all agents but in equilibrium CDS sellers do not go back on promises.

For a range of deadweight losses $\epsilon \in (\epsilon^0, \epsilon^*)$, premium is lower when mutualization takes place as clearing policy and capital requirement is high (low leverage). The allocation is characterized by a higher recovery rate. If deadweight losses are high, there is no default under this policy. The ratio R/q increases for defaulting contracts after mutualizing losses. According to the numerical exercise the size of default funds in comparison to collateral is small and also there is a corner solution ($\phi_s > 0$ and $\phi_b = 0$) when there is a marginal and default fund applied to buyers under a loose seller's clearing budget. If foregoing restriction binds then there is an interior solution ($\phi_s > 0$ and $\phi_b > 0$) that maximizes the social utility. This makes optimal the presence of waterfall rules.

Empirical literature found that clearing decreases premium controlling for related variables of liquidity and networking. Some others found that the effect of clearing on premium is not significant. The risk premium ($\Delta\lambda$) decreases as long as there are more resources under the clearinghouse management. This would force the premium to decrease. Thus, the extend of this fall in the premium is attributed to the size of resources collected by clearinghouse. In order to capture this regularities, empirical work must include a set of explanatory variables related to the size of resources managed by the clearinghouse and also to pinpoint quantitatively clearing practices

Contrary to Stephens and Thompson [99], I show that price competition is not only the factor behind a lower premium under a mutualization policy; with no competition (random matches) the effect of the collectable fund on premium offsets the increase in the value of the position.

Regarding mandatory clearing. Earlier, I show that the success of clearing operations are based on the resources that clearinghouses may collect from participants. Thus, it is imperative to have more participants or contracts under a clearing framework.

Regarding future research. In this chapter, collectable resources are not longer needed when $R + \varphi = 1$ i.e. fully coverage. In a dynamic scenario, more resources would be necessary for trading in illiquid scenarios. If there are more resources at current period, premium maybe would decrease more.

Appendix A

Details of derivations in chapter 1

Derivation of expression (1.3). Derivation of final expression starts with the following expression:

$$\begin{aligned} V_t &= (1-h)e^{-r_t}E_t^Q(V_{t+1}) + he^{-r_t}E_t^Q(c\varphi_{t+1}) \\ &\equiv (1-h)e^{-r_t}E_t^Q(V_{t+1}) + he^{-r_t}E_t^Q(\beta V_{t+1}) \\ &\equiv E_t^Q\Big[V_{t+1}\big((1-h)e^{-r_t} + h\beta e^{-r_t}\big)\Big] \end{aligned} \tag{A.1}$$

Considering the change in notation for expression $(1-h)e^{-r_t} + h\beta e^{-r_t}$ as e^{-R_t} and considering a recursive solution for expression (A.1) up to period $t+\Delta$, I have the following expression,

$$V_t \equiv E_t^Q\Big[V_{t+\Delta}e^{-\sum_j^{\Delta-1} R_{t+j}}\Big]$$

Evaluating the right hand expression a period before the default then I have the expression in (1.3) i.e. $V_{t+\Delta} \equiv X_{t+\Delta}$.

Derivation of expression (1.4). First, I start with the case of full collateralization i.e. $\beta = 1$ which resembles the case specified in Johannes and Sundaresan [64]. Thus, $C_s \equiv c\varphi_s \equiv V_s$. Furthermore, since the probability of default is constant i.e. it does not depend on time of default (τ), then the value of the contract can be equivalently expressed as follows,

$$V_t = E_t^Q\Big[e^{-\int_t^T r_s ds}\Phi_T(1-h) + e^{-\int_t^\tau r_s ds}C_\tau h\Big] + (1-h)P_t$$

Above expression is slightly different to Johannes and Sundaresan [64]. I included an adjustment that let the post of posting and maintaining collateral (P_t) be a fraction of the total value of the contract[1]. The expression $E_t^Q\Big[e^{-\int_t^\tau r_s ds} V_\tau\Big]$ under the martingale Q may be assumed as V_t in current terms. Thus,

$$V_t = E_t^Q\Big[e^{-\int_t^T r_s ds}\Phi_T\Big] + P_t \tag{A.2}$$

Expression P_t is the cost of posting and maintaining collateral in current prices; this is equal to the following expression,

$$P_t = E_t^Q\Big[(1-h)\int_t^T \exp\Big\{-\int_t^s r_u du\Big\} y_s V_s ds + h\int_t^\tau \exp\Big\{-\int_t^s r_u du\Big\} y_s V_s ds\Big]$$

Since τ is random under default ($\tau < T$), a simplification is useful by using the property of the Q measure. The term $E_t^Q\Big[\int_t^\tau \exp\{-\int_t^s r_u du\} y_s V_s ds\Big]$ must be equal to the current cost P_t regardless the probability function of τ under default. The martingale makes the foregoing feasible since the best predictor for the collateral cost relies on the available information at time t. Thus, the solution for P_t is shown in the following lines;

$$\begin{aligned} P_t &= E_t^Q\Big[(1-h)\int_t^T \exp\Big\{-\int_t^s r_u du\Big\} y_s V_s ds\Big] + hP_t \\ &\equiv E_t^Q\Big[\int_t^T \exp\Big\{-\int_t^s r_u du\Big\} y_s V_s ds\Big] \end{aligned} \tag{A.3}$$

Taking into account expressions (A.2) and (A.3) then,

$$V_t = E_t^Q\Big[e^{-\int_t^T r_s ds}\Phi_T\Big] + E_t^Q\Big[\int_t^T \exp\Big\{-\int_t^s r_u du\Big\} y_s V_s ds\Big]$$

Re-arranging above expression and taking into account that $E_t^Q\Big[e^{-\int_t^s r_s du} V_s\Big] \equiv V_t$ for

[1]The cost of posting and maintaining collateral can potentially be treated as a significant part of the value of the contract; however, parties can agree to include at least the aforementioned cost only for non-defaulted contracts. This would justify the fraction (1-h).

any s then,

$$\begin{aligned}
V_t\Big(1 - E_t^Q\Big[\int_t^T y_s ds\Big]\Big) &= E_t^Q\Big[e^{-\int_t^T r_s ds}\Phi_T\Big] \\
V_t E_t^Q\Big(1 - \int_t^T y_s ds\Big) &= E_t^Q\Big[e^{-\int_t^T r_s ds}\Phi_T\Big] \\
V_t E_t^Q\Big(e^{-\int_t^T y_s ds}\Big) &= E_t^Q\Big[e^{-\int_t^T r_s ds}\Phi_T\Big] \\
V_t &= E_t^Q\Big[e^{-\int_t^T (r_s - y_s) ds}\Phi_T\Big]
\end{aligned}$$

Now, I assume that $c\varphi_s \equiv \beta_s V_s$. The value of the contract must be adjusted properly;

$$V_t = E_t^Q\Big[(1-h)e^{-\int_t^T r_s ds}\Phi_T + h\int_t^T e^{-\int_t^\tau r_u du}\beta_s V_\tau ds\Big] + \Big(1 - h\int_t^T \beta_s ds\Big)P_t$$

I assume that collateral is taken to maturity under default. The foregoing explains the boundary T instead of τ over the integral in the above modified-contract value. Using aforementioned assumptions for the value of the contract under default and considering a new arrangement, then;

$$\begin{aligned}
V_t\Big(1 - h\int_t^T \beta_s ds\Big) &= E_t^Q\Big[(1-h)e^{-\int_t^T r_s ds}\Phi_T\Big] + \Big(1 - h\int_t^T \beta_s ds\Big)P_t \\
V_t\Big(e^{-h\int_t^T \beta_s ds}\Big) &= E_t^Q\Big[e^{-h}e^{-\int_t^T r_s ds}\Phi_T\Big] + \Big(1 - h\int_t^T \beta_s ds\Big)P_t \\
V_t &= E_t^Q\Big[e^{-\int_t^T (r_s + h(1-\beta_s)) ds}\Phi_T\Big] + P_t
\end{aligned}$$

The cost of posting and maintaining collateral can be adjusted as follows;

$$\begin{aligned}
P_t &= E_t^Q\Big[(1-h)\int_t^T \exp\Big\{-\int_t^s r_u du\Big\} y_s \beta_s V_s ds\Big] + hP_t \\
&\equiv E_t^Q\Big[\int_t^T \exp\Big\{-\int_t^s r_u du\Big\} y_s \beta_s V_s ds\Big]
\end{aligned}$$

Gathering up terms;

$$
\begin{aligned}
&V_t = E_t^Q\Big[e^{-\int_t^T (r_s+h(1-\beta_s))ds}\Phi_T\Big] + E_t^Q\Big[\int_t^T \exp\Big\{-\int_t^s r_u du\Big\}y_s\beta_s V_s ds\Big] \\
&V_t(1-\int_t^T y_s\beta_s ds) = E_t^Q\Big[e^{-\int_t^T (r_s+h(1-\beta_s))ds}\Phi_T\Big] \\
&V_t e^{-\int_t^T y_s\beta_s ds} = E_t^Q\Big[e^{-\int_t^T (r_s+h(1-\beta_s))ds}\Phi_T\Big] \\
&V_t = E_t^Q\Big[e^{-\int_t^T (r_s+h(1-\beta_s)-y_s\beta_s)ds}\Phi_T\Big] \quad \blacksquare
\end{aligned}
$$

Alternatively to above derivation, Borovykh [23], by using the Feynman-Kac formula, tediously derives the mathematical expression for the value of the contract; the author pinpoints the value of the contract when the investor is either shorting or longing the asset. The author starts with the change in continuous time of the value of the contract (by Ito's lemma),

$$
\begin{aligned}
dV_t &= \frac{\partial V}{\partial t}dt + \frac{\partial V}{\partial S}dS_t + \frac{1}{2}\frac{\partial^2 V}{\partial S_t^2}\Big(dS_T^2\Big)^2 \\
&\equiv \left(\frac{\partial V}{\partial t} + \frac{1}{2}\frac{\partial^2 V}{\partial S_t^2}\sigma_{S,t}^2 S_t^2\right)dt + \frac{\partial V}{\partial S}s_t
\end{aligned}
$$

Last above expression includes the usage of the Black-Scholes formula. Since the value of the contract must resembles an alternative opportunity cost, Borovykh [23] states that arbitrage applies by inducing the replication of a portfolio of underlying stocks (Δ_t). Thus, $V_t = \Delta_t S_t + \gamma_t$ where last term is the cash which depend on four different interest rates

$$
\gamma_t = \Big(r_{c,t}C_t + r_{f,t}(V_t - C_t) - r_{r,t}\Delta_t S_t + r_{d,t}\Delta_t S_t\Big)dt
$$

$r_{c,t}$, $r_{f,t}$, $r_{r,t}$ and $r_{d,t}$ are the risk-free, floating, repo and dividend interest rate respectively. The portfolio is affected by the former interest rates. By removing uncertainty i.e. $\Delta_t = \frac{\partial V}{\partial S}$, using Feynman-Kac formula and identifying drift terms (see Borovykh [23] for details), the value of the contract is as follows,

$$
V_t = E_t\Big[e^{-\int_t^T r_{c,s}}V_T\Big] - E_t\Big[\int_t^T e^{-\int_t^\mu r_{c,\mu}d\mu}(r_{f,s} - r_{c,s})(V_s - C_s)ds\Big]
$$

In order to make the equivalence to my final expression in (1.4) when $y_s = 0$ then

$r_{f,s} - r_{c,s} = h \equiv (T-t)^{-1}$ and $C_s = \beta_s V_s$ are assumed. Doing some final arrangement to above expression and taking into consideration the measure Q

$$\begin{aligned}
V_t &= E_t\Big[e^{-\int_t^T r_{c,s}} V_T\Big] - E_t\Big[\int_t^T e^{-\int_t^\mu r_{c,\mu} d\mu} h(1-\beta_s)V_s ds\Big] \\
&= E_t\Big[e^{-\int_t^T r_{c,s}} V_T\Big] - E_t\Big[\int_t^T h(1-\beta_s)V_t ds\Big] \\
&= E_t\Big[e^{-\int_t^T r_{c,s} + h(1-\beta_s)} V_T\Big]
\end{aligned}$$

Finally, $r_c \equiv r$ is the risk-free interest rate for lending. The value of the contract is $V_T = L(T) - s^w$ which means that the investor is holding the collateral. This completes the proof.

