# The Impact of Central Clearing on Banks' Lending Discipline

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**Abstract**

This article investigates the impact of central clearing in credit risk transfer markets on a loan-originating bank's lending behavior. Access to central clearing changes the bank's optimal loan risk hedging strategy so as to undermine lending discipline. The effect on lending discipline depends crucially on the regulatory design of central clearing in terms of capital requirements, disclosure standards, risk retention, and access to uncleared credit risk transfer. I also show that lending discipline is an important channel to assess the total impact of central clearing on systemic risk.

*JEL Classification Codes:* G18, G28

*Keywords:* Credit Risk Transfer, Central Clearing, Lending Discipline, Systemic Risk

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# 1 Introduction

Banks are major players in the credit risk transfer (CRT) market, and typically use it to manage credit exposure (see, e.g., Hirtle 2009; Bongaerts et al. 2011). Market observers fear that banks' activity in the Over-the-Counter (OTC) CRT market creates a channel for counterparty risk contagion (Acharya and Bisin 2014). As a response to the 2007-2009 financial crisis, the United States Congress passed the Dodd-Frank Act, which stipulates that all sufficiently standardized OTC derivatives traded by large market players must be cleared with regulated central counterparties. The European Commission and the recent G20 reform of the OTC derivatives market took similar steps. Centrally clearing standardized OTC credit derivatives has thus increased recently to $31\%$ of the outstanding credit derivative notional (BIS 2015). The main promise of this regulation is to mitigate systemic risk by reducing counterparty risk (see, e.g., Zawadowski 2013). The empirical literature, however, suggests that CRT conditions also influence banks' lending behavior (see, e.g., Purnanandam 2011; Arentsen et al. 2015). Despite the fundamental change to CRT conditions from the introduction of central clearing, no studies have explored the consequences of the change on banks' lending behavior. This gap is surprising given that insufficient lending discipline is among the main causes of the financial crisis (Diamond and Rajan 2009; Acharya et al. 2009).

This paper investigates the impact of central credit derivative clearing on banks' behavior in the primary loan market. I model a bank that can grant a loan and hedge it on a centrally cleared or uncleared OTC market. Screening the loan is costly, but allows the bank to detect and reject a low-quality loan. This lending discipline decreases the probability that a loan is granted, and increases the expected quality of an originated loan. The model generates three main results. First, access to central clearing undermines banks' lending discipline. Second, the impact of central clearing on lending discipline depends crucially on the regulatory design of the centrally cleared market. Third, the lending discipline channel is important for systemic risk.

The intuition behind the first result starts from the observation that standard credit default swaps (CDS)[1] eligible for central clearing do not allow a bank to signal loan quality when it hedges a loan. Hence, the cost to hedge a loan's default risk is identical for high- and low-quality loans. Since this cost is too small for a low loan, the bank is incentivized to grant and hedge a detected low-quality loan instead of rejecting it. Therefore, lending discipline is low with access to central clearing. This problem is less pronounced on the uncleared OTC market on which banks can signal loan quality with tailored credit derivatives.

Starting from this simple intuition, I investigate how the regulatory design of central clearing affects lending discipline. Public disclosure of the centrally cleared position or a risk retention provision influences the bank's optimal hedging strategy. This influence feeds back into the loan granting decision and encourages lending discipline. With voluntary central clearing, however, the bank can circumvent disclosure and risk retention provisions on the centrally cleared market by hedging on the uncleared OTC market. Hence, lending discipline is determined by the conditions on the uncleared market. Mandatory

[1] In a CDS, the protection buyer pays the credit spread to the protection seller. Upon default of the reference loan, the latter pays the buyer the nominal minus the recovery rate.

central clearing, i.e., prohibiting a bank's access to the uncleared OTC market, can therefore improve the impact of disclosure and risk retention provisions on lending discipline.

I also show that higher capital requirements do not improve lending discipline in the current regulatory framework for central clearing that is voluntary and unrestricted. With public disclosure of centrally cleared positions, tighter capital requirements can even undermine lending discipline. The regulator only improves lending behavior with the stricter capital requirements currently implemented under Basel III when it simultaneously enforces risk retention provisions on the centrally cleared market. Lending discipline then improves with capital requirements for unhedged loan exposure when central clearing is mandatory and with capital requirements for OTC-hedged loan exposure when central clearing is voluntary. Additionally, market observers currently discuss stimulating central clearing by reducing regulatory capital, margins, or transaction costs of hedges with central counterparties (Duffie et al. 2010; BIS 2012). I find that the impact of this reduction on lending discipline depends critically on the regulatory design of central clearing.

The main regulatory motive behind introducing central clearing is to mitigate counterparty risk frictions that increase systemic risk (see, e.g., Duffie and Zhu 2011; Zawadowski 2013). I find, however, that the current implementation of central clearing entails a trade-off between increasing and decreasing the loan default exposure of a bank that is a fundamental element of systemic risk. On the one hand, central clearing can reduce counterparty risk, which mitigates default exposure. On the other hand, central clearing undermines lending discipline, which increases the probability that a loan is granted and reduces the expected quality of a granted loan. This lending discipline channel increases default exposure critically. With a standard parameter calibration, for example, the pure lending discipline channel increases default exposure by $56\%$. Using Loon and Zhong (2014)'s estimate of the mitigation of counterparty risk with central counterparties implies that central clearing even increases net default exposure because of the dominant effect of the lending discipline channel. Thus, it is important to address the lending discipline problem when regulating central clearing to mitigate systemic risk. Voluntary central clearing with a risk retention provision, for example, minimizes default exposure if the central counterparty's counterparty risk is lower than that of the OTC counterparty. Restricting access to the uncleared OTC market (mandatory central clearing) increases default exposure in this case because a bank reacts to the restriction by leaving loan exposure unhedged due to investors' equilibrium beliefs about the quality of a loan hedged on a centrally cleared market. This effect dominates the improved lending discipline associated with mandatory central clearing. If the counterparty risk of a central counterparty is larger than that of the OTC counterparty, a ban on central clearing minimizes default exposure. The current market setting in which central clearing is voluntary, unrestricted, and without disclosure requirements only minimizes default exposure if the counterparty risk of a central counterparty is much lower than that of the OTC counterparty.

My results imply that it is vital to understand the various channels through which central clearing affects the financial system. Any appraisal of the regulatory design of central clearing rules must mind both the direct consequences for the transferred risk exposure and the unintended impact on banks' lending behavior. Additionally, as the effect of this design depends on capital adequacy rules, I suggest regulating capital requirements and central clearing in a comprehensive approach that incorporates their interdependence.

The model generates novel testable predictions. The introduction of central clearing with the current regulatory setting should increase the outstanding loan volume and decrease the average quality of granted loans. It should also increase the quality of loans that banks hedge on the uncleared OTC market. These predictions have implications for adequate recovery and resolution procedures for central counterparties. As the latter are important connectors within the financial system, there are concerns about the risk concentrated in these institutions. Therefore, considerable work is devoted to developing safety procedures such as margin requirements, equity capital, default funds, capital calls, and third-party guarantees (see, e.g., Pirrong 2011). Determining the adequacy of the mechanisms with stress tests and default simulations requires a quantification of the risks underlying the products cleared. The results from my study imply that it is misleading to simply use historical data for the tests and simulations because the introduction of central clearing itself influences the traded exposure size and quality of the underlying loans. Additionally, I find that the cost of recovery and resolution procedures that increases a bank's hedging cost on the centrally cleared market is of minor systemic concern.

My study is most closely related to the recent literature that analyzes the impact of the introduction of central clearing on the banking system. Koeppl et al. (2012) provide a theoretical investigation of how efficient clearing arrangements for exchanges depend on the cost of liquidity. Zawadowski (2013) shows why banks fail to hedge counterparty risk in the OTC market, thereby creating a channel for contagion. He argues that with a central counterparty, banks can be forced to contribute ex-ante to bailing out counterparties of the failing bank, which eliminates the inefficiency. Acharya and Bisin (2014) suggest that OTC market participants create a counterparty risk externality by taking excessive risk. Position transparency from central clearing can help market participants internalize this counterparty risk externality by conditioning the terms of the contract they trade on the total financial position of the counterparty and not just on bilateral positions. Loon and Zhong (2014) use data on voluntarily cleared CDS contracts to show that central clearing reduces counterparty risk and increases CDS liquidity. Duffie and Zhu (2011) and Duffie et al. (2015) argue that introducing central clearing decreases or increases the average exposures to counterparty default risk and collateral demand depending on the fragmentation of clearing services. The literature, so far, discusses only the impact of central clearing on banks' hedging activity, ignoring the effect on banks' lending activity. This gap is surprising because several recent studies identify looser lending standards with easier access to the CRT market (see,e.g., Keys et al. 2010; Purnanandam 2011; Subrahmanyam et al. 2014; Arentsen et al. 2015; Wang and Xia 2014), some of them emphasizing this channel as a key driving force behind the 2007 to 2008 financial crisis. I complement the central clearing literature by analyzing the consequences of central clearing on banks' primary business, namely their lending activity, and by showing that this channel is a crucial component of systemic risk. I do not endogenously derive the differences between centrally cleared and uncleared hedging such as standardization, capital requirements, transaction cost, and counterparty risk that already contain extensive analyses in the existing literature. Instead, the goal of this study is to investigate the impact of these exogenous differences on lending discipline.

I additionally contribute to the stream of research on information asymmetry problems in CRT markets. Gorton and Pennacchi (1995) argue that if a bank can implicitly commit to holding a certain fraction of a loan, the moral hazard associated with the loan sales market is mitigated. Similar ideas apply to credit derivatives. Duffee and Zhou (2001) show how banks hedging high-quality loans may use credit derivatives with a maturity mismatch[2] to shift the risk of early default to outsiders. By retaining the risk of late default, they avoid the "lemons" problem. Nicolò and Pelizzon (2008) demonstrate how OTC credit derivatives are flexibly tailored to signal loan quality. In particular, a credit default basket contract in which the hedging bank pays a penalty when defaults are above a certain level provides a signal of quality. If the bank cannot commit to risk exposure because the market is opaque, it may still signal quality with the initial price of the credit default basket contract. Parlour and Plantin (2008) analyze the trade-off associated with the emergence of a liquid secondary market for loans. Liquidity increases a bank's flexibility to recycle capital, but reduces its incentive to monitor as it can more easily sell non-performing loans. Parlour and Winton (2013) investigate banks that choose between loan sales and a CDS to transfer credit risk. The latter undermines efficient monitoring unless banks have strong reputational incentives because CDSs leave borrower control rights in the hands of the bank. The literature on information asymmetry recognizes that the type of contract the bank chooses to transfer credit risk influences the asymmetric information problem. I expand this idea by showing that the introduction of central clearing and its regulatory design affects the mix of contract types banks use, and that this mix determines bank behavior in the primary loan market. Additionally, I illustrate how the well-known risk retention approach to information asymmetry problems must be implemented and combined with disclosure to mitigate the lending discipline problem with central clearing.

My results on the deterioration in lending discipline also complement the literature on the unintended consequences of financial stability regulations, which often lead to perverse outcomes. Besanko and Kanatas (1996) analyze the impact of stricter capital requirements on monitoring. Banks need to raise more equity from outside shareholders to comply with higher capital requirements. Faced with dilution, internal shareholders have less incentive to monitor loans, which increases loan losses. Kopecky and VanHoose (2006) agree with the notion that stricter capital requirements do not necessarily increase monitoring. When capital requirements suddenly constrain the banking system, lending declines. At the same time, the equilibrium share of banks that optimally chooses to monitor loans decreases. Hence, capital requirements have an ambiguous effect on aggregate loan quality. Battalio and Schultz (2011) find that the 2008 short sale ban caused a dramatic increase in the cost of liquidity in U.S. equity option markets. According to Malherbe (2014), imposing liquidity requirements on financial institutions may create cash hoarding behavior and a breakdown of the market for long-term risky assets. Finally, Sundaresan and Wang (2015) argue that contingent bank capital with a market trigger can introduce price uncertainty, market manipulation, inefficient capital allocation, and conversion errors.

## 2 Model structure

I extend Nicolò and Pelizzon (2008)'s model to incorporate lending discipline and central clearing. A risk-neutral, profit maximizing bank operates in the loan market. It can grant a loan with a nominal of

[2] In a maturity mismatch, the maturity of the credit derivative contract does not match the underlying loan contract.

one to a borrower. The loan has a certain rating that is public information. To capture credit quality differences within the same rating category as observed by, for example, Helwege and Turner (1999), I stipulate that the repayment probability of a loan with a certain rating is either high ($p_H$) or low ($p_L$), with $1 \geq p_H > p_L \geq 0$. The ex-ante probability that a loan is of high type corresponds to $\mu \in (0, 1)$. Hence, the ex-ante expected repayment probability of a loan is $p_\mu = \mu p_H + (1 - \mu)p_L$. As in Parlour and Plantin (2008), the bank can screen the loan to collect private information at cost $C$ due to its lending relationship to the borrower. I assume that the private information is the loan repayment probability that is perfectly revealed with screening. $C \in (0, 1)$ is standard uniformly distributed ex-ante. The bank learns this cost once the borrower asks for a loan. The notion that banks have private information about their borrowers is well established (see, e.g., Acharya and Johnson 2007).

The model considers two dates. At date zero, a borrower asks the bank for a loan. The bank observes the screening cost, and may screen the applicant before deciding whether to grant the loan. At date one, the loan matures. The borrower repays the nominal value of the loan if he does not default. Otherwise, the repayment is zero.

In practice, the relationship between loan quality and loan interest rate is opaque due to information asymmetry between borrowers and banks, the parties' bargaining power, the market structure, the competition for borrowers, among others (Stiglitz and Weiss 1981; Petersen and Rayan 1995; Von Thadden 2004). Rather than explicitly modeling this relationship, I simplify the analysis by assuming that any loan type granted in one rating category pays the same publicly known interest rate $i$ at date zero. Hence, it is not possible to infer the loan's repayment probability from the interest rate. This simplification is relaxed in Section 4.1. The risk-free interest rate is normalized to zero.

Since a bank finances a loan with deposits, the regulator requires the bank to hold a certain amount of regulatory capital as a buffer to cover losses. The Basel Accord requires that a bank's regulatory capital exceeds 8 percent of risk-weighted assets, i.e., of the sum of each asset holding multiplied by its risk weight. Risk weights are based on estimates of the probability of default, the loss given default, the exposure at default, and maturity. The regulatory practice requires banks to calibrate these parameters from broad quality classes such as rating categories, and to assign identical parameter values to each loan type in the same rating category (BIS 2011). To reflect this practice, I determine identical regulatory capital requirements of $\lambda$ for each granted loan type in the corresponding rating category. This capital is invested in a short-term asset that cannot be used to finance the loan. Following Nicolò and Pelizzon (2008), I assume that the unitary cost of capital, $\delta$, is greater than the cost of deposits that is normalized to zero.[3] I interpret $\delta$ as the required expected return on equity, i.e., the return that the bank needs to pay the bank's owners to induce them to provide equity capital. The regulatory capital costs per granted loan then correspond to $\lambda\delta$.

