The Limits of Central Counterparty Clearing: Collusive Moral Hazard and Market Liquidity*

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June, 2013

Abstract

Can central counterparty (CCP) clearing control counterparty risk in the presence of risk taking that can aggravate such risk? When counterparty risk is not observable, I show that central clearing leads to higher collateral requirements for two different reasons. Without collusion about risk taking, a CCP offering diversification of risk cannot selectively forgo incentives for transactions that use collateral only for insurance. With collusion about risk taking, a CCP needs to charge collateral in line with the worst counterparty quality to control risk taking. Requiring more collateral reduces market liquidity and worsens incentives causing a feedback effect that amplifies collateral costs.

Keywords: CCP Clearing, Counterparty Risk, Moral Hazard, Collateral, Market Liquidity

JEL Classification: G32, G38, D82, D83

*I would like to thank James Chapman, Jonathan Chiu, Cyril Monnet, Georg Noeldeke, Wolf Wagner and Gunther Wuyts for their comments. I appreciate comments from audiences at the Bank of Canada workshop on Financial Intermediation and Market Dynamics, the UvT/DNB Financial Infrastructures Research Conference, the 5th Swiss Winter Conference on Financial Intermediation, the 6th Economics of Payments Conference, the Konstanz Seminar on Monetary Theory and Monetary Policy and seminars at the Universities of Basel, Bern and Zurich, the Ludwig Maximilian University of Munich, the Bank for International Settlements, the Federal Reserve Bank of New York, the IMF and the Swiss National Bank. I acknowledge support from SSHRC grant SRG 410-2010-0610 and the Governor's Award of the Bank of Canada. The views expressed are entirely my own and not necessarily those of the Bank of Canada.

I. Introduction

Risk management practices of financial institutions have been deemed insufficient in the aftermath of the financial crisis. One particular area of concern is the low level of collateral applied to secure over-the-counter (OTC) derivatives transactions. While trading in such instruments has risen sharply over the last decade, a total exposure of about 1 to 2 trillion USD in derivative exposures are not at all collateralized or deemed under-collateralized.[1] This has raised the perception that participants in the OTC derivatives market severely underestimate the risk that a counterparty defaults on a transaction. The common policy response to this issue is to move derivative transactions under the umbrella of a clearinghouse that would offer central counterparty (CCP) clearing and ensure that "proper" collateral is posted in these transactions.[2]

This paper asks to what degree CCP clearing can control counterparty risk in financial markets and, if so, at what cost for financial market participants. I start from the premise that clearing through a CCP offers novation of trades.[3] A clearinghouse pools counterparty risk by interposing itself as the sole buyer and the sole seller of any contract traded in a financial market. The clearinghouse then requires collateral to protect itself against losses from counterparty risk involved in these transactions. Pooling of counterparty risk leads to a diversification of such risk, but also invites moral hazard. If the quality and the actions of the counterparties are not observable to the clearinghouse, the transfer of risk can lead to additional risk taking by market participants. Evaluating the effectiveness of CCP clearing requires then a basic framework that lays out the incentives for taking on counterparty risk in financial transactions and for controlling it via the posting of collateral.

Consider two parties – called a seller and a buyer – negotiating a forward transaction. With some probability one counterparty – say the buyer – will default on the transaction. I regard this as the basic counterparty risk associated with the transaction itself. Suppose further that there is the potential of excess risk taking in the sense that the buyer has a private (and non-contractible) benefit from increasing counterparty risk. I interpret this as a buyer's quality as a counterparty, since a higher benefit raises the incentives for the buyer to become

[1]See ISDA (2012) which provides estimates of uncollaterlized exposures after netting based on survey data.

[2]For example, the Dodd-Frank Act not only mandates central clearing of formerly unregulated OTC derivatives transactions, but also that sufficient collateral of high quality is posted to secure such trades. The European Market Infrastructure Regulation (EMIR) is looking for a similar type of regulation in EU financial markets.

[3]I abstract from other services offered by central clearing such as multilateral netting and netting across different financial products, more efficient collateral management or better information on positions and net credit exposures of individual participants.

a riskier counterparty.