Derivation of expresson in proposition (2). In general terms, there are two variables: z which is stochastic and μ is a trend. The expression into discussion is $E\{f'(z+\nu\mu)\}$ since Stein's lemma delivers $cov(f(z+\nu\mu), y) \equiv cov(z+\nu\mu, y)E\{f'(z+\nu\mu)\}$, ν is a scalar. In that matter, I have the following

$$E\{f'(z+\nu\mu)\} = \int_0^{\overline{\mu}} \int_0^\infty f'(z+\nu\mu)\phi(z)dzdu$$

Since $\phi(z)$ is σ-finite and $\overline{\mu}$ is a real number, Fubini and Tornelli's theorema applies, thus it allows the order of integration to be changed in iterated integrals. Additionally, $f(x) = e^x$ which makes terms separable. Thus, above expression can be arranged as follows,

$$\begin{aligned}
E\{f'(z+h\mu)\} &= \int_0^{\overline{\mu}} \int_0^\infty \Big[f'(z)f(\nu\mu) + f(z)f'(\nu\mu)\Big]\phi(z)dzdu \\
&\equiv \int_0^{\overline{\mu}} \Big[\int_0^\infty f'(z)f(\nu\mu)\phi(z)dz\Big]du + \int_0^{\overline{\mu}} \nu\Big[\int_0^\infty f(z)f'(\nu\mu)\phi(z)dz\Big]du \\
&\equiv \int_0^{\overline{\mu}} f(\nu\mu)\Big[\int_0^\infty f'(z)\phi(z)dz\Big]du + \int_0^{\overline{\mu}} \nu f'(\nu\mu)\Big[\int_0^\infty f(z)\phi(z)dz\Big]du \\
&\equiv E\Big[f'(z)\Big]E\Big[f(\nu\mu)\Big] + \nu E\Big[f(z)\Big]E\Big[f'(\nu\mu)\Big] \\
&\equiv (1+\nu)E\Big[f(z)\Big]E\Big[f(\nu\mu)\Big]
\end{aligned}$$

Appendix B

Details of derivations in chapter 2

Derivation of expression (2.6). I have the following steps in order to get an analytical expression for the basis ΔS_t;

$$
\begin{aligned}
\Delta S_t - \varepsilon_t - \gamma &= (\gamma_A - \gamma_B)t \\
\Delta \tilde{S}_t &\equiv (\gamma_A - \gamma_B)t \\
&\equiv \ln(1 + \gamma_A - \gamma_B)t \\
e^{\Delta \tilde{S}_t} &\equiv e^{\ln(1+\gamma_A-\gamma_B)t} \\
e^{\Delta \tilde{S}_t} &\equiv (1 + \gamma_A - \gamma_B)^t \\
\Delta \tilde{S}_t + 1 &\equiv (1 + \gamma_A - \gamma_B)^t \\
\Delta \tilde{S}_t + 1 &\equiv (1 + \gamma_A - \gamma_B) \times (1 + \gamma_A - \gamma_B)^{t-1} \\
\Delta \tilde{S}_t + 1 &\equiv (1 + \gamma_A - \gamma_B) \times (\Delta \tilde{S}_{t-1} + 1) \\
\Delta S_t + 1 - \gamma - \varepsilon_t &\equiv (1 + \gamma_A - \gamma_B) \times (\Delta S_{t-1} - \gamma - \varepsilon_{t-1} + 1) \\
\Delta S_t - \varepsilon_t &\equiv (\gamma_A - \gamma_B) \times (1 - \gamma) + (1 + \gamma_A - \gamma_B) \times (\Delta S_{t-1} - \varepsilon_{t-1})
\end{aligned}
$$

Finally,

$$
\Delta S_t = (\gamma_A - \gamma_B) \times (1 - \gamma) + (1 + \gamma_A - \gamma_B) \times \Delta S_{t-1} + \varepsilon_t - (1 + \gamma_A - \gamma_B) \times \varepsilon_{t-1}
$$

Appendix C

The Metropolis-Hasting routine

I use a Markov-Chain Monte Carlo (MCMC) method. The basic idea behind MCMC is to specify a Markov chain whose transition kernel has a limiting distribution equal to the target posterior. The key to constructing an appropriate Markov chain is to break the joint posterior into various conditional distributions or submodels from which it is easy to sample. If implementable sampling procedures can be devised for the full set of submodels, then one can construct a Markov chain by cycling through simulations of each of them. The process of alternating between draws from conditional distributions is a special case of MCMC known as the 'Gibbs sampler' (Gelfand and Smith [53], Casella and George [29]). Remarkably, under mild and verifiable regularity conditions, the stationary distribution of the Gibbs sampler is the joint distribution of interest. Thus it is possible to sample from the joint posterior without knowledge of its form.

The Gibbs sampler is a suitable method when integration on posteriori are extremely dificult to perform either analitically and numerically. Rather than compute a specified function for example $f(x)$ directly the Gibbs sampler allows us effectively to generate a sample $X_1, ..., X_m \sim f(x)$ without requiring f(x). By simulating a large enough sample, the mean, variance or whatever moment can be calculated to a degree of accuracy. Gibbs sampling turns out that under reasonably general conditions, the distribution of $X_K^{'}$ converges to $f(x)$ as $k \to \infty$.On the other way, we must to sure the sufficient conditions for convergence of irreducibility and aperiodicity (law of large numbers), for this we need to implement a transient period or "burn-it".

We compose a Gibbs sampler for the unrestricted Bayesian VAR with a Metropolis-Hasting within Gibbs in the step to get volatilities. The Markov chain cycles through 5 steps:

(a) sampling θ^T from $f\left(\theta^T|Y^T, H^T, Q, \sigma, a\right)$ using Filter Kalman with forward and backing recursion

(b) sampling Q from $f\left(Q|Y^T, \theta^T, H^T, \sigma, a\right)$ using a prior distribution for the covariance matrix Q, in this case we use an inverse-Wishart.

(c) sampling a from $f\left(a|Y^T, \theta^T, H^T, Q, \sigma\right)$ using regressions on normalized BVAR residuals -gotten in step (a)-.

(d) sampling σ from $f\left(\sigma|Y^T, \theta^T, H^T, Q, a\right)$ using an inverse gamma distribution as posteriori.

(e) Samplin h_i from $f\left(h_{it}|h_{-it}, Y^T, \theta^T, H^T, Q, a\right)$ where h_{-it} denotes the rest of the h_i vector dates other than t. We use date-by-date blocking scheme of Jacquier et al. [61] but using instead a metropolis-hasting algorithm.

This sampling algorithm, where each step supdated in turn, is sometimes referred to as the systematic sweep Gibbs sampler. However, as Brooks [24] pointed out, the Gibbs transition kernels need not to be used in this systematic manner, and many other implementations are possible, such as the random sweep Gibbs sampler[1], which randomly permut a component to update at each iteration, and thus uses a mixture (rather a cycle) of Gibbs updates. We implement this procedure and thus we get gains in inducing reversibility of the chain.

In some cases, Bayes' theorem delivers a convenient expression for a conditional kernel but not the conditional density. For example, sometimes the normalizing constant is too costly to compute Gibbs sampling is infeasible in such cases, because it requires the full set of conditional densities. But one can resort to hybrid MCMC method known as 'Metropolis-within-Gibbs' that involves replacing some of the Gibbs steps with Metropolis accept/reject steps. The latter typically involve the conditional kernel instead of the conditional density, but the target posterior is still the stationary distribution of the chain.

[1] Liu and Rubin [78].

To design a Metropolis-Hastings[2] step, one chooses a proposal density which is cheap to simulate and which closely mimics the shape of target and accepts or rejects with a certain probability, designed to make the proposal sample conform to a sample from the target.

The log normal form of the volatility equation and the normal form for the conditional sampling density imply results in:

$$p\left(h_t|h_{t+1},h_{t-1},\varepsilon_t,\sigma\right)\propto h_{it}^{-3/2}\exp\{-\frac{\varepsilon_t^2}{2h_{it}}-\frac{\left(\ln h_{it}-\mu_{it}\right)^2}{2\sigma_i^2}\} \tag{C.1}$$

$$\mu_{it}=\frac{\ln h_{it-1}+\ln h_{it+1}}{2}$$

At the beginning and end of the sample, the formula (C.1) has to be modified because only one of the adjacent values for h_{it} is available, and also there is no observed value of ε_t.Direct sampling from (C.1) is difficult due to the nonstandard functional form. In fact, the right side of (C.1) is a conditional kernel y not a density, the constant is expensive in computational procedure as well as it is a function of argument conditional and varies as the sampler progresses. Jacquier et al. [61] points out that if we get a procedure with a low computational cost, we still may deal with a valid accept-reject density that would be efficient; a code with a high percentage of accepting draws could be difficult to implement.

$$\begin{aligned}\alpha\left(x,y\right) &= \min\left[\frac{\pi\left(y\right)q\left(y,x\right)}{\pi\left(x\right)q\left(x,y\right)}\right] && if\ \pi\left(x\right)q\left(x,y\right)>0\\ &= 1 && otherwise\end{aligned}$$

As pointed out by Chib and Greenberg [35, 34] an efficient solution -when available- is to exploit the known form of $\pi\left(\cdot\right)$. the metropolis algorithm that we use here uses a proposal density q which is cheap to simulate and which closely mimics the shape of $\pi\left(\cdot\right)$. We choose q to be the log-normal density implied by the volatility equation:

$$q\left(h_{it}\right)\propto h_{it}^{-1}\exp\{-\frac{\left(\ln h_{it}-\mu_{it}\right)}{2\sigma_i^2}\}$$

[2] See Metropolis et al. [84] and Hastings [55].

The acceptance of probability for the m_{th}- draw can be computed as

$$\alpha_m = \frac{\pi\left(\varepsilon_t, h_{it}^{'}\right) q\left(h_{it}^{'}\right)}{\pi\left(\varepsilon_t, h_{it}\right) q\left(h_{it}^{'}\right)}$$

$\pi(\cdot)$ can be written as $\pi(\cdot) \propto \psi(\varepsilon_t|h_{it})\,\phi(h_{it})$ where $\phi(h_{it})$ is a density that can be sampled and $\psi(\varepsilon_t|h_{it})$ is uniformly bunded, in our case $q(h_{it}) = \phi(h_{it})$. In this case, the probability of moving requires only the computation of the ψ term (not $\pi(\cdot)$) and is given by:

$$\alpha_m = \frac{\left(h_{it}^{j}\right)^{-1/2} \exp\{-\frac{\varepsilon_t^2}{2h_{it}^{j}}\}}{\left(h_{it}^{j-1}\right)^{-1/2} \exp\{-\frac{\varepsilon_t^2}{2h_{it}^{j-1}}\}}$$

the draws are regarded as a sample from the target density $\pi(\cdot)$ only after the chain has passed the transient stage and the effect of the fixed starting value has become so small that it can be ignored.