At time zero, the bank can also hedge a granted loan by transferring the default risk to an investor on either a centrally cleared or an uncleared OTC CRT market. Both markets are competitive. The investor cannot observe the motive behind a trade, the screening activity, or the bank's risk exposure. However, the investor knows the probability distribution of the bank's ex-ante screening cost, the rating

[3] Froot and Stein (1998) discuss why $\delta$ is greater than the cost of deposits.

of a loan, and all remaining model parameters. As soon as a loan is granted, its default risk is liquidly traded on both CRT markets by investors (but not necessarily by the bank itself).

With central clearing, a central counterparty steps into bilateral trades as the counterparty to each seller and buyer. It is beyond the scope of this study to endogenously derive the differences between centrally cleared and uncleared trading, which is analyzed extensively in previous studies. Instead, I consider the following four key differences exogenously, and endogenize their impact on a bank's lending behavior.

First, central counterparties only clear frequently traded standardized contracts due to the cost of setting up, analyzing, and pricing each type of derivative daily for the purpose of calculating variation margins, or due to the sudden need to unwind positions held with a defaulted clearing member (Bliss and Steigerwald 2006; Duffie et al. 2010; Slive et al. 2012). According to FSB (2015), solely standardized index credit derivatives and single-name CDSs obtain clearing offerings from central counterparties. Hence, I assume that the bank can centrally hedge a loan with a standard CDS that matures at date one. In contrast, it can use a customized credit derivative to hedge via the uncleared OTC market. Duffee and Zhou (2001) and Nicolò and Pelizzon (2008) describe how a bank can mitigate information asymmetry problems by trading tailored contracts on the uncleared OTC market, based on the idea that it is more costly for a bank to signal a high underlying loan quality for low-quality loans than for a high-quality loan with a tailored credit derivative. To capture this notion simply, I assume that tailoring a credit derivative to signal loan quality leads to costs $\Omega(P_i \mid p_j)$, with $P_i$ being the representative loan quality and $p_j$ the true loan quality, and $i, j = \{H, \mu, L\}$. I describe the case in which $\Omega(P_H \mid p_H) = \Omega(P_\mu \mid p_\mu) = \Omega(P_L \mid p_L) = 0$ and $\Omega(P_i \mid p_j) > i - (1 - p_H) - \delta(m + \xi_C)$ if $i > j$. Hence, signaling a quality higher than the true loan quality via tailoring is costly.[4]

Second, capital requirements under Basel III consider whether a bank hedges a loan and through which channel the hedging occurs. Specifically, they depend on the expected default exposure that is calculated based on the rating of a loan and a risk weight. To stimulate hedging (with solid counterparties), the risk weight of the loan can be replaced by the risk weight of the hedging counterparty. Central counterparties obtain a lower risk weight (minimum of $2\%$) than an uncleared OTC counterparty (BIS 2012), thereby providing a capital incentive for central clearing. I incorporate this regulation by imposing $\lambda > \gamma > m > 0$, in which $m$ is the regulatory capital requirement for one unit of a centrally hedged loan and $\gamma$ for an OTC hedged loan. I also define regulatory capital requirements, $\epsilon > 0$, for one unit of speculative credit exposure a bank incurs on the centrally cleared CRT market. "Speculative" means that the credit derivative position is not covered by the underlying loan.

Third, central clearing can increase banks' transaction costs of hedging a loan compared to hedging in uncleared OTC markets due to central counterparties' stricter margin requirements or mandatory

[4] The literature contains many examples of such a signaling cost. In Duffee and Zhou (2001), a hedging bank with a high-quality loan retains the risk of late default. This approach, however, only works if the maturity of hedging contracts is not standardized but can be tailored to the time variation of the information asymmetry problem. Nicolò and Pelizzon (2008) suggest that a good bank can accept a penalty for defaults above a certain level. In both examples, the signaling cost is the difference between the price obtained for the contract feature and its cost to the hedging bank. This signaling cost is larger for a low-quality than for a high-quality loan, and can be zero for the latter.

contributions to a bailout fund (see, e.g., Zawadowski 2013; Duffie et al. 2015).[5] To investigate how the relative magnitude of transaction costs influence lending discipline, I incorporate $\xi_C > 0$ and $\xi_O > 0$ denoting the transaction funds required for hedging one unit of a loan on the centrally cleared and uncleared markets, respectively.[6] I keep the relation $m+\xi_C < \gamma+\xi_O < \lambda$ to maintain a regulatory incentive to hedge a loan, particularly via central clearing.

Finally, a centrally cleared hedge can entail a different counterparty risk than an uncleared OTC hedge (see, e.g., Duffie and Zhu 2011). To capture this notion, $\Psi_C$ reflects the probability that the investor's obligation is not satisfied in a centrally cleared hedge conditional on loan default, and $\Psi_O$ is the corresponding probability in an uncleared hedge.[7]

Lending discipline on the primary loan market influences a bank's loan default risk exposure along two dimensions. First, it affects the probability $p_G$ that a loan is granted. Second, it has an impact on the expected quality $p_Q = Qp_H + (1-Q)p_L$ of a granted loan, in which Q is the expected probability that the repayment probability of a granted loan is high. As a bank's default risk exposure is an important element of systemic risk (Duffie and Zhu 2011; Huang et al. 2011), I investigate how different market structures influence $p_G$ and $p_Q$. Throughout the analysis, I assume that $1 - p_\mu + \delta\lambda < i < 1 - p_L + \delta(m + \xi_C) < 1 - \delta(\lambda - m - \xi_C)$. I also impose $\epsilon(\delta + \xi) > (p_H - p_L)$ to prevent insider trading by the loan-originating bank on the CRT market. In the First Best, i.e., if the loan quality is publicly known, $p_G^{FB} = \mu$ and $p_Q^{FB} = p_H$ because only a high-quality loan type is granted.

# 3 Results

I start by investigating lending discipline in a benchmark market structure without CRT. To generate policy implications, I then analyze the impact of different CRT market structures on a bank's lending behavior. First, I consider CRT with mandatory central clearing. Second, I investigate a market structure with voluntary central clearing, in which the bank can select between centrally cleared and uncleared OTC CRT.

## 3.1 No access to credit risk transfer (CRT) markets

A potential strategy of a bank without access to CRT is to just grant a loan without screening. This non-screening strategy yields an expected profit of

$$\Pi_{NS} = i - (1 - p_\mu) - \delta\lambda > 0. \tag{1}$$

[5] When an investor trades a contract, the central counterparty requests a deposit in a margin account of cash or cash-equivalent instruments to ensure that the investor satisfies contract obligations.

[6] In a CDS, a margin may only be required from the protection seller, since the protection buyer faces no further obligations after paying the credit spread. Nevertheless, Santa-Clara and Saretto (2009) and Gârleanu and Pedersen (2011) show that margin requirements can translate into prices, which still makes them costly for the protection buyer. Additionally, required margins can entail components from the protection buyer for recovery, liquidity, and concentration risk.

[7] There is no counterparty risk from the bank to the investor because the bank incurs the long position in the CRT contract and the credit spread is paid at time zero.

The bank earns interest $i$, and bears a regulatory capital cost of $\delta\lambda$. The expected default cost on the granted loan corresponds to $1 - p_\mu$. As $i$ does not compensate the total costs of a low loan, i.e., $i < 1 - p_L + \delta\lambda$ as $i < 1 - p_L + \delta m$ and $\lambda > m$, the low type loan is cross-subsidized by the high type. Because the bank grants each loan type with this strategy, $p_G = 1 > \mu = p_G^{FB}$, and $p_Q = p_\mu < p_H = p_Q^{FB}$. Hence, the non-screening strategy entails excessive lending, and a lower expected quality of a granted loan than in the First Best.

Instead of following the non-screening strategy, the bank can screen a loan at cost $C$, which fully reveals the loan's repayment probability. Once the loan type is known, it grants a high loan because $i > 1 - p_H + \delta\lambda$, and rejects a low loan as $i < 1 - p_L + \delta\lambda$. By rejecting the low loan, the bank avoids cross-subsidization. The expected profit from this screening strategy for a given loan applicant is

$$\Pi_S = \mu(i - (1 - p_H) - \delta\lambda) + (1 - \mu)0 - C. \tag{2}$$

Hence, a bank screens a new loan applicant and rejects a low type if the expected profit in Equation (2) is greater or equal to the expected profit from the non-screening strategy in Equation (1), i.e., if

$$(1 - p_L - i + \delta\lambda)(1 - \mu) \geq C. \tag{3}$$

In case the screening condition (3) is satisfied, the expected profit from avoiding cross-subsidization by screening is larger than the screening cost. As the screening cost is standard uniformly distributed, the ex-ante probability that a bank screens and only grants a high type is given by $p_S = \frac{(1-p_L-i+\delta\lambda)(1-\mu)}{1}$. With probability $1 - p_S$, it does not screen and grants both loan types, which leads to Proposition 1.

**Proposition 1.** *The probability that a loan is granted is given by*

$$1 > p_G = p_S\mu + (1 - p_S) > \mu. \tag{4}$$

*The expected quality of a granted loan corresponds to*

$$p_H > p_Q = Qp_H + (1 - Q)p_L > p_\mu, \tag{5}$$

*where*

$$Q = \frac{\mu}{p_G}. \tag{6}$$

*Proof.* See the Appendix. □

As $p_G > \mu = p_G^{FB}$ and $p_Q < p_H = p_Q^{FB}$, there still is excessive lending and a loan quality problem compared to the First Best. However, lending discipline, i.e., the fact that the bank screens with probability $p_S$ and rejects a detected low loan type, induces $p_G < 1$ and $p_Q > p_\mu$. Hence, the excessive lending and loan quality problems are ameliorated compared to a setting without screening. Figure 1 illustrates the lending decisions of the bank.

INSERT FIGURE 1 NEAR HERE

I also analyze the impact of stricter regulatory capital requirements, $\lambda$, on the results in Proposition 1. If a bank follows the screening strategy, it only grants a loan and, hence, incurs a regulatory cost in case the loan is of high type. With the non-screening strategy, the bank bears the regulatory cost of both types as the loan is granted anyway. Therefore, larger regulatory capital costs render the non-screening strategy relatively less attractive compared to the screening-strategy, and the screening condition in Inequality (3) is relaxed. As a result, the probability that a bank screens, $p_S$, increases, which makes it more likely that a low loan type is winnowed. Hence, tighter regulatory capital requirements encourage lending discipline. A stricter lending discipline decreases the probability that a loan is granted, and increases the expected quality of an accepted loan, i.e.,

$$\frac{\partial p_G}{\partial \lambda} = -(1-\mu)^2\delta < 0, \tag{7}$$

and

$$\frac{\partial p_Q}{\partial \lambda} = \frac{\mu(1-\mu)^2\delta}{\big(1-p_S(1-\mu)\big)^2}(p_H - p_L) > 0. \tag{8}$$

## 3.2 Access to CRT market with mandatory central clearing

I now incorporate that a loan-originating bank has access to the CRT market but must centrally clear a loan hedge. Hence, the bank can only use a standardized CDS to hedge a loan.

### 3.2.1 Unrestricted central clearing

I first analyze a centrally cleared CRT market, in which the bank faces no trading restrictions and there are no public disclosure requirements regarding the bank's trading activity. The superscript "M,U" indicates that while central clearing is mandatory for a bank that hedges a loan, this CRT market is otherwise unrestricted.

The expected profit from granting a loan and transferring the corresponding default risk without screening is

$$\Pi_{NS}^{M,U} = i - (1 - p_I^{M,U}) - \delta(m + \xi_C). \tag{9}$$

The first term on the right hand side of Equation (9) is the interest rate that the bank earns from granting a loan.

The second term is the bank's total (expected) cost of a loan's default risk that it hedges on the CRT market. This cost comprises two components, namely the credit spread plus the expected loss from the counterparty risk of the investor.

The credit spread that a bank needs to pay to the investor to hedge a loan reflects investors' equilibrium beliefs about loan quality. Specifically, let $I^{M,U}$ be the probability expected by investors in the equilibrium that a granted loan is of high type. In a competitive CRT market, a bank then pays the credit spread $(1 - p_I^{M,U})(1 - \Psi_C)$ to hedge a loan, in which $p_I^{M,U} = I^{M,U}p_H + (1 - I^{M,U})p_L$ is the repayment probability of a granted loan expected by investors and $\Psi_C$ is the probability that the investor cannot satisfy his obligation on the centrally cleared CRT market if loan default occurs. Thus, the counterparty risk of the investor reduces the credit spread as shown by (Arora et al. 2012).

A bank's expected loss from the counterparty risk of the investor is $(1 - p_I^{M,U})\Psi_C$.[8] Hence, the bank's total cost of a loan's default risk that it hedges is $(1 - p_I^{M,U})(1 - \Psi_C) + (1 - p_I^{M,U})\Psi_C = (1 - p_I^{M,U})$. It simply corresponds to the default loss of the underlying loan expected by investors.

The term $\delta m$ in Equation (9) is the regulatory cost of a granted loan that is hedged via central clearing, and $\delta\xi_C$ reflects the transaction cost.

Next, I analyze the screening strategy. Suppose a bank has detected a low loan type. As the bank cannot signal loan quality with the standardized contracts that are centrally clearable and because trading is anonymous, the only information to an investor about loan quality from the bank's behavior is whether a loan is granted or not. Thus, the loan's default loss expected by the investor corresponds to $(1 - p_I^{M,U})$=$(1 - p_Q^{M,U})$, in which $p_Q^{M,U}$ is the (ex-ante) repayment probability of a granted loan. If $i - (1 - p_Q^{M,U}) - \delta(m + \xi_C) > 0$, the bank grants the loan. Next, assume the bank has detected a high loan type. It can accept this loan and transfer the corresponding default risk, which yields an expected profit of $i - (1 - p_Q^{M,U}) - \delta(m + \xi_C)$. The default loss expected by investors $(1 - p_Q^{M,U})$ can be larger than the true expected loss of $(1 - p_H)$ because the bank has no mean to signal the high quality of the loan to the investor. The bank may alternatively grant the high loan and keep the associated credit risk in its own books, which yields an expected profit of $i - (1 - p_H) - \delta\lambda > 0$. If the difference between the expected and true default loss is higher than the regulatory capital cost saved by transferring the credit risk minus the transaction cost, i.e., if $D = p_H - p_Q^{M,U} - \delta(\lambda - m - \xi_C) \geq 0$, the bank keeps the credit risk of a high loan in its own books. Thus, the expected profit from the screening strategy, $\Pi_S^{M,U}$, for a loan is

$$\begin{array}{ll} \mu(i - (1 - p_H) - \delta\lambda) + (1 - \mu)(i - (1 - p_Q^{M,U}) - \delta(m + \xi_C)) - C & if \quad D \geq 0, \\ i - (1 - p_Q^{M,U}) - \delta(m + \xi_C) - C & if \quad D < 0. \end{array} \tag{10}$$

The first term in the first line of Expression (10) is the expected profit from granting and maintaining the credit risk of an accepted high loan on the balance sheet times the probability of detecting a high loan. The second term corresponds to the expected profit from granting and transferring the credit risk of a low loan times the probability of finding a low loan type. Therefore, the first line is the bank's expected profit from the screening strategy if it is optimal to keep a high loan's default risk in the own books. The second line of Expression (10) corresponds to the expected profit from the screening strategy if it is optimal for the bank to transfer the default risk of both loan types.

To derive the condition under which screening is optimal, I compare $\Pi_S^{M,U}$ to $\Pi_{NS}^{M,U}$. The bank does not screen a loan if $D < 0$ because $C > 0$. Comparing the first line of Expression (10) to $\Pi_{NS}^{M,U}$ in Equation (9) yields the screening condition:

$$C \leq \mu(p_H - p_Q^{M,U} - \delta(\lambda - m - \xi_C)). \tag{11}$$

[8] I assume that the bank faces the market price of counterparty risk on the centrally cleared CRT market due to, for example, mandatory contributions to a bailout fund that cover this risk.

The right hand side of Inequality (11) is the expected profit from screening. It corresponds to the probability of detecting a high loan, times the bank's expected gain from bearing a granted high loan's credit risk in its own books instead of transferring it on the centrally cleared market. This gain is the difference between the loan's default loss $(1-p_Q^{M,U})$ expected by investors on the CRT market and the true expected default loss $(1-p_H)$, minus the difference in capital and transaction costs $\delta(\lambda-m-\xi_C)$ between keeping a loan's risk on the own balance sheet and transferring it. From Inequality (11), the probability that a bank screens is then $p_S^{M,U} = \frac{\mu(p_H - p_Q^{M,U} - \delta(\lambda-m-\xi_C))}{1}$.

INSERT FIGURE 2 NEAR HERE

Figure 2 depicts the lending and hedging decisions of the bank. The bank's motivation to screen a loan is to avoid the high default cost expected by investors for a detected high loan on the CRT market, and not to reject a low loan as in Figure 1 in Section 3.1. The unique equilibrium with unrestricted central clearing is the pooling equilibrium in which the bank grants any loan. The beliefs associated with the equilibrium are that a loan is always granted, inducing a loan default loss of $(1-p_Q^{M,U}) = (1-p_\mu)$ expected by investors on the CRT market. Given these beliefs, the bank makes a profit from granting and hedging a low loan type. The probability that a loan is accepted increases from $p_G$ to $p_G^{M,U} = 1$, and the expected quality of a granted loan decreases from $p_Q$ to $p_Q^{M,U} = p_\mu$ compared to the case without CRT in Proposition 1.[9] Hence, bank access to a CRT market with mandatory central clearing jeopardizes lending discipline.

The capital requirements for retained or hedged credit risk, and the transaction cost on the centrally cleared CRT market determine the bank's expected profit from keeping a detected high loan's risk on the own balance sheet, and, hence, the probability $p_S^{M,U}$ that it screens a loan. They do, however, not affect the lending discipline because the bank always grants both loan types.

### 3.2.2 Public disclosure of centrally cleared position

A regulatory response to the lending discipline problem is to disclose information about a loan-originating bank's trading position on the centrally cleared CRT market.[10] I denote by $p_Q^{M,P}$ the (ex-ante) repayment probability of a granted loan, and by $p_I^{M,P}$ the loan repayment probability expected by the investor on the centrally cleared CRT market given he knows whether a loan is hedged by the originating bank. Note that in this market structure, $Q^{M,P}$ does not correspond to $I^{M,P}$ because the investor has information about the bank's hedging strategy.

A bank with a detected low loan faces worse beliefs on the CRT market with disclosure than without disclosure because the investor knows when a bank is hedging. Specifically, for $p_\mu - p_I^{M,P} \geq \delta(\lambda-m-\xi_C)$, a bank does not use the centrally cleared market without screening because the regulatory capital cost advantage net of transaction cost from hedging the loan exposure $\delta(\lambda-m-\xi_C)$, is smaller than the disadvantage of incurring a total cost of the loan's default risk of $(1-p_I^{M,P})$ by hedging

[9] Thus, CRT investors' beliefs are correct in the pooling equilibrium. As each granted loan type is traded on CRT markets by investors (and not only a loan type that a bank hedges), the expected loan default loss is $(1-p_\mu)$.

[10] A trading position entails both hedging and speculative positions.

compared to $(1 - p_\mu)$ by bearing the risk. Hence, the investor knows that a loan risk transferred by a bank would be of low type. His equilibrium beliefs then induce the bank with a low type to reject the loan, which implies lending discipline.

For $p_\mu - p_I^{M,P} < \delta(\lambda - m - \xi_C)$, however, a bank that does not screen prefers to hedge the loan instead of bearing the default risk in its own books. In this case, the investor does not know whether a transferred loan risk corresponds to a low or an unscreened type. His equilibrium beliefs reduce the cost at which the bank with a low type can hedge the loan and, hence, deteriorate lending discipline.

**Proposition 2.** *With disclosure of a bank's trading position, the probability $p_G^{M,P}$ that a loan is granted and the expected quality $p_Q^{M,P}$ of a granted loan are identical to the case without CRT if $p_\mu - p_I^{M,P} \geq \delta(\lambda - m - \xi_C)$, with $I^{M,P} = \frac{(1-p_S)\mu}{1-p_S\mu}$.*

*Proof.* See the Appendix. □

As a bank does not hedge the loan in the equilibrium with lending discipline, which is a concern for systemic risk, I consider a risk retention mechanism in the next section.

### 3.2.3 Restricted central clearing

I now impose that the loan-originating bank must keep at least a fraction $\theta^{M,R}$ of the credit risk it transfers via central clearing, and publicly disclose its trading position. The superscript "M,R" indicates that the bank only has access to such a restricted centrally cleared CRT market. The idea of the retention provision is to discipline the lending behavior by requiring a bank to maintain stakes in the credit exposure it originates. The fraction $\theta^{M,R*}$ that maximizes the expected bank profit and simultaneously maintains a unique perfect Bayesian separating equilibrium satisfying the Intuitive Criterion of Cho and Kreps (1987), in which a bank screens and rejects a detected low type loan, is obtained by solving the following program:

$$\max_{\theta^{M,R}} \quad i - \theta^{M,R}(1 - p_H) - (1 - \theta^{M,R})(1 - p_Q^{M,R}) - (1 - \theta^{M,R})(m + \xi_C)\delta - \theta^{M,R}\delta\lambda \tag{12}$$

s.t.

$$\begin{aligned}
&\mu\left(i - \theta^{M,R}(1 - p_H) - (1 - \theta^{M,R})(1 - p_I^{M,R}) - (1 - \theta^{M,R})(m + \xi_C)\delta - \theta^{M,R}\delta\lambda\right) - C \geq \\
&i - \mu\theta^{M,R}(1 - p_H) - (1 - \mu)\theta^{M,R}(1 - p_L) - (1 - \theta^{M,R})(1 - p_I^{M,R}) - \\
&(1 - \theta^{M,R})(m + \xi_C)\delta - \theta^{M,R}\delta\lambda
\end{aligned} \tag{13}$$

Expression (12) is the expected profit of a bank that grants and hedges a high loan. It maintains a fraction $\theta^{M,R}$ of the underlying credit risk in its own books, and hedges the fraction $1-\theta^{M,R}$. $1-p_I^{M,R}$ is the loan default loss expected by investors on the restricted centrally cleared CRT market. Inequality (13) is the incentive compatibility constraint. The first line reflects the expected profit of a bank that screens the loan at cost C, grants a high loan and retains the fraction $\theta^{M,R}$ of the corresponding credit risk, and rejects a low loan (screening strategy). The second and third lines are the expected profit of a mimicking bank that grants any loan type without screening (mimicking strategy). It also retains the fraction $\theta^{M,R}$ to pretend having detected a high loan.

The Program (12) to (13) is valid for $\theta^{M,R} \leq 1$. For $\theta^{M,R} > 1$ it can be derived analogously, with $\xi_C^S$ denoting the transaction funds required for selling one unit of loan default risk protection on the centrally cleared CRT market. The following proposition shows the smallest fraction $\theta^{M,R*}$ such that the screening strategy still dominates the mimicking strategy.

**Proposition 3.** *The optimal mandatory fraction of credit risk to be retained by the loan-originating bank is given by*

$$\theta^{M,R*} = \begin{cases} \frac{i-(1-p_H)-(m+\xi_C)\delta+C/(1-\mu)}{p_H-p_L+\delta(\lambda-m-\xi_C)} & if \quad \theta^{M,R*} \leq 1, \\ \frac{i-(1-p_H)+\delta(\epsilon+\xi_C^S-\lambda)+C/(1-\mu)}{p_H-p_L+\delta(\epsilon+\xi_C^S)} & if \quad \theta^{M,R*} > 1. \end{cases} \tag{14}$$

*This fraction induces a unique perfect separating Bayesian equilibrium, in which a bank with a detected high loan grants and partially hedges the loan, and rejects a detected low loan. The investors' beliefs are such that if a loan is granted and partially hedged it is of high type with probability one.*

*Proof.* See the Appendix. □

The fraction $\theta^{M,R*}$ is optimal because it maximizes the expected profit of a bank with a detected high loan, while still maintaining the separating equilibrium. Maximizing this expected profit simultaneously maximizes the attractiveness of the screening strategy, and, hence, the screening incentives.

As investors on the CRT market know that a fractionally hedged loan is of high type in the equilibrium, $(1 - p_I^{M,R})$ corresponds to $(1 - p_H)$. Hence, using Expression (12), the expected profit from the screening strategy for a given loan with optimal risk retention is

$$\Pi_S^{M,R} = \begin{cases} \mu(i - (1 - p_H) - (1 - \theta^{M,R*})(m + \xi_C)\delta - \theta^{M,R*}\delta\lambda) - C & if \quad \theta^{M,R*} \leq 1, \\ \mu(i - (1 - p_H) - \lambda\delta - (\epsilon + \xi_C^S)\delta(\theta^{M,R*} - 1)) - C & if \quad \theta^{M,R*} > 1. \end{cases} \tag{15}$$

The alternative non-screening strategy is to grant the loan without screening, and to keep the entire credit risk in the own books.[11] The expected profit, $\Pi_{NS}^{M,R}$, of this strategy simply corresponds to Expression (1) in Section 3.1. Comparing $\Pi_S^{M,R}$ in (15) to $\Pi_{NS}^{M,R}$ yields the condition for screening:

$$\begin{array}{lll} (1 - p_L - i + \delta\lambda)(1 - \mu) + \mu(1 - \theta^{M,R*})\delta(\lambda - m - \xi_C) \geq C & if & \theta^{M,R*} \leq 1 \\ (1 - p_L - i + \delta\lambda)(1 - \mu) - \mu(\epsilon + \xi_C^S)\delta(\theta^{M,R*} - 1) \geq C & if & \theta^{M,R*} > 1 \end{array} \tag{16}$$

From Condition (16), one can directly derive the following proposition.

**Proposition 4.** *With restricted centrally cleared CRT, the probability $p_G^{M,R}$ that a loan is granted and the expected quality $p_Q^{M,R}$ of a granted loan are identical to the case without CRT.*

[11] The strategy in which the bank screens, keeps the entire credit risk of a high loan in its own books, and rejects a low loan type yields an expected profit of $\mu(i - (1 - p_H) - \delta\lambda) - C$. As this expected profit is always smaller than that of the first line of Expression (15) for $\lambda > m + \xi_C$, the strategy cannot be optimal for $\theta^{M,R*} \leq 1$.

*Proof.* See the Appendix. □

The intuition for Proposition 4 is as follows: Retaining risk is more costly for a mimicking bank than for one that has detected a high type loan because the former must retain unscreened credit exposure in its own books. The larger the screening cost, the higher the $\theta^{M,R*}$ necessary to prevent a bank from mimicking. The case without CRT, i.e., with $\theta^{M,R*} = 1$, yields that screening is profitable if $C \leq (1 - p_L - i + \delta\lambda)(1 - \mu)$. Hence, a screening cost above this level requires a retention $\theta^{M,R*} > 1$ to prevent mimicking. Any $\theta^{M,R*} > 1$, however, imposes incremental cost $(\epsilon + \xi_C^S)\delta(\theta^{M,R*} - 1) > 0$ to the bank due to the additional fraction $\theta^{M,R*} - 1$. This cost always renders the screening strategy less attractive than the non-screening strategy. Hence, as in the case without CRT, screening is not the optimal strategy if $C > (1 - p_L - i + \delta\lambda)(1 - \mu)$, which induces $p_S^{M,R} = p_S$, $p_G^{M,R} = p_G$, and $p_Q^{M,R} = p_Q$.

As $\frac{\partial p_S^{M,R}}{\partial \lambda} = \delta(1 - \mu) > 0$, $\frac{\partial p_S^{M,R}}{\partial m} = 0$, and $\frac{\partial p_S^{M,R}}{\xi_C^S} = 0$, the probability that a low loan is detected and rejected increases with the regulatory capital cost of an unhedged granted loan but is independent of $m$ and $\xi_C^S$. The marginal effects of $\lambda$ on the probability $p_G^{M,R}$ that a loan is granted, and on the expected quality $p_Q^{M,R}$ of a granted loan are identical to the case without CRT (see Expressions (7) and (8)).

INSERT FIGURE 3 NEAR HERE

Figure 3 shows that lending discipline is established with restricted central clearing because, as in Figure 1, a bank rejects a low loan type along the path "screen and detect a low loan."

Note that the screening cost of a bank is not a necessary information for the regulator to implement the risk retention mechanism. The retaining fraction can be set equal to $\bar{\theta}^{M,R}$ for all banks, which still induces a bank with a $C$ that would entail a $\theta^{M,R*} \leq \bar{\theta}^{M,R}$ to screen and reject a low type loan.[12] With $\bar{\theta}^{M,R} = 1$, lending discipline is the same as in the case without CRT.