Appendix D

Regressions

Table D.1: Regressions for Interest Rate Swaps

VARIABLES	(1) lprice	(2) lprice	(3) lprice	(4) lprice	(5) lprice	(6) lprice	(7) lprice	(8) lprice	(9) lprice	(10) lprice	(11) lprice	(12) lprice	(13) lprice	(14) lprice	(15) lprice	(16) lprice
vclear	-0.0463***	-0.0414***	-0.113***	-0.113***	-0.113***	-0.120***	-0.117***	-0.117***	-0.117***	-0.118***	-0.120***	-0.120***	-0.127***	-0.126***	-0.126***	-0.122***
	(0.00180)	(0.00187)	(0.00176)	(0.00176)	(0.00176)	(0.00175)	(0.00178)	(0.00178)	(0.00178)	(0.00176)	(0.00175)	(0.00175)	(0.00174)	(0.00178)	(0.00178)	(0.00178)
lsize	-0.0907***	-0.0907***	-0.0454***	-0.0450***	-0.0450***	-0.0448***	-0.0456***	-0.0457***	-0.0450***	-0.0462***	-0.0463***	-0.0463***	-0.0461***	-0.0464***	-0.0465***	-0.0465***
	(0.000352)	(0.000352)	(0.000353)	(0.000353)	(0.000353)	(0.000352)	(0.000347)	(0.000347)	(0.000345)	(0.000348)	(0.000347)	(0.000347)	(0.000347)	(0.000342)	(0.000342)	(0.000341)
vSEF		-0.00879***	-0.0255***	-0.0467***	-0.0390**	-0.140***	-0.154***	-0.154***	-0.146***	-0.0501***	-0.0580***	-0.0370**	-0.138***	-0.143***	-0.143***	-0.145***
		(0.000783)	(0.000684)	(0.000748)	(0.0179)	(0.0185)	(0.0186)	(0.0186)	(0.0185)	(0.000715)	(0.000730)	(0.0178)	(0.0184)	(0.0184)	(0.0184)	(0.0185)
difM			6.93e-05***	6.96e-05***	6.96e-05***	6.98e-05***	6.97e-05***	7.11e-05***	7.13e-05***	7.03e-05***	7.05e-05***	7.05e-05***	7.07e-05***	7.07e-05***	7.19e-05***	7.20e-05***
			(1.29e-07)	(1.30e-07)	(1.30e-07)	(1.30e-07)	(1.29e-07)	(1.39e-07)	(1.39e-07)	(1.28e-07)	(1.27e-07)	(1.27e-07)	(1.27e-07)	(1.26e-07)	(1.37e-07)	(1.37e-07)
sefdt				0.115***	0.115***	-0.110***	-0.151***	-0.148***	-0.164***		0.159***	0.159***	-0.0664***	-0.0780***	-0.0771***	-0.0885***
				(0.00202)	(0.00203)	(0.00323)	(0.00364)	(0.00364)	(0.00377)		(0.00322)	(0.00323)	(0.00409)	(0.00430)	(0.00429)	(0.00438)
vSEFsefdt					-0.00768	0.0952***	0.109***	0.106***	0.0913***			-0.0211	0.0819***	0.0870***	0.0848***	0.0869***
					(0.0179)	(0.0185)	(0.0186)	(0.0186)	(0.0185)			(0.0179)	(0.0184)	(0.0185)	(0.0185)	(0.0185)
Blkszdt						0.295***	0.285***	0.285***	0.280***				0.295***	0.292***	0.292***	0.287***
						(0.00385)	(0.00387)	(0.00387)	(0.00385)				(0.00385)	(0.00386)	(0.00386)	(0.00385)
lmonthNot							0.0507***	0.0508***	0.0735***					0.0179***	0.0180***	0.0356***
							(0.00199)	(0.00199)	(0.00233)					(0.00204)	(0.00204)	(0.00248)
tenor5								0.0365***	0.0362***						0.0335***	0.0335***
								(0.000957)	(0.000943)						(0.000927)	(0.000923)
VIXClose									-0.0126***							-0.00239***
									(9.26e-05)							(0.000117)
2013.year										0.374***	0.328***	0.328***	0.261***	0.235***	0.229***	0.194***
										(0.0267)	(0.0267)	(0.0267)	(0.0267)	(0.0269)	(0.0269)	(0.0271)
2014.year										0.503***	0.349***	0.349***	0.281***	0.251***	0.246***	0.208***
										(0.0266)	(0.0268)	(0.0268)	(0.0268)	(0.0271)	(0.0270)	(0.0273)
2015.year										0.432***	0.279***	0.279***	0.211***	0.183***	0.179***	0.149***
										(0.0266)	(0.0268)	(0.0268)	(0.0268)	(0.0271)	(0.0270)	(0.0273)
2016.year										0.254***	0.100***	0.100***	0.0321	0.00487	0.000583	-0.0310
										(0.0266)	(0.0268)	(0.0268)	(0.0268)	(0.0271)	(0.0270)	(0.0273)
2017.year										0.559***	0.407***	0.407***	0.339***	0.307***	0.303***	0.255***
										(0.0266)	(0.0268)	(0.0268)	(0.0268)	(0.0271)	(0.0271)	(0.0274)
Constant	2.283***	2.282***	1.311***	1.209***	1.209***	1.140***	-0.0875*	-0.101**	-0.490***	0.904***	0.906***	0.906***	0.904***	0.496***	0.489***	0.124*
	(0.00636)	(0.00636)	(0.00669)	(0.00699)	(0.00699)	(0.00706)	(0.0503)	(0.0503)	(0.0588)	(0.0273)	(0.0273)	(0.0273)	(0.0273)	(0.0549)	(0.0548)	(0.0635)
Observations	1,481,551	1,481,551	1,481,551	1,481,551	1,481,551	1,481,551	1,481,551	1,481,551	1,477,071	1,481,551	1,481,551	1,481,551	1,481,551	1,481,551	1,481,551	1,477,071
R-squared	0.071	0.071	0.216	0.220	0.220	0.225	0.228	0.228	0.239	0.259	0.262	0.262	0.267	0.267	0.268	0.270

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table D.2: 2SLS Regressions for Interest Rate Swaps

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
VARIABLES	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice
lsize	0.596***	0.654***	0.868***	0.417***	0.417***	0.381***	0.382***	0.525***	0.219***	0.120***	0.120***	0.0895***	0.0902***	0.200***
	(0.0230)	(0.0254)	(0.0319)	(0.0186)	(0.0186)	(0.0181)	(0.0181)	(0.0206)	(0.0157)	(0.0157)	(0.0157)	(0.0155)	(0.0155)	(0.0174)
vclear	-0.683***	-0.710***	-0.994***	-0.558***	-0.558***	-0.531***	-0.531***	-0.672***	-0.376***	-0.282***	-0.282***	-0.259***	-0.260***	-0.365***
	(0.0212)	(0.0227)	(0.0306)	(0.0177)	(0.0177)	(0.0173)	(0.0172)	(0.0199)	(0.0150)	(0.0149)	(0.0149)	(0.0148)	(0.0147)	(0.0167)
vSEF		-0.0484***	-0.102***	-0.0919***	-0.133***	-0.240***	-0.240***	-0.255***	-0.0847***	-0.0792***	-0.0704***	-0.169***	-0.170***	-0.192***
		(0.00248)	(0.00359)	(0.00229)	(0.0262)	(0.0274)	(0.0274)	(0.0313)	(0.00226)	(0.00217)	(0.0197)	(0.0205)	(0.0205)	(0.0227)
difM			0.000205***	0.000138***	0.000138***	0.000133***	0.000134***	0.000155***	0.000110***	9.52e-05***	9.52e-05***	9.08e-05***	9.20e-05***	0.000108***
			(4.77e-06)	(2.79e-06)	(2.79e-06)	(2.72e-06)	(2.70e-06)	(3.07e-06)	(2.35e-06)	(2.35e-06)	(2.35e-06)	(2.32e-06)	(2.30e-06)	(2.59e-06)
sefdt				0.150***	0.150***	-0.106***	-0.104***	-0.100***		0.150***	0.150***	-0.0825***	-0.0818***	-0.0949***
				(0.00310)	(0.00310)	(0.00465)	(0.00466)	(0.00545)		(0.00355)	(0.00356)	(0.00473)	(0.00473)	(0.00522)
vSEFsefdt					0.0413	0.153***	0.152***	0.143***			-0.00885	0.0960***	0.0941***	0.102***
					(0.0260)	(0.0273)	(0.0273)	(0.0311)			(0.0195)	(0.0203)	(0.0203)	(0.0225)
Blkszdt						0.332***	0.332***	0.345***				0.307***	0.307***	0.316***
						(0.00552)	(0.00552)	(0.00641)				(0.00430)	(0.00431)	(0.00472)
tenor5							0.0193***	0.0129***					0.0289***	0.0252***
							(0.00169)	(0.00205)					(0.00108)	(0.00125)
VIXClose								-0.0173***						-0.00286***
								(0.000260)						(0.000161)
2013.year									0.282***	0.273***	0.273***	0.213***	0.208***	0.160***
									(0.0370)	(0.0312)	(0.0312)	(0.0300)	(0.0300)	(0.0362)
2014.year									0.401***	0.293***	0.293***	0.232***	0.228***	0.179***
									(0.0370)	(0.0314)	(0.0314)	(0.0301)	(0.0301)	(0.0363)
2015.year									0.359***	0.241***	0.241***	0.177***	0.174***	0.144***
									(0.0368)	(0.0311)	(0.0311)	(0.0298)	(0.0298)	(0.0360)
2016.year									0.215***	0.0840***	0.0839***	0.0161	0.0124	-0.00520
									(0.0366)	(0.0309)	(0.0309)	(0.0296)	(0.0296)	(0.0358)
2017.year									0.525***	0.393***	0.393***	0.325***	0.322***	0.293***
									(0.0366)	(0.0309)	(0.0309)	(0.0296)	(0.0296)	(0.0358)
Constant	-9.150***	-10.11***	-14.31***	-6.715***	-6.718***	-6.179***	-6.195***	-8.401***	-3.556***	-1.895***	-1.895***	-1.377***	-1.395***	-3.195***
	(0.383)	(0.423)	(0.546)	(0.320)	(0.320)	(0.312)	(0.312)	(0.353)	(0.267)	(0.267)	(0.267)	(0.263)	(0.263)	(0.295)
Observations	1,481,551	1,481,551	1,481,551	1,481,551	1,481,551	1,481,551	1,481,551	1,477,071	1,481,551	1,481,551	1,481,551	1,481,551	1,481,551	1,477,071
R-squared										0.072	0.072	0.141	0.140	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table D.3: Regressions for CDX.NA.HY

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
VARIABLES	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice
vclear	-0.0808***	-0.00133	-0.0170	-0.0170	0.0540***	0.0572***	-0.0890***	-0.0818***	-0.0825***	-0.555***	-0.657***	-0.631***	-0.656***	-0.440***	-0.444***
	(0.0215)	(0.0177)	(0.0183)	(0.0183)	(0.0175)	(0.0174)	(0.0221)	(0.0218)	(0.0219)	(0.0403)	(0.0751)	(0.0748)	(0.0752)	(0.0738)	(0.0744)
vclear_seriesHYn	0.0114***	0.00566***	0.00639***	0.00639***	0.00264***	0.00231***	0.00921***	0.00867***	0.00875***	0.0318***	0.0363***	0.0349***	0.0361***	0.0256***	0.0259***
	(0.000779)	(0.000538)	(0.000558)	(0.000558)	(0.000512)	(0.000504)	(0.000773)	(0.000754)	(0.000761)	(0.00189)	(0.00348)	(0.00346)	(0.00348)	(0.00343)	(0.00345)
lsize	0.00886***	0.00999***	0.00927***	0.00927***	0.00908***	0.00967***	0.00501**	0.00434**	0.00426**	0.00708***	0.00639***	0.00701***	0.00355*	0.00331	0.00313
	(0.00208)	(0.00210)	(0.00208)	(0.00208)	(0.00208)	(0.00208)	(0.00207)	(0.00207)	(0.00207)	(0.00172)	(0.00206)	(0.00206)	(0.00207)	(0.00206)	(0.00207)
vSEF		0.0751***	0.0759***	0.0759***	0.166***	0.143***	0.139***	0.123***	0.123***	0.0211***	0.182***	0.161***	0.154***	0.134***	0.135***
		(0.00598)	(0.00603)	(0.00603)	(0.00979)	(0.00939)	(0.00929)	(0.00886)	(0.00885)	(0.00730)	(0.0100)	(0.00967)	(0.00945)	(0.00886)	(0.00884)
difM			-4.98e-05***	-4.98e-05***	6.20e-06	1.43e-05	-2.93e-05**	-0.000150***	-0.000154***	-0.000118***	-0.000121***	-0.000109***	-0.000128***	-0.000199***	-0.000201***
			(1.29e-05)	(1.29e-05)	(1.32e-05)	(1.33e-05)	(1.40e-05)	(1.72e-05)	(1.73e-05)	(1.26e-05)	(2.02e-05)	(2.01e-05)	(2.05e-05)	(2.14e-05)	(2.15e-05)
sefdt					0.174***	0.0557***	0.0638***	0.104***	0.105***		0.243***	0.133***	0.126***	0.129***	0.128***
					(0.0107)	(0.0136)	(0.0136)	(0.0136)	(0.0136)		(0.0113)	(0.0140)	(0.0139)	(0.0139)	(0.0139)
vSEFsefdt					-0.180***	-0.156***	-0.149***	-0.128***	-0.127***		-0.220***	-0.196***	-0.187***	-0.156***	-0.157***
					(0.0113)	(0.0111)	(0.0110)	(0.0108)	(0.0108)		(0.0118)	(0.0115)	(0.0112)	(0.0106)	(0.0105)
Blkszdt						0.153***	0.171***	0.135***	0.136***			0.142***	0.159***	0.128***	0.130***
						(0.0147)	(0.0151)	(0.0144)	(0.0144)			(0.0147)	(0.0151)	(0.0143)	(0.0143)
lmonthNot							0.0671***	0.0709***	0.0740***				0.0585***	0.0609***	0.0674***
							(0.00410)	(0.00422)	(0.00423)				(0.00404)	(0.00412)	(0.00424)
tenor5								0.118***	0.118***					0.111***	0.110***
								(0.00649)	(0.00664)					(0.00687)	(0.00693)
VIXClose									-0.00114***						-0.00285***
									(0.000340)						(0.000391)
2013.year										1.694***	1.642**	1.612*	1.475*	1.503*	1.478*
										(0.163)	(0.826)	(0.826)	(0.826)	(0.828)	(0.828)
2014.year										1.761***	1.562*	1.533*	1.404*	1.480*	1.457*
										(0.163)	(0.826)	(0.826)	(0.826)	(0.828)	(0.828)
2015.year										1.700***	1.499*	1.472*	1.380*	1.458*	1.446*
										(0.163)	(0.826)	(0.826)	(0.826)	(0.827)	(0.827)
2016.year										1.595***	1.387*	1.363*	1.270	1.372*	1.356
										(0.164)	(0.826)	(0.826)	(0.826)	(0.827)	(0.827)
2017.year										1.548***	1.331	1.309	1.222	1.345	1.315
										(0.164)	(0.826)	(0.826)	(0.826)	(0.827)	(0.827)
2018.year										1.556***	1.335	1.316	1.198	1.398*	1.387*
										(0.164)	(0.826)	(0.826)	(0.826)	(0.827)	(0.827)
Constant	4.305***	4.284***	4.382***	4.382***	4.221***	4.165***	2.832***	2.899***	2.852***	2.853***	2.872***	2.842***	1.768**	1.738**	1.668**
	(0.0352)	(0.0354)	(0.0415)	(0.0415)	(0.0426)	(0.0430)	(0.0944)	(0.0917)	(0.0920)	(0.168)	(0.827)	(0.827)	(0.830)	(0.831)	(0.832)
Observations	121,293	121,293	121,293	121,293	121,293	121,293	121,293	121,293	120,862	121,293	121,293	121,293	121,293	121,293	120,862
R-squared	0.012	0.013	0.013	0.013	0.018	0.020	0.024	0.028	0.028	0.017	0.023	0.025	0.027	0.030	0.031

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table D.4: 2SLS Regressions for CDX.NA.HY

VARIABLES	(1) lprice	(2) lprice	(3) lprice	(4) lprice	(5) lprice	(6) lprice	(7) lprice	(8) lprice	(9) lprice	(10) lprice	(11) lprice	(12) lprice	(13) lprice
lsize	0.217***	0.243***	0.221***	0.221***	0.265***	0.286***	0.299***	0.299***	0.223***	0.236***	0.261***	0.271***	0.277***
	(0.0181)	(0.0195)	(0.0170)	(0.0170)	(0.0175)	(0.0183)	(0.0188)	(0.0181)	(0.0176)	(0.0178)	(0.0189)	(0.0193)	(0.0186)
vclear	-0.225***	-0.111***	-0.0780***	-0.0780***	-0.0226	-0.0246	-0.0150	-0.0131	-0.337***	-0.417***	-0.358***	-0.141*	-0.137*
	(0.0288)	(0.0233)	(0.0216)	(0.0216)	(0.0216)	(0.0220)	(0.0219)	(0.0221)	(0.0734)	(0.0741)	(0.0743)	(0.0759)	(0.0769)
vclear_seriesHYn	0.0176***	0.00896***	0.00761***	0.00761***	0.00425***	0.00397***	0.00324***	0.00319***	0.0198***	0.0231***	0.0199***	0.00937***	0.00921**
	(0.00116)	(0.000769)	(0.000685)	(0.000685)	(0.000692)	(0.000704)	(0.000705)	(0.000719)	(0.00342)	(0.00345)	(0.00347)	(0.00358)	(0.00362)
vSEF		0.123***	0.117***	0.117***	0.219***	0.194***	0.183***	0.182***	0.0729***	0.222***	0.198***	0.181***	0.182***
		(0.00883)	(0.00840)	(0.00840)	(0.0154)	(0.0154)	(0.0154)	(0.0153)	(0.00893)	(0.0148)	(0.0148)	(0.0146)	(0.0146)
difM			6.93e-05***	6.93e-05***	0.000149***	0.000170***	7.28e-05***	6.97e-05***	4.90e-05**	5.75e-05**	9.12e-05***	3.27e-05	3.54e-05
			(1.46e-05)	(1.46e-05)	(1.60e-05)	(1.66e-05)	(1.67e-05)	(1.67e-05)	(2.25e-05)	(2.26e-05)	(2.35e-05)	(2.28e-05)	(2.29e-05)
2013.year									1.699**	1.652**	1.614**	1.646**	1.644**
									(0.814)	(0.812)	(0.811)	(0.812)	(0.812)
2014.year									1.761**	1.578*	1.542*	1.620**	1.617**
									(0.814)	(0.812)	(0.811)	(0.812)	(0.812)
2015.year									1.740**	1.557*	1.529*	1.609**	1.609**
									(0.814)	(0.812)	(0.811)	(0.812)	(0.811)
2016.year									1.687**	1.500*	1.482*	1.586*	1.587*
									(0.814)	(0.812)	(0.811)	(0.812)	(0.811)
2017.year									1.648**	1.454*	1.439*	1.564*	1.562*
									(0.814)	(0.812)	(0.811)	(0.812)	(0.811)
2018.year									1.637**	1.438*	1.424*	1.623**	1.623**
									(0.814)	(0.812)	(0.811)	(0.812)	(0.811)
sefdt					0.169***	0.0212	0.0551***	0.0551***		0.225***	0.0812***	0.0821***	0.0806***
					(0.0111)	(0.0151)	(0.0150)	(0.0150)		(0.0115)	(0.0153)	(0.0154)	(0.0155)
vSEFsefdt					-0.180***	-0.149***	-0.130***	-0.130***		-0.199***	-0.167***	-0.136***	-0.136***
					(0.0152)	(0.0155)	(0.0156)	(0.0156)		(0.0144)	(0.0147)	(0.0146)	(0.0148)
Blkszdt						0.192***	0.161***	0.160***			0.182***	0.153***	0.154***
						(0.0166)	(0.0159)	(0.0159)			(0.0165)	(0.0158)	(0.0158)
tenor5							0.105***	0.106***				0.105***	0.105***
							(0.00641)	(0.00664)				(0.00709)	(0.00723)
VIXClose								0.000296					-0.000610
								(0.000452)					(0.000493)
Constant	0.905***	0.489	0.728**	0.728**	-0.206	-0.621*	-0.731**	-0.724**	-0.977	-1.197	-1.670*	-1.831**	-1.931**
	(0.297)	(0.321)	(0.290)	(0.290)	(0.301)	(0.318)	(0.323)	(0.312)	(0.869)	(0.869)	(0.875)	(0.878)	(0.874)
Observations	121,293	121,293	121,293	121,293	121,293	121,293	121,293	120,862	121,293	121,293	121,293	121,293	120,862

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table D.5: Regressions for CDX.NA.IG

VARIABLES	(1) lprice	(2) lprice	(3) lprice	(4) lprice	(5) lprice	(6) lprice	(7) lprice	(8) lprice	(9) lprice	(10) lprice	(11) lprice	(12) lprice	(13) lprice	(14) lprice	(15) lprice
vclear	0.498***	0.532***	0.738***	0.738***	0.781***	0.784***	0.744***	0.729***	0.719***	0.740***	0.727***	0.733***	0.720***	0.598***	0.614***
	(0.0188)	(0.0198)	(0.0196)	(0.0196)	(0.0192)	(0.0192)	(0.0203)	(0.0199)	(0.0199)	(0.0305)	(0.0320)	(0.0319)	(0.0319)	(0.0350)	(0.0349)
vclear_seriesIGn	0.000696	-0.00200***	-0.0125***	-0.0125***	-0.0152***	-0.0153***	-0.0133***	-0.0125***	-0.0118***	-0.0128***	-0.0123***	-0.0126***	-0.0119***	-0.00569***	-0.00631***
	(0.000615)	(0.000759)	(0.000758)	(0.000758)	(0.000710)	(0.000708)	(0.000783)	(0.000769)	(0.000770)	(0.00148)	(0.00139)	(0.00139)	(0.00139)	(0.00158)	(0.00158)
lsize	-0.0179***	-0.0180***	-0.0139***	-0.0139***	-0.0137***	-0.0138***	-0.0151***	-0.0149***	-0.0153***	-0.00956***	-0.00992***	-0.0100***	-0.0126***	-0.0121***	-0.0123***
	(0.00201)	(0.00201)	(0.00196)	(0.00196)	(0.00197)	(0.00197)	(0.00198)	(0.00198)	(0.00198)	(0.00204)	(0.00196)	(0.00196)	(0.00198)	(0.00198)	(0.00198)
vSEF		0.0401***	0.0748***	0.0748***	-0.0822	-0.0956	-0.0985	-0.0953	-0.110*	0.0162*	-0.0846	-0.0977	-0.104*	-0.0977	-0.107*
		(0.00594)	(0.00585)	(0.00585)	(0.0607)	(0.0617)	(0.0616)	(0.0619)	(0.0617)	(0.00871)	(0.0607)	(0.0617)	(0.0615)	(0.0619)	(0.0618)
difM			0.000388***	0.000388***	0.000392***	0.000392***	0.000388***	0.000390***	0.000388***	0.000389***	0.000387***	0.000388***	0.000383***	0.000382***	0.000381***
			(9.34e-06)	(9.34e-06)	(9.38e-06)	(9.38e-06)	(9.43e-06)	(9.47e-06)	(9.46e-06)	(7.95e-06)	(9.88e-06)	(9.88e-06)	(9.89e-06)	(9.99e-06)	(1.00e-05)
sefdt					0.119***	0.0793***	0.0899***	0.0768***	0.0692***		0.129***	0.0894***	0.0947***	0.0909***	0.0920***
					(0.00995)	(0.0168)	(0.0170)	(0.0171)	(0.0171)		(0.0125)	(0.0184)	(0.0184)	(0.0184)	(0.0184)
vSEFsefdt					0.0980	0.112*	0.115*	0.113*	0.113*		0.0771	0.0907	0.0973	0.0920	0.0969
					(0.0610)	(0.0620)	(0.0619)	(0.0621)	(0.0619)		(0.0609)	(0.0619)	(0.0617)	(0.0622)	(0.0620)
Blkszdt						0.0506***	0.0555***	0.0637***	0.0601***			0.0497***	0.0649***	0.0828***	0.0803***
						(0.0182)	(0.0182)	(0.0181)	(0.0181)			(0.0182)	(0.0182)	(0.0181)	(0.0181)
lmonthNot							0.0240***	0.0235***	0.00974***				0.0666***	0.0619***	0.0488***
							(0.00368)	(0.00371)	(0.00370)				(0.00421)	(0.00437)	(0.00439)
tenor5								-0.0279***	-0.0179***					-0.0681***	-0.0617***
								(0.00574)	(0.00590)					(0.00723)	(0.00730)
VIXClose									0.0159***						0.0114***
									(0.000481)						(0.000547)
2013.year										-0.268	-0.289	-0.300	-0.470	-0.481	-0.409
										(0.193)	(0.446)	(0.446)	(0.446)	(0.446)	(0.446)
2014.year										-0.228	-0.338	-0.348	-0.503	-0.551	-0.482
										(0.193)	(0.446)	(0.446)	(0.446)	(0.446)	(0.446)
2015.year										-0.144	-0.252	-0.262	-0.360	-0.412	-0.382
										(0.193)	(0.446)	(0.446)	(0.446)	(0.446)	(0.446)
2016.year										0.00154	-0.106	-0.116	-0.219	-0.284	-0.241
										(0.193)	(0.446)	(0.446)	(0.446)	(0.446)	(0.446)
2017.year										-0.302	-0.410	-0.419	-0.518	-0.596	-0.496
										(0.194)	(0.446)	(0.446)	(0.446)	(0.446)	(0.446)
2018.year										-0.386**	-0.496	-0.504	-0.636	-0.761*	-0.733
										(0.194)	(0.446)	(0.446)	(0.447)	(0.447)	(0.447)
Constant	4.034***	4.037***	3.273***	3.273***	3.225***	3.215***	2.687***	2.708***	2.798***	3.445***	3.457***	3.457***	2.128***	2.285***	2.350***
	(0.0362)	(0.0362)	(0.0398)	(0.0398)	(0.0403)	(0.0405)	(0.0898)	(0.0909)	(0.0911)	(0.197)	(0.449)	(0.449)	(0.457)	(0.458)	(0.458)
Observations	110,262	110,262	110,262	110,262	110,262	110,262	110,262	110,262	109,902	110,262	110,262	110,262	110,262	110,262	109,902
R-squared	0.055	0.055	0.077	0.077	0.079	0.079	0.079	0.079	0.083	0.088	0.089	0.089	0.091	0.092	0.093