Without public disclosure of the retained risk fraction, the investor does not know whether a granted loan corresponds to a bank that has detected and fractionally hedged a high loan, or to a bank that has granted an unscreened loan without hedging. He only knows whether a loan is granted or not. Hence, the loan's default risk expected by investors is $(1 - p_I^{M,R,ND}) = (1 - p_Q^{M,R,ND})$. The superscript "M,R,ND" indicates that a bank has access to the mandatory restricted centrally cleared CRT market without disclosure. $\theta^{M,R,ND}$ is the fraction to be retained, and $p_I^{M,R,ND} = I^{M,R,ND} p_H + (1 - I^{M,R,ND}) p_L$ the probability expected by the investor that a granted loan is repayed. Similar to Proposition 3, the smallest fraction to be retained that prevents the mimicking strategy is

$$\theta^{M,R,ND*} = \begin{cases} \frac{i - (1 - p_I^{M,R,ND}) - (m + \xi_C)\delta + C/(1-\mu)}{p_I^{M,R,ND} - p_L + \delta(\lambda - m - \xi_C)} & if \quad \theta^{M,R,ND*} \leq 1, \\ \frac{i - (1 - p_I^{M,R,ND}) + \delta(\epsilon + \xi_C^S - \lambda) + C/(1-\mu)}{p_I^{M,R,ND} - p_L + \delta(\epsilon + \xi_C^S)} & if \quad \theta^{M,R,ND*} > 1. \end{cases} \tag{17}$$

[12] $\bar{\theta}^{M,R}$ would, however, reduce the expected profit of such a bank compared to $\theta^{M,R*}$.

Because $p_H \geq p_I^{M,R,ND}$, the fraction $\theta^{M,R,ND*}$ is smaller or equal to $\theta^{M,R*}$. Intuitively, mimicking is less attractive for a bank that does not screen than with disclosure as the expected default cost $(1 - p_I^{M,R,ND})$ is larger or equal to $(1 - p_H)$ for the fraction hedged on the centrally cleared market if it would pretend having detected a high loan. Hence, the regulator can decrease the risk fraction that an originating bank has to maintain on the centrally cleared market.

By comparing the expected profit from the screening strategy with $\theta^{M,R,ND*}$ to $\Pi_{NS}^{M,R,ND} = i - (1 - p_\mu) - \delta\lambda$, I obtain the following proposition.

**Proposition 5.** *Without disclosure of the trading position of a loan-originating bank, the probability $p_G^{M,R,ND}$ that a loan is granted and the expected quality $p_Q^{M,R,ND}$ of a granted loan are identical to the case with disclosure if $(p_H - p_L) < \delta(\epsilon + \xi_C^S)$.*

*Proof.* See the Appendix. □

Proposition 5 shows that public information about the hedging position of a loan-originating bank is not necessary to induce the same lending discipline as in the case without CRT. The intuition is that while the expected loan default cost of a bank with a detected high loan on the centrally cleared market increases from $(1 - p_H)$ to $(1 - p_Q^{M,R,ND})$ without disclosure, this increase is not relevant to the bank with $\theta^{M,R,ND*} = 1$ (full risk retention) that determines the probability that a loan is screened.

### 3.3 Access to CRT market without central clearing

The superscript "O" indicates that a loan-originating bank only has access to the uncleared OTC market to hedge a loan. The bank's expected profit from the optimal screening strategy for a given loan applicant is

$$\Pi_S^O = \mu(i - (1 - p_H) - \delta(\gamma + \xi_O)) + (1 - \mu)0 - C. \tag{18}$$

With probability $\mu$ it detects and hedges a high loan. The bank then earns interest i from granting this loan. It can signal the loan's high type on the uncleared OTC market by using a tailored credit derivative at cost $\Omega(P_H \mid p_H) = 0$. Tailoring on the OTC market to signal loan quality is well established in the literature (see, e.g., Duffee and Zhou 2001; Nicolò and Pelizzon 2008). Hence, the bank pays a credit spread of $(1 - p_H)(1 - \Psi_O)$ to hedge the loan, in which $(1 - \Psi_O)$ is the probability that the obligation of the investor is satisfied on the uncleared CRT market if loan default occurs. The bank's expected loss from counterparty risk is $(1 - p_H)\Psi_O$. Therefore, the total cost of a high loan's default risk that a bank hedges is $(1 - p_H)(1 - \Psi_O) + (1 - p_H)\Psi_O = (1 - p_H)$. It simply corresponds to the expected default loss of a high loan. Finally, the bank incurs regulatory capital and transaction costs. With probability $(1 - \mu)$ a low loan type is detected. This loan is rejected because tailoring the credit derivative to pretend hedging a higher type loan is too costly, i.e., $i - (1 - p_H) - \delta(\gamma + \xi_O) - \Omega(P_H \mid p_L) < 0$ and $i - (1 - p_\mu) - \delta(\gamma + \xi_O) - \Omega(P_\mu \mid p_L) < 0$.

The optimal non-screening strategy of granting the loan without screening and hedging it uncleared OTC with a tailored contract yields an expected profit of $\Pi_{NS}^O = i - (1 - p_\mu) - \delta(\gamma + \xi_O) > 0$.

Comparing $\Pi_S^O$ of Equation (18) to $\Pi_{NS}^O$ gives the screening condition

$$(1 - p_L - i + \delta(\gamma + \xi_O))(1 - \mu) \geq C. \tag{19}$$

Hence, the screening probability is $p_S^O = \frac{(1-p_L-i+\delta(\gamma+\xi_O))(1-\mu)}{1}$, which leads to Proposition 6.

**Proposition 6.** *If a bank only has access to an uncleared OTC market, the probability $p_G^O$ that a loan is granted is larger and the expected quality $p_Q^O$ of a granted loan is lower than in the case without CRT.*

*Proof.* See the Appendix. □

Lending discipline with access to the uncleared OTC market maintains because the tailoring cost is too large for a bank with a detected low type to profitably grant, tailor, and hedge the loan. Not tailoring the credit derivative induces a total cost from a high loan's default risk of $(1 - p_L)$ on the uncleared OTC market as the investor anticipates that the underlying loan is of low type with probability one. Therefore, a bank with a detected low type rejects the loan. The incentive to screen a loan arises because a bank anticipates that it can tailor a credit derivative on a detected high loan to signal its type on the uncleared OTC market. With $\gamma + \xi_O < \lambda$, however, lending discipline is weaker than in the case without CRT in Section 3.1 because a reduction in the cost of a granted loan increases the attractiveness of the non-screening strategy relative to the screening strategy.

### 3.4 Access to CRT market with voluntary central clearing

I now analyze the case in which a bank can choose between hedging on a centrally cleared or uncleared OTC market.

#### 3.4.1 Unrestricted central clearing

In case of unrestricted central clearing without disclosure of the bank's trading position, the bank cannot signal loan quality with the standardized contracts on the centrally cleared market. Hence, the investor on this market assigns the same default probability to each hedged loan. The equilibrium associated with this setting is as follows: A bank with a detected low type anticipates that it can hedge the loan (untailored) on the centrally cleared market. Investors realize that any loan type is granted. Therefore, they expect a default probability of $(1 - p_\mu)$ for a loan on the centrally cleared market. This expectation makes it worthwhile for the bank to grant and centrally hedge a low loan. A bank with a detected high type grants the loan, and decides between hedging on the uncleared or the cleared market. A bank that does not screen grants the loan and hedges via central clearing.

The expected profit, $\Pi_S^{V,U}$, of the optimal screening strategy in this equilibrium is

$$\begin{array}{ll} \mu(i - (1 - p_H) - \delta(\gamma + \xi_O)) + (1 - \mu)(i - (1 - p_\mu) - \delta(m + \xi_C)) - C & if \quad D \geq 0 \\ i - (1 - p_\mu) - \delta(m + \xi_C) - C & if \quad D < 0, \end{array} \tag{20}$$

with $D = p_H - p_\mu - \delta(\gamma + \xi_O - m - \xi_C)$. The superscript "V,U" indicates that the bank can select between an unrestricted centrally cleared and an uncleared OTC hedge (voluntary central clearing). In the first line of Expression (20), a bank with a detected high loan type prefers to hedge on the uncleared OTC market on which investors expect a default loss $(1-p_H)$ for the loan underlying the tailored credit derivative contract. A bank with a low type hedges the granted loan on the centrally cleared market. Investors expect a default loss of $(1 - p_\mu)$ on this market. In the second line of Expression (20), it is optimal for the bank to hedge both loan types via central clearing. The expected profit from the optimal non-screening strategy in the equilibrium corresponds to $\Pi_{NS}^{V,U} = i-(1-p_\mu)-\delta(m+\xi_C)$. Comparing $\Pi_S^{V,U}$ to $\Pi_{NS}^{V,U}$ shows that the bank screens if[13]

$$C \leq \mu(p_H - p_\mu - \delta(\gamma + \xi_O - m - \xi_C)). \tag{21}$$

According to Inequality (21), a bank may decide to screen a loan because it can signal high loan quality to the investor of a tailored credit derivative on the uncleared OTC market if it detects a high type. Hence, the incentive to screen is to obtain a hedge at a lower cost. As any loan type is granted in the equilibrium, however, there is no lending discipline, which induces $p_G^{V,U} = 1$, and $p_Q^{V,U} = p_\mu$. The possibility to trade untailored credit derivatives via central clearing without revealing loan type reduces lending discipline compared to the case with only uncleared OTC hedging.

### 3.4.2 Public disclosure of centrally cleared position

I denote by $p_I^{V,P}$ the loan repayment probability expected by the investor on the centrally cleared CRT market in the setting in which central clearing is voluntary and information about the bank's trading position on the centrally cleared CRT market is publicly disclosed. The only difference to Section 3.2.2 is that the bank uses the uncleared OTC market for unhedged loan exposures.

**Proposition 7.** *With disclosure of a bank's centrally cleared trading position, the probability $p_G^{V,P}$ that a loan is granted and the expected quality $p_Q^{V,P}$ of a granted loan are identical to the case in which the bank only has access to the uncleared OTC CRT market if $p_\mu - p_I^{V,P} \geq \delta(\gamma + \xi_O - m - \xi_C)$, with $I^{V,P} = \frac{(1-p_S^Q)\mu}{1-p_S^Q\mu}$.*

### 3.4.3 Restricted central clearing

Finally, the superscript "V,R" indicates that a bank has access to both a restricted centrally cleared CRT market, on which it must retain at least the fraction $\theta^{V,R}$ of the originated loan default risk it transfers and disclose its centrally cleared trading activity, and an uncleared OTC market. The unique perfect Bayesian separating equilibrium satisfying the Intuitive Criterion of Cho and Kreps (1987) associated with this setting can be described as follows: A bank with a detected low type rejects the loan because granting, tailoring, and hedging the loan on the uncleared OTC market yields a profit below zero due to the large tailoring cost. Additionally, the fraction $\theta^{V,R*}$ is chosen such that it is not profitable for

[13] In what follows, I explain the solution for $D \geq 0$. Otherwise, screening is never optimal as shown by a comparison of the second line of Equation (20) to $\Pi_{NS}^{V,U}$.

the bank to grant and hedge an unscreened or low loan on the centrally cleared market. Compared to the case without uncleared OTC market access in Section 3.2.3, an additional condition must be satisfied such that the bank does not grant a low loan: The profit from the strategy of granting a low loan, hedging it on the centrally cleared market by retaining the required fraction $\theta^{V,R*}$, and silently hedging this fraction on the uncleared OTC market by tailoring the credit derivative must be smaller than zero.[14] A bank with a detected high type fractionally hedges the loan on the centrally cleared market, and transfers the remaining default risk fraction $\theta^{V,R*}$ on the uncleared OTC market. The expected profit from the optimal screening strategy is

$$\Pi_S^{V,R} = \begin{cases} \mu(i-(1-p_H)-(1-\theta^{V,R*})\delta(m+\xi_C)-\theta^{V,R*}\delta(\gamma+\xi_O))-C & if \quad \theta^{V,R*}\leq 1, \\ \mu(i-(1-p_H)-\delta(\gamma+\xi_O)-(\epsilon+\xi_C^S)\delta(\theta^{V,R*}-1))-C & if \quad \theta^{V,R*}>1. \end{cases} \tag{22}$$

The optimal non-screening strategy of granting a loan without screening and hedging this exposure on the uncleared OTC market with a tailored contract yields a profit of $\Pi_{NS}^{V,R} = i-(1-p_\mu)-\delta(\gamma+\xi_O)$. Comparing $\Pi_S^{V,R}$ to $\Pi_{NS}^{V,R}$ gives the screening condition

$$\begin{cases} (1-p_L-i+\delta(\gamma+\xi_O))(1-\mu)+\mu(1-\theta^{V,R*})\delta(\gamma+\xi_O-m-\xi_C)\geq C & if \quad \theta^{V,R*}\leq 1, \\ (1-p_L-i+\delta\lambda)(1-\mu)-\mu(\epsilon+\xi_O^S)\delta(\theta^{V,R*}-1)\geq C & if \quad \theta^{V,R*}>1. \end{cases} \tag{23}$$

Figure 4 summarizes the bank's lending and hedging decisions.

INSERT FIGURE 4 NEAR HERE

**Proposition 8.** *If a bank has simultaneously access to an uncleared OTC market and a restricted centrally cleared CRT market, the probability $p_G^{V,R}$ that a loan is granted and the expected quality $p_Q^{V,R}$ of a granted loan are identical to the case in which a bank only has access to the uncleared OTC market.*

*Proof.* See the Appendix. □

The intuition for Proposition 8 is that because an originating bank can silently hedge on the uncleared OTC market any fraction that it must retain of a hedge on the centrally cleared market, the incentives to detect and reject a low loan are, ultimately, determined by the incentives for lending discipline on the uncleared market. If, for example, opacity in the uncleared OTC market reduces the tailoring cost $\Omega(P_i \mid p_j)$ for $i > j$, or induces a large tailoring cost for $i = j$ (see, e.g., Nicolò and Pelizzon 2008), the outcome is a pooling equilibrium without lending discipline even if centrally cleared CRT is restricted.

# 4 Discussion of results

In this section, I discuss the implications of my analysis.

[14] The fraction $\theta^{V,R*}$ also needs to imply that it is ex-ante profitable for the bank to screen a loan.

## 4.1 Lending discipline

My results speak to the ongoing discussion among academics, practitioners, and regulators on mitigating the negative impact of CRT on excessive lending and loan quality (see, e.g., Berndt and Gupta 2009; Purnanandam 2011). Sections 3.2.1 and 3.4.1 show that mandatory or voluntary central clearing without appropriate restrictions reduces lending discipline compared to a market setting without CRT or with uncleared CRT. This is because the opportunity to hedge with centrally clearable contracts that cannot be tailored allows a loan-originating bank to profitably grant and hedge each loan type. Therefore, the drawback of the current regulatory efforts to implement central clearing is that they negatively affect banks' lending behavior. A testable prediction from this conclusion for the primary loan market is that loan volume should increase and loan quality decrease with central clearing. The model also yields empirical implications for the riskiness of loans that banks hedge on the OTC market. Specifically, unrestricted central clearing without disclosure should reduce the riskiness of loans that banks transfer OTC. The reason is that while a bank hedges an unscreened loan through the OTC channel if it has no access to central clearing, it hedges this loan with a central counterparty if it has access to unrestricted central clearing without disclosure. Hence, only a detected high-quality loan's risk remains transferred on the uncleared OTC market.