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table D.6: 2SLS Regressions for CDX.NA.IG

VARIABLES	(1) lprice	(2) lprice	(3) lprice	(4) lprice	(5) lprice	(6) lprice	(7) lprice	(8) lprice	(9) lprice	(10) lprice	(11) lprice	(12) lprice	(13) lprice
lsize	0.0941***	0.109***	0.00231	0.00231	0.0916***	0.0960***	0.0933***	0.0288*	0.294***	0.319***	0.323***	0.294***	0.216***
	(0.0192)	(0.0187)	(0.0169)	(0.0169)	(0.0174)	(0.0171)	(0.0172)	(0.0166)	(0.0266)	(0.0242)	(0.0237)	(0.0235)	(0.0216)
vclear	0.405***	0.420***	0.725***	0.725***	0.698***	0.696***	0.680***	0.699***	0.662***	0.646***	0.648***	0.496***	0.535***
	(0.0263)	(0.0273)	(0.0247)	(0.0247)	(0.0242)	(0.0242)	(0.0239)	(0.0233)	(0.0341)	(0.0358)	(0.0358)	(0.0380)	(0.0366)
vclear_seriesIGn	0.00517***	0.00360***	-0.0119***	-0.0119***	-0.0110***	-0.0109***	-0.0101***	-0.0108***	-0.00899***	-0.00836***	-0.00844***	-0.000680	-0.00246
	(0.00104)	(0.00116)	(0.00102)	(0.00102)	(0.00101)	(0.00101)	(0.00101)	(0.000979)	(0.00165)	(0.00160)	(0.00160)	(0.00175)	(0.00168)
vSEF		0.0321***	0.0740***	0.0740***	-0.0876	-0.0988	-0.0950	-0.110*	-0.00636	-0.0979	-0.105	-0.0960	-0.106*
		(0.00617)	(0.00587)	(0.00587)	(0.0612)	(0.0622)	(0.0624)	(0.0619)	(0.00975)	(0.0629)	(0.0639)	(0.0641)	(0.0633)
difM			0.000391***	0.000391***	0.000408***	0.000409***	0.000412***	0.000396***	0.000450***	0.000453***	0.000454***	0.000446***	0.000428***
			(9.64e-06)	(9.64e-06)	(9.77e-06)	(9.76e-06)	(9.78e-06)	(9.60e-06)	(1.02e-05)	(1.20e-05)	(1.19e-05)	(1.19e-05)	(1.13e-05)
2013.year									-0.315	-0.336	-0.342	-0.369	-0.316
									(0.212)	(0.415)	(0.415)	(0.417)	(0.424)
2014.year									-0.263	-0.354	-0.359	-0.433	-0.386
									(0.212)	(0.416)	(0.415)	(0.417)	(0.424)
2015.year									-0.149	-0.236	-0.240	-0.319	-0.309
									(0.212)	(0.416)	(0.415)	(0.417)	(0.424)
2016.year									0.0731	-0.00728	-0.0106	-0.114	-0.109
									(0.212)	(0.416)	(0.415)	(0.418)	(0.424)
2017.year									-0.247	-0.329	-0.332	-0.450	-0.378
									(0.212)	(0.416)	(0.415)	(0.418)	(0.424)
2018.year									-0.434**	-0.525	-0.530	-0.702*	-0.688
									(0.213)	(0.416)	(0.416)	(0.418)	(0.424)
sefdt					0.123***	0.0901***	0.0744***	0.0681***		0.103***	0.0828***	0.0790***	0.0830***
					(0.0101)	(0.0171)	(0.0172)	(0.0170)		(0.0137)	(0.0197)	(0.0195)	(0.0190)
vSEFsefdt					0.0965	0.108*	0.106*	0.110*		0.0714	0.0781	0.0729	0.0829
					(0.0614)	(0.0623)	(0.0625)	(0.0620)		(0.0630)	(0.0641)	(0.0642)	(0.0634)
Blkszdt						0.0413**	0.0516***	0.0552***			0.0246	0.0515***	0.0563***
						(0.0183)	(0.0183)	(0.0182)			(0.0191)	(0.0190)	(0.0186)
tenor5							-0.0336***	-0.0204***				-0.0883***	-0.0771***
							(0.00565)	(0.00577)				(0.00747)	(0.00736)
VIXClose								0.0159***					0.0122***
								(0.000484)					(0.000610)
Constant	2.077***	1.823***	2.985***	2.985***	1.355***	1.267***	1.330***	2.241***	-1.937***	-2.373***	-2.448***	-1.829***	-0.675
	(0.334)	(0.326)	(0.299)	(0.299)	(0.309)	(0.304)	(0.305)	(0.296)	(0.517)	(0.597)	(0.591)	(0.590)	(0.572)
Observations	110,262	110,262	110,262	110,262	110,262	110,262	110,262	109,902	110,262	110,262	110,262	110,262	109,902
R-squared	0.030	0.023	0.076	0.076	0.056	0.054	0.056	0.079					

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table D.7: Regressions for CDX.EM

VARIABLES	(1) lprice	(2) lprice	(3) lprice	(4) lprice	(5) lprice	(6) lprice	(7) lprice	(8) lprice	(9) lprice	(10) lprice	(11) lprice	(12) lprice	(13) lprice	(14) lprice	(15) lprice
vclear	-0.0356	-0.577***	-0.577***	-0.577***	-0.596***	-0.595***	-0.592***	-0.603***	-0.608***	-0.573***	-0.574***	-0.573***	-0.577***	-0.627***	-0.632***
	(0.0357)	(0.0446)	(0.0445)	(0.0445)	(0.0444)	(0.0443)	(0.0443)	(0.0484)	(0.0486)	(0.0448)	(0.0448)	(0.0446)	(0.0447)	(0.0486)	(0.0487)
vclear_seriesEMn	0.0117***	0.00452	0.00450	0.00450	0.00287	0.00292	0.00256	0.00372	0.00383	-0.00226	-0.00194	-0.00189	-0.00148	0.00362	0.00365
	(0.00328)	(0.00311)	(0.00312)	(0.00312)	(0.00308)	(0.00308)	(0.00312)	(0.00359)	(0.00360)	(0.00319)	(0.00319)	(0.00318)	(0.00321)	(0.00356)	(0.00357)
lsize	0.0517***	0.0713***	0.0712***	0.0712***	0.0642***	0.0665***	0.0653***	0.0653***	0.0653***	0.0626***	0.0611***	0.0635***	0.0650***	0.0650***	0.0650***
	(0.00879)	(0.00878)	(0.00878)	(0.00878)	(0.00889)	(0.00891)	(0.00902)	(0.00903)	(0.00910)	(0.00874)	(0.00876)	(0.00878)	(0.00889)	(0.00889)	(0.00895)
vSEF		0.894***	0.894***	0.894***	1.605***	1.569***	1.569***	1.570***	1.575***	0.828***	1.613***	1.577***	1.578***	1.583***	1.586***
		(0.0312)	(0.0309)	(0.0309)	(0.0693)	(0.0699)	(0.0698)	(0.0700)	(0.0702)	(0.0291)	(0.0695)	(0.0700)	(0.0700)	(0.0702)	(0.0703)
difM			1.02e-05	1.02e-05	-3.44e-05	-3.44e-05	-3.66e-05	-5.25e-05	-4.93e-05	-1.70e-05	-3.13e-05	-3.13e-05	-2.85e-05	-0.000103	-0.000103
			(6.39e-05)	(6.39e-05)	(6.33e-05)	(6.33e-05)	(6.31e-05)	(6.87e-05)	(6.95e-05)	(6.26e-05)	(6.25e-05)	(6.25e-05)	(6.25e-05)	(6.75e-05)	(6.82e-05)
sefdt					0.634***	0.404***	0.401***	0.405***	0.407***		0.351***	0.123	0.118	0.116	0.114
					(0.0525)	(0.0684)	(0.0685)	(0.0689)	(0.0690)		(0.0767)	(0.0888)	(0.0887)	(0.0887)	(0.0888)
vSEFsefdt					-0.785***	-0.749***	-0.749***	-0.750***	-0.751***		-0.809***	-0.773***	-0.774***	-0.779***	-0.778***
					(0.0616)	(0.0626)	(0.0626)	(0.0626)	(0.0628)		(0.0616)	(0.0626)	(0.0627)	(0.0628)	(0.0629)
Blkszdt						0.365***	0.364***	0.360***	0.360***			0.364***	0.365***	0.348***	0.348***
						(0.0902)	(0.0901)	(0.0902)	(0.0902)			(0.0902)	(0.0901)	(0.0902)	(0.0902)
lmonthNot							0.0114	0.0109	0.00764				-0.0139	-0.0175	-0.0223*
							(0.0121)	(0.0122)	(0.0124)				(0.0123)	(0.0124)	(0.0128)
tenor5								0.0143	0.0152					0.0711***	0.0721***
								(0.0203)	(0.0213)					(0.0226)	(0.0233)
VIXClose									-0.00116						0.000403
									(0.00128)						(0.00166)
2013.year										-0.943***	-1.064***	-1.198***	-1.156***	-1.125***	-1.109***
										(0.0382)	(0.0494)	(0.0650)	(0.0755)	(0.0760)	(0.0775)
2014.year										-0.783***	-1.126***	-1.259***	-1.209***	-1.157***	-1.139***
										(0.0302)	(0.0800)	(0.0903)	(0.0992)	(0.100)	(0.102)
2015.year										-0.311***	-0.654***	-0.787***	-0.738***	-0.689***	-0.669***
										(0.0133)	(0.0770)	(0.0877)	(0.0976)	(0.0988)	(0.0996)
2016.year										-0.363***	-0.704***	-0.838***	-0.785***	-0.737***	-0.717***
										(0.0159)	(0.0771)	(0.0877)	(0.0990)	(0.100)	(0.102)
2017.year										-0.254***	-0.595***	-0.729***	-0.677***	-0.623***	-0.602***
										(0.0160)	(0.0771)	(0.0877)	(0.0988)	(0.100)	(0.103)
2018.year										-0.200***	-0.540***	-0.674***	-0.620***	-0.530***	-0.509***
										(0.0165)	(0.0776)	(0.0882)	(0.0998)	(0.104)	(0.105)
Constant	3.383***	2.991***	2.975***	2.975***	2.638***	2.464***	2.261***	2.288***	2.366***	3.697***	3.748***	3.708***	3.914***	4.041***	4.113***
	(0.145)	(0.145)	(0.181)	(0.181)	(0.182)	(0.188)	(0.291)	(0.297)	(0.299)	(0.182)	(0.183)	(0.183)	(0.261)	(0.267)	(0.269)
Observations	40,342	40,342	40,342	40,342	40,342	40,342	40,342	40,342	40,123	40,342	40,342	40,342	40,342	40,342	40,123
R-squared	0.002	0.047	0.047	0.047	0.058	0.059	0.059	0.059	0.059	0.072	0.074	0.075	0.075	0.075	0.075

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table D.8: 2SLS Regressions for CDX.EM

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
VARIABLES	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice
lsize	0.251***	0.226***	0.229***	0.229***	0.121**	0.117**	0.115**	0.0984*	-0.00434	0.00757	0.00358	-0.0128	-0.0298
	(0.0448)	(0.0433)	(0.0442)	(0.0442)	(0.0545)	(0.0542)	(0.0544)	(0.0532)	(0.0451)	(0.0541)	(0.0538)	(0.0546)	(0.0537)
vclear	-0.0374	-0.597***	-0.598***	-0.598***	-0.603***	-0.601***	-0.612***	-0.615***	-0.564***	-0.566***	-0.565***	-0.612***	-0.613***
	(0.0350)	(0.0366)	(0.0368)	(0.0368)	(0.0452)	(0.0450)	(0.0487)	(0.0488)	(0.0367)	(0.0456)	(0.0454)	(0.0486)	(0.0486)
vclear_seriesEMn	0.0105***	0.00332	0.00339	0.00339	0.00251	0.00260	0.00380	0.00388	-0.00196	-0.00172	-0.00164	0.00343	0.00340
	(0.00340)	(0.00332)	(0.00332)	(0.00332)	(0.00312)	(0.00311)	(0.00357)	(0.00359)	(0.00332)	(0.00320)	(0.00319)	(0.00353)	(0.00354)
vSEF		0.924***	0.926***	0.926***	1.607***	1.568***	1.569***	1.574***	0.813***	1.612***	1.578***	1.584***	1.588***
		(0.0222)	(0.0226)	(0.0226)	(0.0700)	(0.0706)	(0.0707)	(0.0706)	(0.0227)	(0.0692)	(0.0694)	(0.0694)	(0.0694)
difM			-5.13e-05	-5.13e-05	-5.59e-05	-5.31e-05	-6.89e-05	-6.11e-05	9.80e-06	-1.03e-05	-7.86e-06	-7.69e-05	-6.96e-05
			(4.85e-05)	(4.85e-05)	(6.54e-05)	(6.53e-05)	(7.01e-05)	(7.08e-05)	(4.82e-05)	(6.51e-05)	(6.51e-05)	(6.87e-05)	(6.94e-05)
2013.year									-1.005	-1.117***	-1.247***	-1.241***	-1.256***
									(1.515)	(0.0719)	(0.0777)	(0.0775)	(0.0776)
2014.year									-0.836	-1.178***	-1.308***	-1.282***	-1.298***
									(1.515)	(0.0977)	(0.102)	(0.101)	(0.101)
2015.year									-0.366	-0.707***	-0.838***	-0.815***	-0.826***
									(1.515)	(0.0946)	(0.0986)	(0.0983)	(0.0980)
2016.year									-0.417	-0.758***	-0.888***	-0.868***	-0.882***
									(1.515)	(0.0949)	(0.0989)	(0.0986)	(0.0985)
2017.year									-0.301	-0.642***	-0.772***	-0.744***	-0.759***
									(1.515)	(0.0911)	(0.0958)	(0.0955)	(0.0966)
2018.year									-0.245	-0.585***	-0.715***	-0.650***	-0.658***
									(1.515)	(0.0908)	(0.0957)	(0.0964)	(0.0958)
sefdt					0.622***	0.380***	0.385***	0.393***		0.362***	0.150	0.157*	0.165*
					(0.0535)	(0.0736)	(0.0742)	(0.0740)		(0.0773)	(0.0928)	(0.0929)	(0.0929)
vSEFsefdt					-0.773***	-0.737***	-0.738***	-0.743***		-0.821***	-0.788***	-0.797***	-0.802***
					(0.0630)	(0.0647)	(0.0649)	(0.0648)		(0.0622)	(0.0634)	(0.0635)	(0.0635)
Blkszdt						0.386***	0.382***	0.374***			0.338***	0.314***	0.307***
						(0.0941)	(0.0942)	(0.0941)			(0.0937)	(0.0941)	(0.0940)
tenor5							0.0149	0.0163				0.0713***	0.0707***
							(0.0203)	(0.0211)				(0.0226)	(0.0232)
VIXClose								-0.000834					-0.000494
								(0.00131)					(0.00163)
Constant	0.154	0.484	0.529	0.529	1.759**	1.684*	1.738**	1.997**	4.789***	4.622***	4.686***	5.019***	5.306***
	(0.725)	(0.703)	(0.691)	(0.691)	(0.854)	(0.859)	(0.866)	(0.851)	(1.686)	(0.895)	(0.891)	(0.908)	(0.896)
Observations	40,342	40,342	40,342	40,342	40,342	40,342	40,342	40,123	40,342	40,342	40,342	40,342	40,123
R-squared		0.035	0.035	0.035	0.056	0.058	0.058	0.058	0.070	0.072	0.073	0.072	0.071

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table D.9: Regressions for ITRXA

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
VARIABLES	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice	lprice
vclear	0.0228	0.0233	0.0105	0.0105	-0.120***	-0.120***	-0.114***	-0.113***	-0.0571**	-0.0820	-0.0823**	-0.0824**	-0.0792**	-0.0788**	-0.0726**
	(0.0238)	(0.0240)	(0.0229)	(0.0229)	(0.0214)	(0.0214)	(0.0216)	(0.0222)	(0.0260)	(0.0591)	(0.0335)	(0.0335)	(0.0334)	(0.0335)	(0.0359)
lsize	-0.0325**	-0.0323**	-0.0332***	-0.0332***	-0.0341***	-0.0347***	-0.0432***	-0.0433***	-0.0421***	-0.0324**	-0.0339***	-0.0345***	-0.0420***	-0.0420***	-0.0419***
	(0.0129)	(0.0129)	(0.0124)	(0.0124)	(0.0125)	(0.0125)	(0.0125)	(0.0125)	(0.0129)	(0.0141)	(0.0123)	(0.0123)	(0.0124)	(0.0125)	(0.0131)
vSEF		0.327***	0.285***	0.285***	0.173***	0.173***	0.174***	0.174***	0.161***	0.174	0.172***	0.172***	0.173***	0.173***	0.168***
		(0.0412)	(0.0412)	(0.0412)	(0.0388)	(0.0388)	(0.0385)	(0.0387)	(0.0390)	(0.112)	(0.0361)	(0.0361)	(0.0358)	(0.0359)	(0.0367)
difM			0.000669***	0.000669***	0.000593***	0.000588***	0.000608***	0.000601***	0.000555***	0.000523***	0.000522***	0.000517***	0.000534***	0.000537***	0.000513***
			(7.55e-05)	(7.55e-05)	(7.53e-05)	(7.53e-05)	(7.51e-05)	(8.53e-05)	(8.91e-05)	(5.55e-05)	(7.46e-05)	(7.46e-05)	(7.43e-05)	(8.66e-05)	(9.10e-05)
sefdt					0.759***	0.641***	0.637***	0.639***	0.601***		0.213	0.0889	0.0897	0.0895	0.0478
					(0.0735)	(0.144)	(0.143)	(0.143)	(0.148)		(0.140)	(0.186)	(0.186)	(0.186)	(0.192)
o.vSEFsefdt					-	-	-	-	-		-	-	-	-	-
Blkszdt						0.149	0.154	0.151	0.173			0.157	0.162	0.163	0.188
						(0.164)	(0.164)	(0.164)	(0.168)			(0.164)	(0.164)	(0.164)	(0.168)
lmonthNot							0.0244	0.0242	0.0139				0.0212	0.0213	0.0175
							(0.0156)	(0.0155)	(0.0164)				(0.0155)	(0.0154)	(0.0163)
tenor5								0.00835	0.0222					-0.00272	0.000495
								(0.0406)	(0.0440)					(0.0460)	(0.0490)
VIXClose									0.0138***						0.00884***
									(0.00301)						(0.00328)
2014.year										0.575***	0.404***	0.404***	0.399***	0.399***	0.424***
										(0.0524)	(0.126)	(0.126)	(0.127)	(0.128)	(0.132)
2015.year										0.770***	0.599***	0.599***	0.592***	0.592***	0.580***
										(0.0523)	(0.123)	(0.123)	(0.124)	(0.125)	(0.130)
2016.year										1.010***	0.839***	0.840***	0.836***	0.836***	0.850***
										(0.0534)	(0.122)	(0.122)	(0.123)	(0.125)	(0.129)
2017.year										0.643***	0.471***	0.472***	0.470***	0.469***	0.523***
										(0.0678)	(0.129)	(0.129)	(0.130)	(0.131)	(0.136)
2018.year										0.384***	0.213*	0.213*	0.210*	0.207	0.190
										(0.0905)	(0.126)	(0.126)	(0.127)	(0.136)	(0.142)
Constant	4.914***	4.904***	3.767***	3.767***	3.289***	3.276***	2.922***	2.934***	2.962***	3.419***	3.403***	3.390***	3.083***	3.079***	3.042***
	(0.208)	(0.208)	(0.230)	(0.230)	(0.242)	(0.244)	(0.358)	(0.362)	(0.379)	(0.252)	(0.244)	(0.245)	(0.355)	(0.362)	(0.380)
Observations	6,229	6,229	6,229	6,229	6,229	6,229	6,229	6,229	5,763	6,229	6,229	6,229	6,229	6,229	5,763
R-squared	0.001	0.002	0.024	0.024	0.063	0.063	0.063	0.063	0.066	0.084	0.085	0.085	0.085	0.085	0.087

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table D.10: 2SLS Regressions for ITRXA

VARIABLES	(1) lprice	(2) lprice	(3) lprice	(4) lprice	(5) lprice	(6) lprice	(7) lprice	(8) lprice	(9) lprice	(10) lprice	(11) lprice	(12) lprice	(13) lprice
lsize	-0.0763*	-0.0747*	0.0273	0.0273	0.0299	0.0308	0.0303	-0.00192	0.0199	0.0212	0.0222	0.0227	0.00896
	(0.0444)	(0.0444)	(0.0430)	(0.0430)	(0.0461)	(0.0460)	(0.0460)	(0.0466)	(0.0416)	(0.0455)	(0.0454)	(0.0455)	(0.0460)
vclear	0.0146	0.0154	0.0218	0.0218	-0.108***	-0.108***	-0.107***	-0.0521**	-0.0674	-0.0670*	-0.0667*	-0.0658*	-0.0613*
	(0.0489)	(0.0489)	(0.0484)	(0.0484)	(0.0224)	(0.0224)	(0.0229)	(0.0266)	(0.0601)	(0.0343)	(0.0343)	(0.0343)	(0.0364)
vSEF		0.325***	0.287**	0.287**	0.175***	0.176***	0.176***	0.161***	0.175	0.173***	0.173***	0.173***	0.167***
		(0.116)	(0.115)	(0.115)	(0.0389)	(0.0389)	(0.0391)	(0.0389)	(0.112)	(0.0362)	(0.0362)	(0.0363)	(0.0368)
difM			0.000668***	0.000668***	0.000592***	0.000588***	0.000582***	0.000545***	0.000523***	0.000522***	0.000517***	0.000522***	0.000502***
			(5.68e-05)	(5.68e-05)	(7.55e-05)	(7.55e-05)	(8.57e-05)	(8.86e-05)	(5.55e-05)	(7.47e-05)	(7.46e-05)	(8.66e-05)	(9.03e-05)
2013.year									-0.379***	-0.222*	-0.222*	-0.217	-0.191
									(0.0906)	(0.126)	(0.126)	(0.135)	(0.142)
2014.year									0.206**	0.206***	0.207***	0.211***	0.257***
									(0.0903)	(0.0534)	(0.0534)	(0.0635)	(0.0711)
2015.year									0.394***	0.394***	0.394***	0.399***	0.403***
									(0.0898)	(0.0472)	(0.0472)	(0.0594)	(0.0658)
2016.year									0.630***	0.630***	0.631***	0.634***	0.669***
									(0.0854)	(0.0373)	(0.0373)	(0.0448)	(0.0514)
2017.year									0.262***	0.262***	0.262***	0.266***	0.346***
									(0.0858)	(0.0408)	(0.0408)	(0.0511)	(0.0626)
2018o.year									-	-	-	-	-
sefdt					0.758***	0.652***	0.654***	0.608***		0.196	0.0816	0.0811	0.0406
					(0.0735)	(0.144)	(0.144)	(0.148)		(0.138)	(0.186)	(0.186)	(0.191)
o.vSEFsefdt					-	-	-	-		-	-	-	-
Blkszdt						0.133	0.131	0.162			0.144	0.146	0.173
						(0.164)	(0.164)	(0.168)			(0.164)	(0.164)	(0.168)
tenor5							0.00649	0.0220				-0.00595	-0.00134
							(0.0406)	(0.0440)				(0.0460)	(0.0490)
VIXClose								0.0144***					0.00988***
								(0.00293)					(0.00323)
Constant	5.630***	5.597***	2.780***	2.780***	2.245***	2.209***	2.223***	2.576***	2.940***	2.725***	2.686***	2.668***	2.740***
	(0.727)	(0.727)	(0.709)	(0.709)	(0.758)	(0.757)	(0.758)	(0.776)	(0.697)	(0.766)	(0.765)	(0.778)	(0.808)
Observations	6,229	6,229	6,229	6,229	6,229	6,229	6,229	5,763	6,229	6,229	6,229	6,229	5,763
R-squared		0.001	0.021	0.021	0.060	0.060	0.060	0.065	0.082	0.082	0.083	0.083	0.085