I also address regulators' current plan to increase capital requirements for financial institutions under Basel III to strengthen the stability of the financial system. Sections 3.2.1 and 3.4.1 show that with unrestricted centrally cleared CRT without disclosure, tighter regulatory capital requirements ($\lambda$, $\gamma$, or $m$) influence a bank's incentive to screen a loan. However, they do not change the fact that a bank always grants any loan type. Hence, stricter regulatory capital requirements alone cannot improve lending discipline in the primary loan market as long as a bank has access to unrestricted central clearing without disclosure. According to Proposition 2 in Section 3.2.2, a larger $\lambda$ can even undermine lending discipline with public disclosure because $\frac{\partial(p_\mu - p_I^{M,P} - \delta(\lambda - m - \xi_C))}{\partial \lambda} < 0$. With risk retention, however, the model implies that $\frac{\partial p_S^{M,R}}{\partial \lambda} > 0$ in Section 3.2.3, and $\frac{\partial p_S^{V,R}}{\partial \gamma} > 0$ in Section 3.4.3. As a detected bad loan is rejected in these market settings, the stricter capital requirements for unhedged and uncleared OTC hedged loan exposures under Basel III do increase lending discipline. Therefore, it is necessary to restrict central clearing to discipline banks' lending behavior in addition to increasing capital requirements.

Market observers currently discuss how to encourage banks to centrally clear their OTC trades. Duffie et al. (2010), for example, suggest reducing regulatory capital requirements for financial institutions' centrally cleared derivative positions, a proposal implemented in the current Basel III framework. There are, however, concerns that more appealing conditions for CRT could jeopardize loan-originating banks' lending discipline (see, e.g., Morrison 2005; Keys et al. 2010; Purnanandam 2011; Wang and Xia 2014). Indeed, Proposition 2 in Section 3.2.2 implies that with disclosure of the bank's trading position $\frac{\partial(p_\mu - p_I^{M,P} - \delta(\lambda - m - \xi_C))}{\partial m} > 0$ and $\frac{\partial(p_\mu - p_I^{M,P} - \delta(\lambda - m - \xi_C))}{\partial \xi_C} > 0$. Hence, both lower regulatory capital and lower transaction costs of centrally cleared hedges can reduce lending discipline. In contrast, Sections 3.2.3 and 3.4.3 show that with a risk retention provision, the probability that a bank screens a loan is independent of the regulatory capital and transaction costs of the centrally hedged loan fraction. The intuition for this implication is that at the largest $C$ that still induces the bank to screen a loan, the risk retention fraction is equal to one (full risk retention). Therefore, the expected bank profit from the screening strategy without hedging and, hence, without costs $(m + \xi_C)\delta$, determines the probability that a loan is screened. This result suggests that the regulator can implement more appealing regulatory capital and transaction conditions for centrally cleared hedges without jeopardizing lending discipline if central clearing is accompanied by a risk retention rule. At the same time, Proposition 8 in Section 3.4.3 implies that with voluntary restricted central clearing, lending discipline improves with the capital and transaction costs of uncleared OTC hedges.

Risk retention is a practicable mechanism established, for example, in the syndicated loan market (see, e.g., Sufi 2007), and considered in the Dodd-Frank Act for Asset Backed Securities. Central clearing should facilitate the implementation of risk retention for credit derivative trading. According to Stulz (2010), regulators may identify the counterparties to trades through concentrated data provided by the clearing house to prevent banks from hedging exposures beyond the required retention-fraction. Moreover, regulators can implement the risk retention mechanism with standard CDSs by simply restricting the notional value of a loan that the originating bank is allowed to centrally hedge. The mechanism does not rely on customized signaling contracts that may not be liquid enough for central clearing. Risk retention on the centrally cleared market alone, however, does not mitigate the opacity problem on the uncleared OTC market. If the latter is too opaque to induce lending discipline, the regulator must impose mandatory central clearing with risk retention for loan-originating banks to improve lending discipline (see Proposition 4 in Section 3.2.3). Such mandatory central clearing induces the same lending discipline as in the case without CRT.

A critical aspect of central clearing is the disclosure of the loan-originating banks' trading position. Section 3.2.3 suggests that the risk retention mechanism also entails lending discipline without public disclosure of these positions. The fact that a bank prefers to maintain stakes in a high-quality loan than in a loan with unknown quality drives lending discipline, not the public signal. Without public disclosure, however, the regulator must impose large capital or transaction requirements for speculative positions (see Proposition 5 in Section 3.2.3), or restrict the loan-originating bank's insider trading entirely to induce lending discipline. Hence, disclosing a bank's position in the underlying asset it originates is a valid alternative to this regulatory burden.

My analysis implies that it is essential to regulate the Basel III capital requirements and the framework for centrally cleared CRT with a comprehensive approach that incorporates their interrelationship. Stricter capital requirements, for example, can increase or decrease lending discipline, depending on the market setting for central clearing. Similarly, the optimal retention provision with mandatory central clearing in Section 3.2.3 depends on the regulatory capital requirements for unhedged and centrally hedged loan exposures. In particular, $\frac{\partial \theta^{M,R*}}{\partial \lambda} < 0$, and $\frac{\partial \theta^{M,R*}}{\partial m} \leq 0$. The optimal fraction $\theta^{M,R*}$ decreases with $\lambda$ and $m$ because capital costs accrue for both loan types for a mimicking bank that grants any loan. In contrast, a bank that screens faces these costs only if it detects and grants a high-quality loan. Hence, stricter regulatory capital requirements reduce the attractiveness of the mimicking strategy compared to the screening strategy, which allows the regulator to reduce $\theta^{M,R*}$ while still inducing banks to screen and reject a detected low-quality loan. With voluntary central clearing (Section 3.4.3), the optimal retention provision depends on the regulatory capital requirements for loan exposures hedged on the centrally cleared and uncleared OTC markets. Specifically, $\frac{\partial \theta^{V,R*}}{\partial \gamma} < 0$, and $\frac{\partial \theta^{V,R*}}{\partial m} \leq 0$. Finally, Section 3.2.3 implies that the regulator should incorporate the disclosure requirements in the market for centrally cleared CRT when determining capital requirements, $\epsilon$, for speculative positions.

Relaxing the assumption that both loan types pay the same $i$ into $1 - p_\mu + \delta\lambda < i_H < i_L < 1 - p_L + \delta(m + \xi_C) < 1 - \delta(\lambda - m - \xi_C)$ implies that $p_S = \frac{(1-p_L-i_L+\delta\lambda)(1-\mu)}{1}$, i.e., attenuates the lending discipline without CRT[15] because detecting and rejecting a low-quality loan is less attractive for the bank if this type pays a higher interest rate. The model's qualitative predictions, however, are not affected. There is no lending discipline with unrestricted central clearing without disclosure. To encourage lending discipline, the credit risk fraction the loan-originating bank must retain increases to $\theta^{M,R*} = \frac{i_L-(1-p_H)-(m+\xi_C)\delta+C/(1-\mu)}{p_H-p_L+\delta(\lambda-m-\xi_C)}$ in the case with mandatory central clearing and to $\theta^{V,R*} = \frac{i_L-(1-p_H)-(m+\xi_C)\delta+C/(1-\mu)}{p_H-p_L+\delta(\gamma+\xi_O-m-\xi_C)}$ with voluntary central clearing.

## 4.2 Systemic risk implications

To investigate the implications of central clearing for systemic risk, I analyze the expected loss from loan default (labeled "default exposure") to the representative bank in each market structure. Risk exposure to counterparty default losses is a first-order consideration for systemic risk analysis (Duffie and Zhu 2011). Huang et al. (2011) and Acharya et al. (2011), for example, suggest that the three fundamental elements of a systemic risk measure are exposure size, probability of default, and the correlation of losses with systemic downturns.[16] The default exposure that I calculate captures the first two elements. Intuitively, I show that it is important to incorporate how central clearing affects the amount and quality of loan risk that is originated when discussing systemic risk implications, and not only how the transfer of a *given* amount and quality of originated loan risk affects systemic risk.

The default exposure of a market structure is the weighted sum of the default exposures in each strategy a bank follows in that market structure. The weights correspond to the probabilities that the bank follows a certain strategy. In the regulatory market structure with uncleared OTC CRT without central clearing of Section 3.3, for example, the default exposure of a loan that a bank considers to grant is

$$p_S^O \mu(1 - p_H)\Psi_O + (1 - p_S^O)(1 - p_\mu)\Psi_O. \tag{24}$$

If the bank screens, it grants and hedges a high loan OTC and rejects a low loan. Thus, the bank's default exposure of the screening strategy is $\mu(1-p_H)\Psi_O$ because the exposure size is the loan nominal of one, the probability that the bank detects a high loan is $\mu$, and the probability it suffers a loss from a hedged high loan is $(1 - p_H)\Psi_O$. If the bank does not screen it grants any loan type. Hence, the default exposure of the non-screening strategy is $(1 - p_\mu)\Psi_O$. The probabilities of these strategies are $p_S^O$ and $(1 - p_S^O)$, respectively, which leads to the default exposure in Expression (24). Note that a bank's behavior on both the primary loan market and the CRT market affects its default exposure. The

[15] I assume that the investor cannot observe the loan interest rate.

[16] The additivity principle in Huang et al. (2011), i.e., the property that the systemic risk of a portfolio equals the marginal contributions to systemic risk from each sub-portfolio, suggests that it is meaningful to discuss marginal systemic risk implications of a single loan.

behavior on the loan market influences the expected amount and quality of loan default risk that the bank originates. The behavior on the CRT market determines to what extent originated loan default risk remains with the bank. The bank bears the entire originated default risk of a loan (or loan fraction) that it does not hedge. Hedging a loan (or loan fraction) reduces the originated default risk it faces by the factor $\Psi_C$ or $\Psi_O$, respectively.

In the current market structure regulation described in Section 3.4.1, in which the bank also has access to voluntary central clearing without restrictions, the default exposure is:

$$p_S^{V,U}\mu(1-p_H)\Psi_C + p_S^{V,U}(1-\mu)(1-p_L)\Psi_C + (1-p_S^{V,U})(1-p_\mu)\Psi_C. \tag{25}$$

I use the following baseline parameters in the analysis. To reflect the observation that credit quality within the same rating category can be quite large (Helwege and Turner 1999), I set $p_H$ to $0.974$ and $p_L$ to $0.656$. These numbers are the average cumulative issuer-weighted global ten-year survival rates of investment and speculative grade corporate bonds and loans between 1970 and 2010 (Moody's 2011), respectively. The parameter $\mu$ is set to 0.5 and $\delta$ to 0.06. According to BIS (2011), the total of all components of regulatory capital must exceed $8\%$ of the risk weighted assets. As corporate exposures receive a risk weight of $100\%$, I set $\lambda$ to 0.08. The risk weight to central counterparties is currently $2\%$ (BIS 2012). Therefore, I fix $m$ at $0.0016$. For the risk weight of uncleared OTC hedges, I assume that the counterparty is a bank that has a risk weight of $20\%$ in line with the Basel III Accord, which yields $\gamma = 0.016$. The screening cost per loan is assumed to be uniformly distributed between 0 and 0.2. I choose $\Psi_O = 0.03$. As I derive comparative results on the relative extent of counterparty risk in an uncleared CRT market compared to that in a centrally cleared market, the absolute size of $\Psi^O$ is not important in the analysis. Transaction costs are set to twelve basis points in line with Biswas et al. (2015).[17]

The solid line in Figure 5 depicts the default exposure for Expression (24) and the dashed line that for Expression (25) for a range of $\Psi_C$.

INSERT FIGURE 5 NEAR HERE

Figure 5 shows the trade-off affecting the impact of central clearing on the default exposure. On the one hand, central clearing reduces the risk that a bank faces a loan loss from a given hedged loan exposure if the counterparty risk of the cental counterparty is smaller than that of the OTC counterparty. On the other hand, central clearing undermines lending discipline, which increases the probability that a loan is granted and reduces the expected quality of a granted loan. This lending discipline channel increases the expected originated loan nominal and reduces the expected quality of a granted loan, which raises the default exposure. One can observe the pure impact of reduced lending discipline by comparing the solid and dashed lines for $\Psi_C = \Psi_O = 0.03$. The default exposure from a loan considered in a market providing access to both uncleared and voluntary centrally cleared hedging is much larger ($+56.4\%$) than in a market in which a bank only has access to uncleared OTC hedging.

[17] The interest rate, $i$, is equal to $(1 - p_\mu + \delta\lambda + 1 - p_L + \delta(m + \xi_C))/2$ to satisfy the condition at the end of Section 2.

Figure 5 also shows that to overcome the impact of reduced lending discipline on the default exposure, $\Psi_C$ must be more than $37.3\%$ below $\Psi_O$. Hence, only for very low levels of counterparty risk of the central counterparty ($\Psi_C < 0.0189$) compared to that of an uncleared OTC counterparty ($\Psi_O = 0.03$) does central clearing in the current regulatory design reduce default exposure.

To determine the market regulation that minimizes the default exposure, I also calculate the default exposure from a considered loan in the market structure in Section 3.4.3 with bank access to both restricted central clearing and uncleared OTC hedging:[18]

$$\mu(1-p_H)\int_0^{0.2p_S^{V,R}} (1-\theta^{V,R*})\Psi_C + \theta^{V,R*}\Psi_O \, \mathrm{d}C + (1-p_S^{V,R})(1-p_\mu)\Psi_O \qquad (26)$$

Figure 6 shows the market structure that minimizes default exposure for each counterparty risk $\Psi_C$ of the central counterparty. $\Psi_O$ is again set to 0.03. If $\Psi_C < 0.0187$, the market structure with voluntary unrestricted central clearing entails the lowest default exposure because a low type or unscreened loan is hedged with a central counterparty that has a small counterparty risk. Restricting central clearing reduces default exposure because it enhances lending discipline. The bank, however, hedges an unscreened loan OTC instead of via central clearing if central clearing is restricted, which increases the default exposure for $\Psi_C < \Psi_O$. With $0.0187 \leq \Psi_C < 0.03$, the exposure reduction of restricting central clearing dominates, such that voluntary restricted central clearing minimizes the default exposure. Finally, for $\Psi_C \geq 0.03 = \Psi_O$, the lowest default exposure results in a market structure where the bank can only hedge a loan OTC. Banning restricted central clearing does not affect lending discipline in this case (see Proposition 8 in Section 3.4.3). The fraction, however, of a high-quality loan that is centrally hedged with access to restricted central clearing is OTC hedged without this access. Hence, the default exposure with only uncleared OTC CRT access is larger than that with additional access to restricted central clearing if $\Psi_C < \Psi_O$, and lower if $\Psi_C \geq \Psi_O$. Note that the market structures with public disclosure alone in Sections 3.2.2 and 3.4.2 do not minimize default exposure because the loan exposure remains unhedged and only OTC hedged, respectively. Additionally, mandatory central clearing yields higher default exposure than voluntary central clearing. The reason is that a bank responds to a ban on uncleared OTC CRT by bearing default exposure in its own books instead of hedging it because the cost to hedge on the centrally cleared market is too large for certain loan types under equilibrium investor beliefs. This response increases the default exposure.

INSERT FIGURE 6 NEAR HERE

The importance of lending discipline depends on several parameters. With a larger difference between $p_H$ and $p_L$ or a lower screening cost, lending discipline is particularly crucial for default exposure. Hence, a market structure with voluntary restricted central clearing that improves lending discipline reduces default exposure for a much wider range of $\Psi_C$ compared to the current structure

[18] The default exposure in the market structures in Sections 3.1 and 3.2.2 are obtained by replacing $p_s^O$ with $p_S$ and $\Psi_O$ with one in Expression (24), in the structure in Section 3.2.1 by replacing $p_s^{V,U}$ with $p_S^{M,U}$ and $\Psi_O$ with one in Expression (25), in the structure in Section 3.2.3 by replacing $p_S^{V,R}$ with $p_S^{M,R}$, $\theta^{V,R}$ with $\theta^{M,R*}$, and $\Psi_O$ with one in Expression (26). The default exposure in the structure in Section 3.4.2 equals Expression (24).

with voluntary unrestricted central clearing. For instance, if $p_H = 0.799$ and $p_L = 0.2762$, i.e., the default probabilities correspond to average Baa and Caa-C ratings, respectively, the market structure with voluntary restricted central clearing minimizes default exposure for $0.0124 \leq \Psi_C < 0.03$. It reduces default exposure by up to $4.1\%$ compared to a market structure with the second lowest default exposure. With an additional decline in the screening cost to $C \in (0, 0.15)$, a market structure with voluntary restricted central clearing minimizes default exposure for $0.0045 \leq \Psi_C < 0.03$, mitigating default exposure by up to $11.6\%$ compared to the market with the second lowest default exposure. In this parameter setting, the reduction in lending discipline with central clearing can have dramatic consequences. Specifically, if $\Psi_C = \Psi_O$, the introduction of unrestricted central clearing into uncleared OTC trading increases default exposure by $164\%$.

Market observers currently discuss counterparty risk implications of centrally cleared and uncleared markets. One concern is that dealers in the uncleared OTC market are inconsistent in their approach to managing and monitoring the counterparty risk of OTC positions (Duffie et al. 2010). Central counterparties promise to reduce counterparty risk through bail-out funds, position transparency, robust collateral margin requirements, clear default management procedures, and liquid standardized product trading (see, e.g., Zawadowski 2013; Acharya and Bisin 2014). Duffie and Zhu (2011), however, argue that a reduction in netting efficiency with central counterparties can even increase counterparty risk. Additionally, Arora et al. (2012) illustrate that the current counterparty risk mitigation techniques on the uncleared OTC market, such as the standard practice among dealers of having their counterparties fully collateralize swap liabilities or using the ISDA master agreements structure that facilitates netting in the event of a counterparty default, are largely successful in addressing counterparty risk concerns. In particular, investors price counterparty risk in uncleared OTC CDS contracts as if it were only a minor concern. Similarly, Du et al. (2015) find that credit risk transfer market participants are successful in managing uncleared OTC counterparty risk via the choice of counterparties. Loon and Zhong (2014) find that central clearing reduces the reaction of CDS spreads to an increase in the dealer's credit risk by around $33\%$ compared to the reaction of spreads in uncleared trades. My analysis shows that it is crucial to incorporate banks' lending behavior besides counterparty risk when evaluating systemic risk implications of central clearing. In the baseline setting of Figure 5, for instance, the bank's default exposure with central clearing would be higher than that without central clearing due to the decline in lending discipline even if installing central counterparties reduces counterparty risk by the $33\%$ estimated in Loon and Zhong (2014) (see $\Psi_C = 0.0201$). Therefore, central clearing should be appropriately regulated to mitigate the lending discipline problem, and not only to mitigate counterparty risk.

My results also contribute to the discussion on how to develop adequate recovery and resolution procedures for central counterparties to mitigate systemic risk from banks' CRT activities. Duffie and Zhu (2011), for example, argue that stricter margin requirements can mitigate systemic risk by lowering the likelihood that defaults propagate from counterparty to counterparty. Zawadowski (2013) suggests that banks should contribute to a guarantee fund that bails out counterparties of failing central clearing members. One concern with these procedures is that they increase the central clearing cost to banks, who could respond by transferring more credit risk on uncleared OTC markets if central clearing is voluntary. Raising the transaction cost $\xi_C$ of central clearing relative to $\xi_O$ of uncleared

OTC hedging in the market structures in Sections 3.4.1 and 3.4.3 solely shifts high-quality loan hedges from centrally cleared to uncleared OTC markets, which is of minor importance for default exposure even if $\Psi_C < \Psi_O$. Additionally, a higher central clearing transaction cost does not affect lending discipline. In Section 3.4.2, a larger $\xi_C$ relative to $\xi_O$ can even encourage lending discipline and, hence, reduce default exposure if $p_\mu - p_I^{V,P}$ becomes larger than $\delta(\gamma + \xi_O - m - \xi_C)$. These results imply that the recovery and resolution procedures should be designed without overemphasizing their cost to the hedging banks to adequately address the systemic risk concerns associated with CRT.

Although expected default exposure is an important element of systemic risk measures, my analysis misses some crucial elements of systemic risk. Most importantly, I cannot consider the joint determination of defaults in a network of investors and banks. Incorporating a central counterparty may increase or decrease the potential for joint defaults depending on the recovery and resolution procedures. Similarly, adding a central counterparty could enhance the correlation of losses with systemic downturns because a central counterparty should only struggle if several key clearing members default simultaneously. An analysis of the joint solvency of investors or banks is beyond the scope of my research. What my study, however, suggests is that the impact of central clearing on such elements of systemic risk must be important to overcome the effect of reduced lending discipline quantitatively.

# 5 Conclusion

This paper models a bank with access to CRT that can grant a risky loan to analyze how central clearing affects lending discipline in the primary loan market.

I show that the introduction of a centrally cleared market for credit risk undermines banks' incentive to detect and reject a low-quality loan applicant. This reduced lending discipline aggravates the excessive lending and loan quality problems. The regulator cannot encourage lending discipline by simply tightening capital requirements. It is also necessary to regulate central clearing in terms of risk retention, disclosure, and access to the uncleared OTC market. With the appropriate market design, the regulator can establish the same lending discipline as in the case without CRT. Hence, my results suggest that the regulator should consider the interaction between the regulatory design of the CRT market and capital requirements when addressing the lending discipline problem. Finally, I show that lending discipline is an important channel through which central clearing affects systemic risk.

One caveat is that my analysis only applies to banks' loan granting and credit risk hedging activities, but not to their CRT transactions that are pure dealer activities. According to the OCC (2015), however, U.S. commercial banks were net buyers of credit protection in each single quarter between 2007 and 2015, which suggests that credit risk hedging is an important element of banks' CRT activity. In addition, the collapse of the collateralized debt obligation (CDO) market during the subprime mortgage crisis has painfully revealed that neglecting the deterioration in lending discipline associated with credit risk transfer does not only cause fragility of the originators, but also of dealer banks that only trade the underlying credit risk (see, e.g., Acharya et al. 2009).

A change to the financial system as far-reaching as the introduction of central clearing has systemic effects that extend well beyond the direct consequences on counterparty risk or collateral demand. In fact, it can affect the entire financial system and the real economy as well. A deep analysis of these effects from central clearing is imperative to ensure that market participants, legislators, and regulators cooperate to implement a prudent market structure. My analysis of the consequences of central clearing for lending discipline provides a first step. A fruitful extension of the model would be to incorporate multiple banks. By modeling their interaction, one could additionally endogenize network effects of central clearing that influence both lending discipline in the primary loan market and banks' CRT activities.

## Appendix

**Proof of Proposition 1.**

*Proof.* As the screening cost is standard uniformly distributed, the ex-ante probability that a bank screens a loan is

$$p_S = \frac{(1 - p_L - i + \delta\lambda)(1 - \mu)}{1} = (1 - p_L - i + \delta\lambda)(1 - \mu), \tag{27}$$

and that it does not screen by $(1 - p_S)$. The probability that a granted loan $(G)$ is of high type $(H)$ can be calculated from

$$P(H \mid G) = \frac{P(H \cap G)}{P(G)} = \frac{\mu}{1 - p_S(1 - \mu)} = \frac{\mu}{p_G} = Q. \tag{28}$$

Hence, the expected repayment probability of a granted loan is $p_Q = Qp_H + (1 - Q)p_L$.

It remains to be shown that $1 > p_G > \mu$, and $p_H > p_Q > p_\mu$: From $i < 1-p_L+\delta m < 1-\delta(\lambda-m)$, and $\lambda > m$, it follows that $p_S \in (0, 1)$. Hence, $p_G = p_S\mu + (1 - p_S) \in (\mu, 1)$. From Equation (28), $p_G \in (\mu, 1)$ induces $1 > Q > \mu$ which yields $p_H > p_Q > p_\mu$. □

**Proof of Proposition 2.**

*Proof.* If $p_\mu - p_I^{M,P} \geq \delta(\lambda - m - \xi_C)$, a bank that does not screen prefers to grant the loan and keep this risk in its own books instead of hedging. A bank with a detected high type loan follows the same strategy. An investor then knows that a transferred loan risk is of low type, which induces a bank with a low loan to reject the loan. Following the steps in the proof of Proposition 1 shows that $p_S^{M,P} = p_S$, $p_G^{M,P} = p_G$, and $p_Q^{M,P} = p_Q$ in this case. Note that a bank with a detected low loan cannot mimic a high type, and then recover the associated loss by incurring speculative positions as long as the entire trading position of the loan-originating bank is disclosed.

If the bank that does not screen hedges, the probability that a transferred loan risk (T) is of high type (H) is

$$P(H \mid T) = \frac{P(H \cap T)}{P(T)} = \frac{(1 - p_S^{M,P})\mu}{1 - p_S^{M,P}\mu} = I^{M,P}. \tag{29}$$

Hence, the unique perfect Bayesian separating equilibrium satisfying the Intuitive Criterion maintains if $p_\mu - p_I^{M,P} \geq \delta(\lambda - m - \xi_C)$, with $I^{M,P} = \frac{(1-p_S)\mu}{1-p_S\mu}$.

If $p_\mu - p_I^{M,P} < \delta(\lambda - m - \xi_C)$, a bank that does not screen prefers to hedge. A bank with a detected low type also grants and hedges the loan if its expected profit satisfies

$$i - (1 - p_I^{M,P}) - \delta(m + \xi_C) \geq 0. \tag{30}$$

The investor on the centrally cleared CRT market then knows that a transferred loan risk is either of unscreened or low type. Hence, the investor assigns the probability that a transferred loan (T) is of high type (H) according to

$$P(H \mid T) = \frac{P(H \cap T)}{P(T)} = \frac{(1 - p_S^{M,P})\mu}{1 - p_S^{M,P}\mu} = I^{M,P}, \tag{31}$$

in which $p_S^{M,P}$ is the probability that a bank screens when $p_\mu - p_Q^{M,P} < \delta(\lambda - m - \xi_C)$. There is no lending discipline as each loan is granted. Lending discipline only maintains if Condition (30) is not satisfied and, hence, the bank with a low type does not grant the loan. $i - (1 - p_I^{M,P}) - \delta(m + \xi_C) < 0$, however, is a contradiction to $p_\mu - p_I^{M,P} < \delta(\lambda - m - \xi_C)$ because $i - (1 - p_\mu) - \delta\lambda > 0$ per assumption. □

**Proof of Proposition 3.**

*Proof.* I show that there exists an optimal fraction that induces a unique perfect Bayesian separating equilibrium satisfying the Intuitive Criterion in which a bank with a detected high loan retains this fraction of the granted loan's risk, and a bank with a detected low type rejects the loan. The optimal fraction maximizes the expected profit of the bank with a high loan.

The separating equilibrium has to satisfy both the investor's participation constraint and the bank's self selection criterion. The program to solve for $\theta^{M,R} \leq 1$ is

$$\underset{\theta^{M,R}}{max} \quad i - \theta^{M,R}(1 - p_H) - (1 - \theta^{M,R})(1 - p_I^{M,R}) - (1 - \theta^{M,R})(m + \xi_C)\delta - \theta^{M,R}\delta\lambda \tag{32}$$

s.t.

$$\begin{aligned} &\mu\left(i - \theta^{M,R}(1 - p_H) - (1 - \theta^{M,R})(1 - p_I^{M,R}) - (1 - \theta^{M,R})(m + \xi_C)\delta - \theta^{M,R}\delta\lambda\right) - C \geq \\ &i - \mu\theta^{M,R}(1 - p_H) - (1 - \mu)\theta^{M,R}(1 - p_L) - (1 - \theta^{M,R})(1 - p_I^{M,R}) \\ &-(1 - \theta^{M,R})(m + \xi_C)\delta - \theta^{M,R}\delta\lambda. \end{aligned} \tag{33}$$

The participation constraint for the investor is implicitly satisfied because the CRT market is assumed to be competitive, i.e., the expected default loss per loan unit corresponds to $(1 - p_I^{M,R})$ that reflects the beliefs of the investor about the underlying loan's quality. Beside the incentive compatibility constraint (33), it must also hold that

$$i - \theta^{M,R}(1 - p_L) - (1 - \theta^{M,R})(1 - p_I^{M,R}) - (1 - \theta^{M,R})(m + \xi_C)\delta - \theta^{M,R}\delta\lambda \leq 0, \tag{34}$$

i.e., that a bank that has screened and detected a low type prefers to reject the loan instead of mimicking to be granting and hedging a high type. Inequality (33) is more restrictive than Inequality (34) as long as $C > 0$. Hence, it is sufficient to consider the incentive compatibility constraint (33) in the optimization problem. The expected profit of a bank that grants a detected high loan in Expression (32) is decreasing in the retained fraction $\theta^{M,R}$. Hence, the smallest fraction $\theta^{M,R*}$ that still admits a separating equilibrium maximizes this profit. Maximizing the expected profit of the bank with a detected high loan also maximizes a bank's ex-ante incentive to screen a loan. Due to the linearity of the problem, the solution to the program for $\theta^{M,R} \leq 1$ is obtained by solving Constraint (33) as equality for $\theta^{M,R}$, which yields

$$\theta^{M,R*} = \frac{i - (1-p_H) - (m+\xi_C)\delta + C/(1-\mu)}{p_H - p_L + \delta(\lambda - m - \xi_C)}. \tag{35}$$

The separating equilibrium satisfying the Intuitive Criterion of Cho and Kreps (1987) is given by the following strategy: A bank with a high loan type grants and retains $\theta^{M,R*}$, and a bank with a low loan rejects it. As a fractional hedge of a bank is publicly observable, the unique equilibrium beliefs of the investor are such that a granted loan is of high-type with probability one, i.e., $p_I^{M,R} = p_H$, if it is fractionally hedged. It is easy to check that this belief satisfies the Intuitive Criterion.