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix E

Details of proofs in chapter 3

Proof of lemma 2. I use the change of measure introduced by Collin-Dufresne et al. [37] in order to include the interaction or correlation of default intensities of the bond or reference entity with seller default. Thus, given the default intensities in (3.3.1) I have the following

$$
\begin{aligned}
Pr[\tau^C \geq s^*, \tau^B \geq s^*] \equiv E[1_{\tau^C \geq s^*}, 1_{\tau^B \geq s^*}] \\
=& E_C[1_{\tau^C \geq s^*}, e^{-\int_0^{s^*}(b_0 - b_{1,\tau^C \geq s^*})}] \\
=& E_C[1_{\tau^C \geq s^*}, e^{-s^*(b_0 - b_{1,\tau^C \geq s^*})}] \\
=& e^{-s^* c_0} \int_{s^*}^{\infty} c_0 e^{-c_0 \mu + b_1 s^*} d\mu \\
=& -e^{-s^* c_0} e^{-c_0 \mu + b_1 s^*} \Big|_{s^*}^{\infty} \\
=& e^{-s^*(c_0 + b_0 - b_1)}
\end{aligned}
$$

It is trivial to verify the following joint probabilities using same method.

$$
\begin{aligned}
Pr[\tau^C < s^*, \tau^B \geq s^*] &= e^{-s^* b_0}(1 - e^{-c_0 s^*}) \\
Pr[\tau^C \geq s^*, \tau^B < s^*] &= e^{-s^* c_0}(1 - e^{s^*(b_1 - b_0)}) \equiv p^C(1 - p^B) \\
Pr[\tau^C < s^*, \tau^B < s^*] &= 1 - e^{-s^* b_0} - e^{-s^* c_0}(1 - e^{s^* b_0})
\end{aligned}
$$

The premium is determined by zero-profit condition;

$$
p^C(1 - p^B)[-m + qm] + (1 - p^C)qm + p^C p^S[-R + qm] = 0
$$

Proof of lemma 3. The first order condition is:

$$(1-p^C)[-\mathcal{U}_1'(\cdot)+\mathcal{U}_2'(\cdot)]+p^Cp^B[-\mathcal{U}_3'(\cdot)+\mathcal{U}_2'(\cdot)]-\frac{p^B}{(1-p^B)}a[\mathcal{U}_1'(\cdot)+\mathcal{U}_2'(\cdot)+\mathcal{U}_3'(\cdot)]-\varphi=0$$

Variable $a=\frac{R}{m}$ and $\mathcal{U}_1\equiv\mathcal{U}(w-qm), \mathcal{U}_2\equiv\mathcal{U}(w-qm-L+m)$ and $\mathcal{U}_3\equiv\mathcal{U}(w-qm-L+R)$. φ is the multiplier associated to inequality in the program. Since $\mathcal{U}_1'(\cdot)<\mathcal{U}_2'(\cdot)<\mathcal{U}_3'(\cdot)$ then solution requires $m>R$ and $L>m$. Since R is exogenous, lemma 1 state that a reduction of recovery will reduce premium and as a consequence inequality in (3.3) will be slack. Also, if the intensity of default (b_1) increases then premium decreases and inequality will be slack too. The former can be easily verified in the first order condition i.e range between $\mathcal{U}_2'(\cdot)$ and $\mathcal{U}_1'(\cdot)$ increases which implies insurance will be lower.

Proof of proposition 3. The proposed solution involves the following: i) interior solution for Φ_{df} and Φ_{mrg}; ii) the feasibility condition is binding; iii) consumption at first state of nature must be less than before in exactly Φ_{df} units (the interim participation constraint for c_1 is binding); iv) the incentive compatibility constraint for c_2 is binding.

Proof of proposition 5. I verify the sign of $\frac{\partial R/q}{\partial N}=-\frac{1}{(\Delta\lambda+\lambda)^2}\frac{\partial\Delta\lambda}{\partial N}$. Thus,

$$\begin{aligned}\frac{\partial\Delta\lambda}{\partial N}&=\frac{\omega_b\gamma\lambda(1-\lambda)}{2+N}-\frac{(\omega_b(N+1)-\omega_s)\gamma\lambda(1-\lambda)}{(2+N)^2}\\&=\frac{\omega_b\gamma\lambda(1-\lambda)(2+N)}{(2+N)^2}-\frac{(\omega_b(N+1)-\omega_s)\gamma\lambda(1-\lambda)}{(2+N)^2}\\&=\frac{(\omega_b+\omega_s)\gamma\lambda(1-\lambda)}{(2+N)^2}>0\end{aligned}$$

I assume that all extra buyers are expected to receive same endowment i.e. $\omega_b^i\equiv\omega_b$.

Proof of lemma 4. Since market clearing condition is $m_{ND}=(N+1)m^b$, then,

$$\frac{(N+1)}{R+\kappa}\Big[-\frac{\Delta\lambda}{\gamma\lambda(1-\lambda)}+\omega_b\Big]=\frac{(\Delta\lambda+\lambda)(R+\kappa)-\lambda(\epsilon+\kappa)}{\gamma\lambda(1-\lambda)(\epsilon+\kappa)^2}$$

Above expression can be arranged as follows

$$(R+\kappa)^2(\Delta\lambda+\lambda)-(R+\kappa)\lambda(\epsilon+\kappa)^2-(-\Delta\lambda+\omega_b\lambda(1-\lambda))(N+1)(\epsilon+\kappa)^2$$

Thus $(R+\kappa) = \beta(\Delta\lambda, \lambda, \omega_s, \gamma)(\epsilon+\kappa) \equiv \beta(\Delta\lambda)(\epsilon+\kappa)$ is the root to above expression.

Proof of lemma 5. Applying envelope theorem,

$$\frac{\partial \Pi^i}{\partial \kappa} = -\Delta\lambda \frac{\partial R^+(\kappa)}{\partial \kappa} + \lambda + \gamma\lambda(1-\lambda)[w^i(G) - (R^+ + \kappa)](\frac{\partial R^+(\kappa)}{\partial \kappa} - 1)$$

Doing arrangement of above expression we have that

$$\frac{\partial \Pi^i}{\partial \kappa} = \left[\frac{q - \lambda(R^+ + \kappa)}{\gamma\lambda(1-\lambda)(R^+ + \kappa)} \frac{1}{R^+} + \frac{\lambda}{\gamma\lambda(1-\lambda)R^+}\right](-\kappa + 1) = 0$$

In the case for sellers, in equilibrium $R + \kappa = 1$ thus, both seller's function to maximize is

$$\Pi_D = \theta - \eta^{-1}\kappa m - \lambda(\epsilon+\kappa)m - \frac{\gamma}{2}\lambda(1-\lambda)[(\epsilon+\kappa)m]^2$$
$$\Pi_{ND} = \theta - \eta^{-1}\kappa m + \Delta\lambda + \lambda + \lambda(\omega_s - m) - \frac{\gamma}{2}\lambda(1-\lambda)(\omega_s - m)^2$$

Thus respectively $\frac{\partial \Pi_D}{\partial \kappa} < 0$ and $\frac{\partial \Pi_{ND}}{\partial \kappa} < 0$

Proof of proposition 6. Applying the price rule into seller function when non-defaulting:

$$\begin{aligned}
\Pi_{ND} &= \theta + \Delta m + \lambda\omega_s - \frac{\gamma}{2}\lambda(1-\lambda)(\omega_s - m)^2 \\
&\equiv \theta + \Delta\lambda\Big[\frac{\Delta\lambda}{\gamma\lambda(1-\lambda)} + \omega_s\Big] + \lambda\omega_s - \Big[\frac{\Delta}{\gamma\lambda(1-\lambda)}\Big]^2 \\
&\equiv \theta + \frac{(\Delta\lambda)^2}{\gamma\lambda(1-\lambda)}(1 - \frac{\gamma}{2}) + (\Delta\lambda + \lambda)\omega_s
\end{aligned}$$

Accordingly, for seller function when defaulting

$$\Pi_D = \theta + (\Delta + \lambda)\omega_s - \lambda\epsilon m - \frac{\gamma}{2}\lambda(1-\lambda)(\epsilon m)^2$$

Thus, seller always makes a choice of non-defaulting evaluated at that insurance level (m^*) in particular.

$$\frac{(\Delta\lambda)^2}{\gamma\lambda(1-\lambda)}(1 - \frac{\gamma}{2}) > -\lambda\epsilon m^* - \frac{\gamma}{2}\lambda(1-\lambda)(\epsilon m^*)^2$$

Thus, insurer gets worse beyond $m \geq m^*$; the insurer only suffers larger deadweight costs of default. If parameters γ increases, the RHS of above expression is bounded and it would push the insurance level under defaulting towards zero. In this case there is no solution since market clearing condition fails. It is assumed that $\epsilon > 0$; otherwise, insurance level would be undetermined under choice of defaulting.

Proof of proposition 7. Participation constraint in combination with CDS premium (expression (3.11)) and optimal amount of insurance under default (expression (3.10)) can be expressed as follows:

$$\kappa = \alpha(\Delta\lambda + \lambda)\beta(\epsilon + \kappa) + \frac{(\overline{\theta} - c)\gamma\lambda(1 - \lambda)(\epsilon + \kappa)}{\beta(\Delta\lambda + \lambda) - \lambda}$$

Thus, re-arranging terms, I have the following

$$\kappa = \frac{\alpha(\Delta\lambda + \lambda)\beta + \frac{(\overline{\theta} - c)\gamma\lambda(1-\lambda)}{\beta(\Delta\lambda+\lambda)-\lambda}}{1 - \alpha(\Delta\lambda + \lambda)\beta - \frac{(\overline{\theta} - c)\gamma\lambda(1-\lambda)}{\beta(\Delta\lambda+\lambda)-\lambda}}\epsilon$$

Above expression is linear as long as the collateral budget constraint is slack ($\varsigma = 0$). If not, collateral size is the root to the following polynomial

$$\kappa = \frac{(\alpha(\Delta\lambda + \lambda)^2\beta^2(1 + \varsigma\alpha) - \lambda\alpha(\Delta + \lambda)\beta + (\overline{\theta} - c)\gamma\lambda(1 - \lambda))(\epsilon + \kappa) - \varsigma\kappa\alpha(\Delta\lambda + \lambda)\beta}{(\Delta\lambda + \lambda)\beta(1 + \varsigma\alpha) - \lambda - \frac{\varsigma\kappa}{\epsilon+\kappa}}$$

Proof of proposition 8. In range $\epsilon \in (\underline{\epsilon}, \epsilon^0)$ the second root for R is lower than in range $\epsilon \in (\epsilon^0, \overline{\epsilon})$. The condition $\underline{\epsilon} \leq \varsigma^{-1}$ delivers a guarantee for the existence of an incentive contract when $\varsigma < 0$. To see this I combine the binding clearing budget constraint and the corner solution $\kappa = 1$; Thus, $1 = \kappa \equiv \varsigma\epsilon$.