In the case in which $\theta^{M,R} > 1$, a bank completely hedges the loan and additionally sells a fraction $(\theta^{M,R} - 1)$ of credit protection. On this fraction, it earns a protection fee of $(\theta^{M,R} - 1)(1 - p_I^{M,R})$. With costs $\epsilon > 0$ and $\xi_C^S > 0$ imposed on any fraction of speculative exposure by the originating bank on the centrally cleared market, the expected profit of a bank that screens and retains $\theta^{M,R} > 1$ of a high type loan is

$$\mu(i - \theta^{M,R}(1-p_H) - \lambda\delta - (\epsilon + \xi_C^S)\delta(\theta^{M,R} - 1) + (\theta^{M,R} - 1)(1 - p_I^{M,R})) - C. \tag{36}$$

The incentive compatibility constraint (33) in the program must be replaced by

$$\begin{aligned} &\mu(i - \theta^{M,R}(1-p_H) - \lambda\delta - (\epsilon + \xi_C^S)\delta(\theta^{M,R} - 1) + (\theta^{M,R} - 1)(1 - p_I^{M,R})) - C \geq \\ &i - \mu\theta^{M,R}(1-p_H) - (1-\mu)\theta^{M,R}(1-p_L) - \lambda\delta - (\epsilon + \xi_C^S)\delta(\theta^{M,R} - 1) \\ &+(\theta^{M,R} - 1)(1 - p_I^{M,R}). \end{aligned} \tag{37}$$

The smallest $\theta^{M,R}$ that permits a separating equilibrium with $p_I^{M,R} = p_H$ is given by

$$\theta^{M,R*} = \frac{i - (1-p_H) + \delta(\epsilon + \xi_C^S - \lambda) + C/(1-\mu)}{p_H - p_L + \delta(\epsilon + \xi_C^S)}. \tag{38}$$

□

**Proof of Proposition 4.**

*Proof.* First, consider $C \in (0, (1 - p_L - i + \delta\lambda)(1-\mu)]$. The first term in the screening condition with restricted CRT, i.e., in

$$(1 - p_L - i + \delta\lambda)(1-\mu) + \mu(1 - \theta^{M,R*})\delta(\lambda - m - \xi_C) \geq C, \tag{39}$$

corresponds to the left hand side of the screening condition without CRT in Inequality (3). The second term of Inequality (39), $\mu(1-\theta^{M,R*})\delta(\mu - m - \xi_C)$, is non-negative if $\theta^{M,R*} \in (0,1]$. The denominator of the expression for $\theta^{M,R*}$ in (35) is greater than zero because $p_H > p_L$, and $\lambda > m + \xi_C$. The nominator is larger than zero because, by assumption, $i - (1-p_\mu) - \lambda\delta > 0$, $p_H > p_\mu$, and $C > 0$. As a consequence, $\theta^{M,R*} \in (0,1]$ if $i - (1-p_H) - (m+\xi_C)\delta + C/(1-\mu) \leq p_H - p_L + \delta(\lambda - m - \xi_C)$, or, by rearranging, if

$$(1 - p_L - i + \delta\lambda)(1-\mu) \geq C. \tag{40}$$

Hence, if $C \in (0, (1-p_L-i+\delta\lambda)(1-\mu)]$, the left hand side of Inequality (39) is always larger or equal to $(1-p_L-i+\delta\lambda)(1-\mu)$. Therefore, the bank optimally screens.

Next, I analyze $C > (1-p_L-i+\delta\lambda)(1-\mu)$. From Expressions (38) and (40), it is then known that $\theta^{M,R*} > 1$. The expected profit $\Pi_S^{M,R}$ of a bank that screens and retains $\theta^{M,R*} > 1$ corresponds to

$$\begin{aligned}&\mu(i-\theta^{M,R*}(1-p_H)-\lambda\delta-(\epsilon+\xi_C^S)\delta(\theta^{M,R*}-1)+(\theta^{M,R*}-1)(1-p_H))-C=\\&\mu(i-(1-p_H)-\lambda\delta-(\epsilon+\xi_C^S)\delta(\theta^{M,R*}-1))-C.\end{aligned} \tag{41}$$

Comparing Expression (41) to the expected profit $\Pi_{NS}^{M,R}$ of the non-screening strategy, $i-(1-p_\mu)-\delta\lambda$, yields the following screening condition:

$$(1-p_L-i+\delta\lambda)(1-\mu)-\mu(\epsilon+\xi_C^S)\delta(\theta^{M,R*}-1) \geq C. \tag{42}$$

As $-\mu(\epsilon+\xi_C^S)\delta(\theta^{M,R*}-1) < 0$ for $\theta^{M,R*} > 1$, the left hand side of Inequality (42) is always smaller than $(1-p_L-i+\delta\lambda)(1-\mu)$. Hence, $\Pi_S^{M,R} < \Pi_{NS}^{M,R}$ because $C > (1-p_L-i+\delta\lambda)(1-\mu)$, and no screening takes place.

Because the bank screens if $C \in (0, (1-p_L-i+\delta\lambda)(1-\mu)]$, and does not screen if $C > (1-p_L-i+\delta\lambda)(1-\mu)$, the screening probability is

$$p_S^{M,R} = \frac{(1-p_L-i+\delta\lambda)(1-\mu)}{1} = (1-p_L-i+\delta\lambda)(1-\mu), \tag{43}$$

which is identical to the probability in the case without CRT. If the bank screens, it optimally grants and fractionally hedges a high, and rejects a low loan. If it does not screen, it grants any loan. Hence, the probability that a loan is granted is $p_S^{M,R}\mu + (1-p_S^{M,R}) = 1-p_S^{M,R}(1-\mu) = p_G^{M,R}$, and that a granted loan is of high type is $\frac{\mu}{p_G^{M,R}} = Q^{M,R}$. □

**Proof of Proposition 5.**

*Proof.* The expected profit from the screening strategy can be written as

$$\Pi_S^{M,R,ND} = \begin{cases}\mu(i-\theta^{M,R,ND*}(1-p_H)-(1-\theta^{M,R,ND*})(1-p_I^{M,R,ND})\\ -(1-\theta^{M,R,ND*})(m+\xi_C)\delta-\theta^{M,R,ND*}\delta\lambda)-C & if\ \theta^{M,R,ND*} \leq 1,\\ \mu(i-\theta^{M,R,ND*}(1-p_H)+(\theta^{M,R,ND*}-1)(1-p_I^{M,R,ND})-\lambda\delta-\\ (\epsilon+\xi_C^S)\delta(\theta^{M,R,ND*}-1))-C & if\ \theta^{M,R,ND*} > 1,\end{cases} \tag{44}$$

in which $\epsilon > 0$ is the regulatory capital requirement for speculative exposures on the centrally cleared CRT market.

The alternative strategy of the bank is to just grant the loan without screening and to keep the entire credit risk in the own books. This non-screening strategy yields an expected bank profit of

$$\Pi_{NS}^{M,R,ND} = i-(1-p_\mu)-\delta\lambda. \tag{45}$$

I proof that there is a separating equilibrium with screening under $\hat{I}^{M,R,ND} = \frac{\mu}{1-p_S^{M,R,ND}(1-\mu)}$, and $p_S^{M,R,ND} = (1 - p_L - i + \delta\lambda)(1-\mu)$.

In the case $\theta^{M,R,ND*} \leq 1$, the smallest fraction such that the screening strategy dominates the mimicking strategy is given by

$$\theta^{M,R,ND*} = \frac{i - (1 - p_I^{M,R,ND}) - (m + \xi_C)\delta + C/(1-\mu)}{p_I^{M,R,ND} - p_L + \delta(\lambda - m - \xi_C)}. \tag{46}$$

From Expression (46), it follows that $\theta^{M,R,ND*} \leq 1$ if $C \leq (1 - p_L - i + \delta\lambda)(1-\mu)$. Comparing the first two lines of Expression (44) to (45) yields that $\Pi_S^{M,R,ND} \geq \Pi_{NS}^{M,R,ND}$ if

$$(1-p_L-i+\delta\lambda)(1-\mu)+\mu(1-\theta^{M,R,ND*})\left(\delta(\lambda - m - \xi_C) - (p_H - p_L)(1 - I^{M,R,ND})\right) \geq C. \tag{47}$$

Consider $\delta(\lambda - m - \xi_C) \geq (p_H - p_L)(1 - I^{M,R,ND})$. The term

$$\mu(1 - \theta^{M,R,ND*})\left(\delta(\lambda - m - \xi_C) - (p_H - p_L)(1 - I^{M,R,ND})\right) \tag{48}$$

is non-negative for $\theta^{M,R,ND*} \leq 1$. Hence, Inequality (47) is always satisfied as $C \leq (1 - p_L - i + \delta\lambda)(1-\mu)$.

Next, consider $\delta(\lambda - m - \xi_C) < (p_H - p_L)(1 - I^{M,R,ND})$. Under this condition, the expected profit from the screening strategy in the first two lines of Expression (44) is strictly increasing in $\theta^{M,R,ND}$. Hence, to maximize the expected bank profit, the retained fraction is set to $\theta^{M,R,ND} = 1$.[19] With $\theta^{M,R,ND} = 1$, $\Pi_S^{M,R,ND} \geq \Pi_{NS}^{M,R,ND}$ if

$$(1 - p_L - i + \delta\lambda)(1-\mu) \geq C. \tag{49}$$

Inequality (49) is satisfied for $\theta^{M,R,ND*} \leq 1$.

In the case $\theta^{M,R,ND*} > 1$, the smallest fraction such that the screening strategy dominates the mimicking strategy is given by

$$\theta^{M,R,ND*} = \frac{i - (1 - p_I^{M,R,ND}) + \delta(\epsilon + \xi_C^S - \lambda) + C/(1-\mu)}{p_I^{M,R,ND} - p_L + \delta(\epsilon + \xi_C^S)}. \tag{50}$$

From Expression (50), it follows that $\theta^{M,R,ND*} > 1$ if $C > (1 - p_L - i + \delta\lambda)(1-\mu)$. Comparing the last two lines of Expression (44) to (45) yields that $\Pi_S^{M,R,ND} \geq \Pi_{NS}^{M,R,ND}$ if

$$(1 - p_L - i + \delta\lambda)(1-\mu) + \mu(\theta^{M,R,ND*} - 1)\left((p_H - p_L)(1 - I^{M,R,ND}) - (\epsilon + \xi_C^S)\delta\right) \geq C. \tag{51}$$

Inequality (51) can only be satisfied if

$$\mu(\theta^{M,R,ND*} - 1)\left((p_H - p_L)(1 - I^{M,R,ND}) - (\epsilon + \xi_C^S)\delta\right) > 0 \tag{52}$$

and, hence, if $(p_H - p_L)(1 - I^{M,R,ND}) > \delta(\epsilon + \xi_C^S)$ because $C > (1 - p_L - i + \delta\lambda)(1-\mu)$ for

[19] I show below that there is no screening for $\theta^{M,R,ND} > 1$.

$\theta^{M,R,ND*} > 1$. $(p_H - p_L)(1 - I^{M,R,ND}) > \delta(\epsilon + \xi_C^S)$, however, requires that $(p_H - p_I^{M,R,ND}) > \delta(\epsilon + \xi_C^S)$. As $(p_H - p_L) < \delta(\epsilon + \xi_C^S)$ and $p_L \leq p_I^{M,R,ND}$, Inequality (51) is not satisfied.

Given the conditions for screening in the cases $\theta^{M,R,ND*} \leq 1$ and $\theta^{M,R,ND*} > 1$, the only equilibrium for $(p_H - p_L) < \delta(\epsilon + \xi_C^S)$ satisfying the Intuitive Criterion is that the bank does not screen if $C > (1 - p_L - i + \delta\lambda)(1 - \mu)$, and screens and rejects a low type if $C \leq (1 - p_L - i + \delta\lambda)(1 - \mu)$. The unique beliefs associated with this equilibrium are such that a loan is screened with probability $p_S^{M,R,ND} = (1 - p_L - i + \delta\lambda)(1 - \mu)$, and, hence, $I^{M,R,ND} = \frac{\mu}{1 - p_S^{M,R,ND}(1-\mu)}$. This belief satisfies the Intuitive Criterion.

□

**Proof of Proposition 6.**

*Proof.* The following strategy of the bank is a separating equilibrium satisfying the Intuitive Criterion of Cho and Kreps (1987): If it does not screen, it grants and hedges a loan on the uncleared OTC market. If it screens, the bank grants and hedges a high loan on the uncleared OTC market, and rejects a low loan. The unique beliefs associated with this equilibrium are that the bank that does not screen, and the bank with a high loan tailor the OTC contract to reveal their true type. A bank that does not tailor the contract is believed to be of low type with probability one.

As $\lambda > \gamma + \xi_O$ and $\Omega(P_H \mid p_\mu) > i - (1 - p_H) - \delta(m + \xi_C)$, it is optimal for a bank that does not screen to grant, tailor, and hedge the loan on the uncleared OTC market because

$$i - (1 - p_\mu) - \delta(\gamma + \xi_O) > Max\big(i - (1 - p_\mu) - \delta\lambda, i - (1 - p_H) - \delta(\gamma + \xi_O) - \Omega(P_H \mid p_\mu)\big), \quad (53)$$

in which $i - (1 - p_\mu) - \delta\lambda$ is the expected profit from granting an unscreened loan without hedging, and $(i - (1 - p_H) - \delta(\gamma + \xi_O)) - \Omega(P_H \mid p_\mu)$ is the profit from tailoring the contract to mimic a high type and hedging it at a cost $(1 - p_H)$ on the uncleared OTC market. As $\Omega(P_Q > p_L \mid p_L) > i - (1 - p_H) - \delta(m + \xi_C)$, it is optimal for a bank with a low type to reject the loan because

$$0 > Max\big(i - (1 - p_\mu) - \delta(\gamma + \xi_O) - \Omega(P_\mu \mid p_L), i - (1 - p_H) - \delta(\gamma + \xi_O) - \Omega(P_H \mid p_L)\big), \quad (54)$$

in which $i - (1 - p_\mu) - \delta(\gamma + \xi_O) - \Omega(P_\mu \mid p_L)$ is the profit from tailoring the contract to mimic an unscreened loan and following the optimal non-screening strategy of hedging it at a default cost $(1 - p_\mu)$ on the uncleared OTC market, and $i - (1 - p_H) - \delta(\gamma + \xi_O) - \Omega(P_H \mid p_L)$ is the profit from tailoring the contract to mimic a high type and hedging it at a default cost $(1 - p_H)$ on the uncleared OTC market. Finally, a bank with a detected high type optimally grants, tailors, and hedges the loan on the uncleared OTC market because it cannot reach a profit above $i - (1 - p_H) - \delta(\gamma + \xi_O)$ with any other strategy.

Comparing the expected profit from the optimal screening strategy, $\Pi_S^O = \mu(i - (1 - p_H) - \delta(\gamma + \xi_O)) + (1 - \mu)0 - C$, in the separating equilibrium to that of the optimal non-screening strategy, $\Pi_{NS}^O = i - (1 - p_\mu) - \delta(\gamma + \xi_O) > 0$, leads to $p_S^O = \frac{(1 - p_L - i + \delta(\gamma + \xi_O))(1-\mu)}{1}$. As a detected low loan is rejected, the probability that a loan is granted is $p_G^O = 1 - p_S^O(1 - \mu)$. The expected repayment probability of a granted loan is $p_Q^O = Q^O p_H + (1-Q^O)p_L$, with $Q^O = \frac{\mu}{p_G^O}$. As $p_S^O > 0$, and a detected low loan type is rejected, there is lending discipline that leads to $p_G^O < 1$ and, hence, to $Q^O > \mu$, which induces $p_Q^O > p_\mu$.

Because $\lambda > \gamma + \xi_O$, $p_S^O < p_S$, which implies $p_G^O > p_G$, and $Q^O < Q$. □

**Proof of Proposition 8.**

*Proof.* If the central hedging of a bank is publicly observable, the equilibrium beliefs of participants of the centrally cleared market are that a fractionally hedged loan is of high type with probability one. First, I show that granting a detected low loan type, hedging it on the restricted centrally cleared market by retaining $\theta^{V,R}$, and silently hedging the retained fraction on the uncleared OTC market by tailoring the credit derivative contract is not worthwhile. The profit from this strategy is

$$\begin{aligned} &i - \theta^{V,R}(1-p_L) - (1-\theta^{V,R})(1-p_H) - (1-\theta^{V,R})(m+\xi_C)\delta - \theta^{V,R}\delta\lambda \\ &+\theta^{V,R}(1-p_L) - \theta^{V,R}(1-p_H) + \theta^{V,R}\delta\lambda - \theta^{V,R}\delta(\gamma+\xi_O) - \Omega(P_H \mid p_L). \end{aligned} \tag{55}$$

The profit in Expression (55) is always smaller than $\theta^{V,R}\delta(m+\xi_C-\gamma-\xi_O)$, which is, by definition, smaller than zero for any $1 \geq \theta^{V,R} > 0$.[20]

Next, a bank with a detected high type loan fractionally hedges on the centrally cleared market, and transfers the remaining fraction $\theta^{V,R}$ on the uncleared OTC market with a tailored contract. The profit from this strategy, $i - (1-p_H) - (1-\theta^{V,R})(m+\xi_C)\delta - \theta^{V,R}\delta(\gamma+\xi_O)$, is larger than the expected profit from hedging on the centrally cleared market and retaining $\theta^{V,R}$ of the loan risk in the own books, or any other strategy.

Finally, I derive the smallest $\theta^{V,R}$ such that the optimal screening strategy still dominates the mimicking strategy. The incentive compatibility constraint is given by

$$\begin{aligned} &\mu\left(i - \theta^{V,R}(1-p_H) - (1-\theta^{V,R})(1-p_H) - (1-\theta^{V,R})(m+\xi_C)\delta - \theta^{V,R}\delta(\gamma+\xi_O)\right) - C \\ &\geq i - \mu\theta^{V,R}(1-p_H) - (1-\mu)\theta^{V,R}(1-p_L) - (1-\theta^{V,R})(1-p_H) - (1-\theta^{V,R})(m+\xi_C)\delta \\ &-\theta^{V,R}\delta(\gamma+\xi_O). \end{aligned} \tag{56}$$

The first line of Expression (56) is the profit of a bank that screens at cost C, grants a high loan, centrally hedges the fraction $(1-\theta^{V,R})$, and silently hedges the fraction $\theta^{V,R}$ of the underlying loan default risk on the uncleared OTC market. A detected low type loan is rejected. The second and third lines are the profit of a mimicking bank that grants any loan type without screening. This bank also retains the fraction $\theta^{V,R}$ to pretend having detected a high loan, and silently hedges the remaining fraction on the uncleared OTC market with a tailored credit derivative contract. The optimal fraction of credit risk to be retained on the centrally cleared market is obtained by following the steps in the proof of Proposition 3, in which $\lambda$ is replaced by $\gamma + \xi_O$. It follows that

$$\theta^{V,R*} = \begin{array}{ll} \frac{i-(1-p_H)-(m+\xi_C)\delta+C/(1-\mu)}{p_H-p_L+\delta(\gamma+\xi_O-m-\xi_C)} & if \quad \theta^{V,R*} \leq 1 \\ \frac{i-(1-p_H)+\delta(\epsilon+\xi_C^S-\gamma-\xi_O)+C/(1-\mu)}{p_H-p_L+\delta(\epsilon+\xi_C^S)} & if \quad \theta^{V,R*} > 1. \end{array} \tag{57}$$

[20] Due to $\epsilon$, there is no screening for $\theta^{V,R} > 1$.

Using this $\theta^{V,R*}$ in the screening condition of Expression (23), and following the steps in the proof of Proposition 4 by replacing $\lambda$ with $\gamma + \xi_O$ shows that $p_S^{V,R}$=$p_S^O$, $p_G^{V,R}$=$p_G^O$, and $p_Q^{V,R}$=$p_Q^O$. $\square$

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# Figures

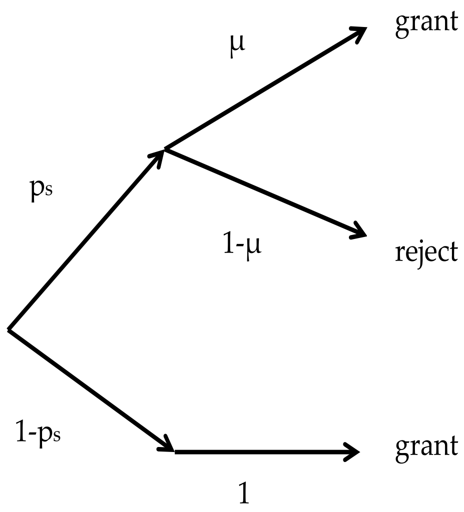


**Figure 1:** Bank lending decision without CRT. With probability $p_S$, the bank screens a loan. If the loan is of high type, which occurs with probability $\mu$, the screened loan is granted. If the bank detects a low type loan, which occurs with probability $1 - \mu$, it is rejected. With probability $1 - p_S$, the bank does not screen. In this case, the loan is granted with probability one.

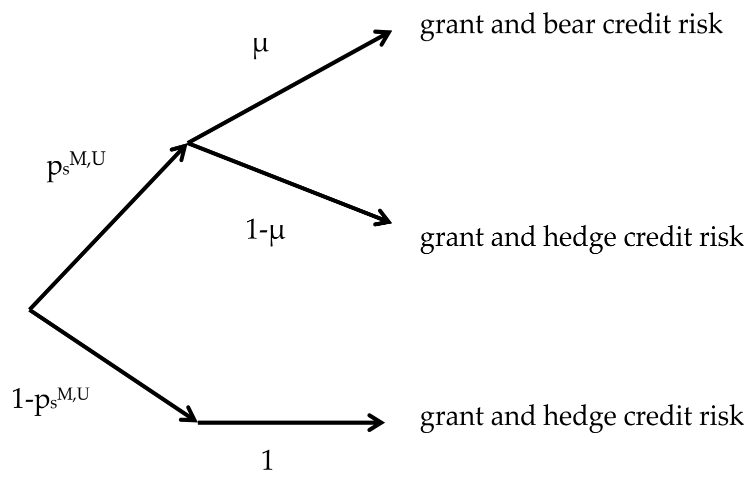


**Figure 2:** Bank lending and hedging decisions with centrally cleared CRT. With probability $p_S^{M,U}$, the bank screens a loan. If the loan is of high type, which occurs with probability $\mu$, the screened loan is granted but not hedged. If the bank detects a low type loan, which occurs with probability $1 - \mu$, it is granted and hedged. With probability $1 - p_S^{M,U}$, the bank does not screen. In this case, the loan is granted and hedged with probability one.

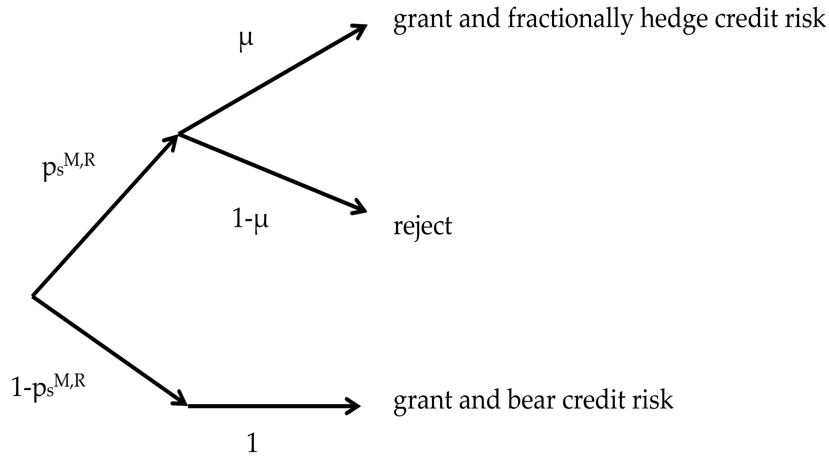


**Figure 3:** Bank lending and hedging decisions with restricted centrally cleared CRT. With probability $p_S^{M,R}$, the bank screens a loan. If the loan is of high type, which occurs with probability $\mu$, the screened loan is granted and partially hedged. If the bank detects a low type loan, which occurs with probability $1-\mu$, it is rejected. With probability $1-p_S^{M,R}$, the bank does not screen. In this case, the loan is granted without hedging.

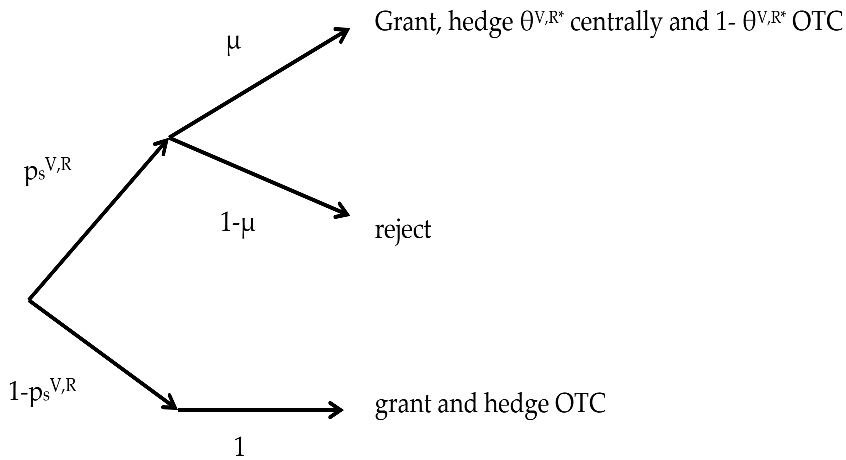


**Figure 4:** Bank lending and hedging decisions with access to both restricted centrally cleared and uncleared OTC CRT. With probability $p_S^{V,R}$, the bank screens a loan. If the loan is of high type, which occurs with probability $\mu$, the screened loan is granted. The fraction $\theta^{V,R*}$ is hedged via central clearing, and the fraction $(1-\theta^{V,R*})$ via OTC market. If the bank detects a low type loan, which occurs with probability $1-\mu$, it is rejected. With probability $1-p_S^{V,R}$, the bank does not screen. In this case, the loan is granted and hedged on the uncleared OTC market.

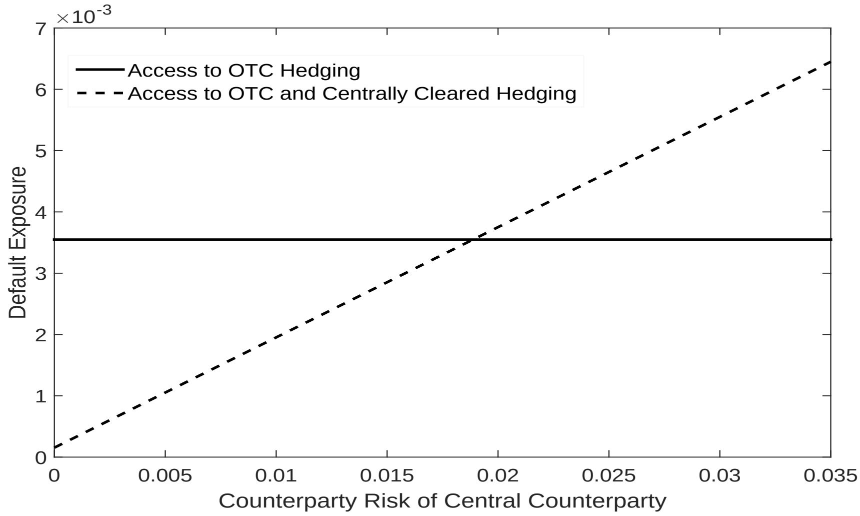


**Figure 5:** Default exposure from a potential loan grant. The solid line shows the default exposure to a bank from a considered loan if the bank only has access to the uncleared OTC CRT market for different values of the counterparty risk of the central counterparty. The dashed line depicts the default exposure if the bank has access to both uncleared OTC and centrally cleared CRT markets.

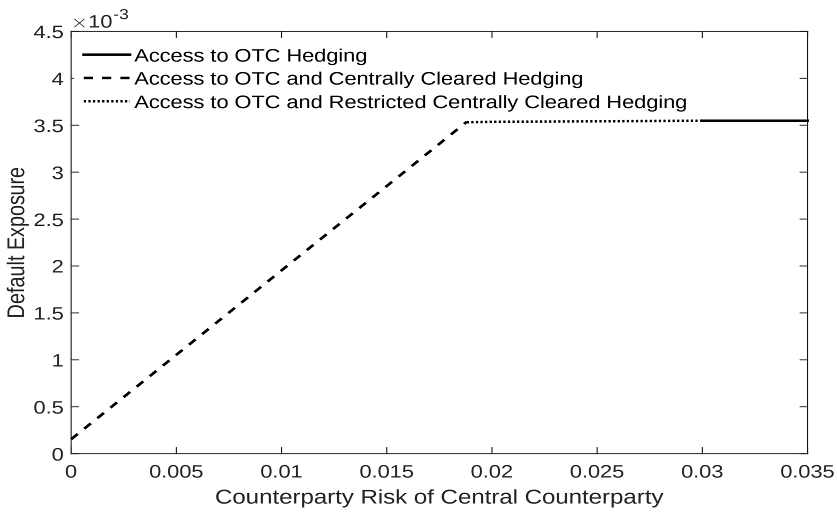


**Figure 6:** Minimum default exposure from a potential loan granting. The solid line shows the default exposure to a bank from a potential loan grant if the bank only has access to uncleared OTC hedging for different values of the counterparty risk of the central counterparty. The dashed line depicts the default exposure if the bank has access to both uncleared OTC and centrally cleared CRT markets. The dotted line is the default exposure with a market structure in which the bank can hedge a loan uncleared OTC and via restricted central clearing.