Proof of proposition 11. Since clearing budget constraint is slack, the multiplier associated to this restriction (ϱ) must be equal to zero. There is no overidentification since there are 4 pair of equations and variables (ϕ_s, ϕ_b, R and q). Since a solution considering $\phi_s > 0$ forces to have non-defaulting contracts i.e. higher value of social utility function, then a corner solution exists. This result ($\phi_b = 0$) hinges on the amount of resources available in the clearinghouse. Once the clearing budget constraint is binding, the multiplier related to that restriction must be greater than zero and therefore additional resources need to be collected ($\phi_b > 0$).

Proof of lemma 6. Market clearing condition must be satisfied for a non-defaulting choice; thus, insurance supply is given by expression;

$$m_{nd} \equiv \frac{1}{R}\left[\frac{q(1+\varrho\alpha) - \lambda R - (1+\varrho)\phi_s}{\gamma\lambda(1-\lambda)R} + \omega_s\right]$$

Since $R + \varphi = 1$ the insurance demand is as follows;

$$m^b = \frac{-q+\lambda}{\gamma\lambda(1-\lambda)} + \omega_b$$

Thus, in equilibrium $m^{nd} = (N+1)m^b$. Notice that $\phi_b = 0$ given by solution in program ($P2$).

Proof of proposition 12. I evaluate the following expression across range of $\epsilon > \epsilon^0$

$$\frac{\partial\beta}{\partial\Delta\lambda} \equiv \frac{\omega_s\gamma\lambda(1-\lambda)\Big(\lambda + 4\omega_s\gamma\lambda(1-\lambda)[\Delta\lambda+\lambda]\Big)^{-\frac{1}{2}}}{\Delta\lambda+\lambda} - \Big(\frac{\lambda + \sqrt{\lambda + 4\omega_s\gamma\lambda(1-\lambda)[\Delta\lambda+\lambda]}}{2(\Delta\lambda+\lambda)^2}\Big) \tag{E.1}$$

since β is equal to $\frac{\lambda\pm\sqrt{\lambda+4\omega_s\gamma\lambda(1-\lambda)[\Delta\lambda+\lambda]}}{2(\Delta\lambda+\lambda)}$; then I plug the former into expression (E.1)

$$\begin{aligned}
\frac{\partial\beta}{\partial\Delta\lambda} \equiv & \frac{\omega_s\gamma\lambda(1-\lambda)\left[\frac{1}{\beta-\frac{\lambda}{2(\Delta\lambda+\lambda)}}\right]}{2(\Delta\lambda+\lambda)^2} - \frac{\beta}{\Delta\lambda+\lambda} \\
\equiv & \frac{1}{\Delta\lambda+\lambda}\left[\frac{\omega_s\gamma\lambda(1-\lambda)}{2\beta(\Delta\lambda+\lambda)-\lambda} - \beta\right] \\
\equiv & \frac{1}{(\Delta\lambda+\lambda)(2\beta(\Delta\lambda+\lambda)-\lambda)}\left[\omega_s\gamma\lambda(1-\lambda) - \beta(2\beta(\Delta\lambda+\lambda)-\lambda)\right]
\end{aligned}$$

The roots of above right hand expression is

$$\tilde{\beta} = \frac{\lambda - \sqrt{\lambda^2 + 8\omega_s\gamma\lambda(1-\lambda)[\Delta\lambda+\lambda]}}{4(\Delta\lambda+\lambda)}$$

Since $\beta > \tilde{\beta}$ then, $\frac{\partial\beta}{\partial\Delta\lambda} < 0$. Since default fund ϕ^s increases and decreases accordingly to restriction $R + \varphi \leq 1$, $\frac{\partial R}{\partial\phi^s} < 0$ when former restriction is binding; thus R is always increasing across range of ϕ^s which behaves according to size of ϵ.

Appendix F

Solution for programs

F.1 Program P1

In order to solve the program (P1) I propose a numerical method. Since the function is not continuous and , the solution is found in the following steps:

1. I setup a search grid for the collateral size in the limits $\kappa \in [0, \overline{\kappa}]$.
2. If set $B(\epsilon) = \Big\{\kappa \mid + \kappa\epsilon - 1\Big\}$ is not empty for a small enough ϵ then there is a candidate κ^c.
3. If restrictions in program (P1) are fulfilled then κ^c is a solution and premium associated to this level of collateral is the premium under collateralization. Otherwise, $\kappa^* = 0$ and the premium is identical under bilateral negotiation.

F.2 Program P2

The first order conditions are:

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial \phi_s} \equiv & \frac{\Pi_B}{(1-\lambda)^2}\Big\{(\Delta\lambda + \lambda)\frac{\partial R}{\partial \phi_s} - 1 + \frac{\partial \Delta\lambda}{\partial \phi_s} R\Big\} m^s + \varsigma\Big(\alpha(\Delta\lambda + \lambda)\frac{\partial R}{\partial \phi_s} - 1 + \frac{\partial \Delta\lambda}{\partial \phi_s}\Big) m^s \\ & + \frac{\Pi_D}{(1-\lambda)^2}\Big\{ - \Delta\lambda \frac{\partial R}{\partial \phi_s} + 1 - \frac{\partial \Delta\lambda}{\partial \phi_s} + \gamma\lambda(1-\lambda)\big[\omega_b - (R + \varphi + \phi_b) m_b\big]\Big(\frac{\partial R}{\partial \phi_s} + \lambda^{-1}\Big)\Big\} m^b \\ & \psi_{s0} - \psi_{s1} + \psi\Big(\frac{\partial R}{\partial \phi_s} + \lambda^{-1}\Big) = 0\end{aligned} \tag{F.1}$$

$$\frac{\partial \mathcal{L}}{\partial \phi_b} \equiv \frac{\Pi_D}{(1-\lambda)^2}\Big\{ -(\Delta\lambda+\lambda)\frac{\partial R}{\partial \phi_b} - (1-\lambda) + \lambda\Big(\frac{\partial R}{\partial \phi_b} + \frac{\partial \varphi}{\partial \phi_b}\Big) - \frac{\partial \Delta\lambda}{\partial \phi_b}R +$$
$$\gamma\lambda(1-\lambda)[\omega_b - (R+\varphi+\phi_b)m^b]\Big(\frac{\partial R}{\partial \phi_b} + 1 + \frac{\partial \varphi}{\partial \phi_b}\Big)\Big\}m^b + \varsigma\alpha\Big((\Delta\lambda+\lambda)\frac{\partial R}{\partial \phi_b} + R\frac{\partial \Delta\lambda}{\partial \phi_b}\Big)m^b$$
$$+ \frac{\Pi_B}{(1-\lambda)^2}\Big((\Delta\lambda+\lambda)\frac{\partial R}{\partial \phi_b} + \frac{\partial \Delta\lambda}{\partial \phi_b}R\Big)m^s + \psi_{b0} - \psi_{b1} - \psi\Big(\frac{\partial R}{\partial \phi_b} + \frac{\partial \varphi}{\partial \phi_b}\Big) = 0 \tag{F.2}$$

Thus, jointly with above expressions (F.1) and (F.2),premium determination, clearinghouse balance sheet and clearing market condition, below conditions needs to be fulfilled for the optimal solution,

$$\varsigma((\alpha q - \phi_s)m^s + \overline{\theta} - c) = 0$$
$$\psi(1 - R - \varphi) = 0$$
$$\psi_{s0}\phi_s = 0$$
$$\psi_{s1}(1-\phi_s) = 0$$
$$\psi_{b0}\phi_b = 0$$
$$\psi_{b1}(1-\phi_b) = 0$$

Solution is found for ϕ_s and ψ_{b0} using expressions (F.1) and (F.2). An interior solution (i.e. $\phi_s > 0$ and $\phi_b > 0$) is also provided for a binding clearing budget participation i.e. $\varsigma > 0$ and a demanding calls for more resources i.e. higher ω_b and λ.

Partial derivatives in expressions (F.1) and (F.2) are defined as follows;

$$\frac{\partial \Delta\lambda}{\partial \phi_s} = -\Big(\frac{-1}{\hat{R}^2}\Big(\lambda - \gamma\lambda(1-\lambda)\Big(\frac{\omega_s}{\hat{R}} - \omega_b\Big)\Big) + \frac{1}{\hat{R}}\gamma\lambda(1-\lambda)\frac{\omega_s}{\hat{R}^2}\Big)\frac{1}{\lambda}$$

$$\frac{\partial \Delta\lambda}{\partial \phi_b} = -\Big(\frac{-1}{\hat{R}^2}\Big(\lambda - \gamma\lambda(1-\lambda)\Big(\frac{\omega_s}{\hat{R}} - \omega_b\Big)\Big) + \frac{1}{\hat{R}}\gamma\lambda(1-\lambda)\frac{\omega_s}{\hat{R}^2}\Big)\frac{1-\lambda}{\lambda} - \frac{1-\lambda}{\hat{R}};$$

$$\frac{\partial R}{\partial \phi^s} = \frac{\Omega_{s,0}(\epsilon) - \frac{2(\phi^b+R+\varphi)}{\lambda}\big[(\Delta\lambda+\lambda)R(1+\varrho\alpha) - \lambda\epsilon - \phi^s(1+\varrho)\big] + (\phi^b+R+\varphi)^2[(1+\varrho\alpha)\frac{\partial\Delta\lambda}{\partial\phi_s} + (1+\varrho)]}{\Omega_{s,1}(\epsilon) + 2(\phi^b+R+\varphi)\big[(\Delta\lambda+\lambda)R(1+\varrho\alpha) - \lambda\epsilon - \phi^s(1+\varrho)\big] + (\phi^b+R+\varphi)^2(\Delta\lambda+\lambda)(1+\varrho\alpha)}$$

$$\frac{\partial R}{\partial \phi^b} = \frac{\Omega_{b,0}(\epsilon) - (\phi^b+R+\varphi)^2\frac{\partial\Delta\lambda}{\partial\phi_b}(1+\varrho\alpha)R - \frac{2(\phi^b+R+\varphi)}{\lambda}\big[(\Delta\lambda+\lambda)R(1+\varrho\alpha) - \lambda\epsilon - \phi^s(1+\varrho)\big]}{\Omega_{b,1}(\epsilon) + (\phi^b+R+\varphi)^2(\Delta\lambda+\lambda)(1+\varrho\alpha) + 2(\phi^b+R+\varphi)\big[(\Delta\lambda+\lambda)R(1+\varrho\alpha) - \lambda\epsilon - \phi^s(1+\varrho)\big]}$$

Where above expressions as a function of deadweight losses are;

$$\Omega_{s,0}(\epsilon) \equiv \Big(\frac{\partial \Delta\lambda}{\partial \phi_s} R + 1 + \gamma(1-\lambda)\omega_b\Big)\epsilon^2$$

$$\Omega_{s,1}(\epsilon) \equiv (-\gamma\lambda(1-\lambda)\omega_b + \Delta\lambda)\epsilon^2$$

$$\hat{R} = \hat{\varphi} - 1$$

$$\Omega_{b,0}(\epsilon) \equiv \Big(\frac{\partial \Delta\lambda}{\partial \phi_s} R + \gamma(1-\lambda)\omega_b\Big)\epsilon^2$$

$$\Omega_{b,1}(\epsilon) \equiv \Omega_{s,1}(\epsilon)$$

Expressions $\hat{R}$ and $\hat{\varphi}$ are the recovery rate and collectable funds in a scenario with fully coverage.

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