The seller can use collateral to control counterparty risk in two different ways. First, collateral can act as a prepayment, essentially insuring against the risk of default. Second, collateral can serve as a bond providing incentives for the buyer to keep counterparty risk low. When collateral is costly, the contracting parties have an incentive to economize on it: they can opt for a trade that requires little collateral at the expense of higher counterparty risk. In particular, for transactions with bad counterparty quality, collateral requirements could be too large to make it (privately) optimal to control all risk taking by the buyer and, thus, all counterparty risk exposure.

What are the implications of this basic framework for central clearing? I look at a CCP that is charged with the task to minimize counterparty risk[4], but is unlikely to be perfectly informed about counterparty quality. From observing collateral levels alone, it will not be able to infer the underlying counterparty risk in a transaction. Collateral could be low because the quality of the buyer is high, or because the contracting parties opted for high risk to save on collateral costs.

Interestingly, I show that a CCP can nevertheless control counterparty risk easily whenever sellers have a strong incentive to avoid risk taking by the buyer in the first place. When a buyer can increase his default risk independently of the transaction itself, the seller cannot extract surplus from the buyer by allowing him to take on additional risk. The seller's choice of collateral is then solely driven by the deadweight cost that collateral imposes on the surplus of the trade. A CCP that minimizes counterparty risk can then charge the minimum collateral required for low counterparty risk given any level of counterparty quality. The reason is that the moral hazard problem associated with transfering counterparty risk to the CCP has no bite: when negotiating their trade, the two counterparties cannot agree on terms that would overstate the buyer's counterparty quality to avoid posting costly collateral. Either the buyer would not find the trade profitable, or the seller would receive a lower payoff from the cleared trade. Still collateral charged by the CCP increases on transaction with bad counterparty quality, where the seller and buyer preferred to have low collateral and, as a consequence, counterparty risk was high.

Moral hazard becomes collusive, however, when sellers can hold up buyers to extract additional surplus. This is the case whenever buyers can realize their private benefit from risk taking only when trading with a seller. I show that such collusion to take on more risk

[4]I presume here that a certain level of counterparty risk that is acceptable for the counterparties to a trade might not be optimal from a societal perspective. This can be due to contagion, knock-on effects outside asset markets or leveraged positions in derivatives transactions among many other reasons.

forces the CCP to charge collateral levels associated with the worst counterparty quality *on all* transactions. If the CCP did not follow this collateral policy, sellers and buyers would now agree to overstate counterparty quality in the transaction. This leads to the extreme result that counterparty risk remains unchanged in transactions where counterparty quality is good, even though collateral requirements increase on these transactions. Hence, CCP clearing increases collateral requirements – and, thus, collateral costs – *for all* transactions *independent* of counterparty quality.

I then look at a dynamic framework to uncover a further channel for amplification of collateral requirements with central clearing. Suppose there are trading frictions that make long-term relationships attractive, where the same seller and buyer engage repeatedly in trades. More specifically, consider a search friction: when losing a trading partner it takes time to engage in a new trade. This search cost can be interpreted as a proxy for how easy it is to transact in the market, which I interpret as market liquidity. When search costs are low, the seller can credibly threaten to terminate a relationship in response to risk taking by the buyer. It is cheaper to immediately search for a new trading partner than to be exposed to the increased counterparty risk from the transaction when sticking with the buyer and delaying the search for a new trading partner. I call this strategy by sellers *market discipline*. Market liquidity thus plays a key role for market discipline to act as a substitute for costly collateral in order to provide incentives against risk taking.

It turns out that collateral requirements to limit counterparty risk and market liquidity are related in a highly non-monotonic way. When markets are sufficiently liquid, collateral and liquidity are positively correlated. As market liquidity falls, the cost for buyers of losing a seller increases. Hence, market discipline becomes more effective allowing sellers to require lower levels of collateral. Once market liquidity drops to a critical level, however, a seller's threat of terminating a relationship is not credible anymore. Then, market discipline fails, causing a discontinuous increase in collateral requirements for any given counterparty quality.

When central clearing increases collateral to lower counterparty risk, it will increase the costs of trading rendering some transactions non-profitable for sellers. This will adversely affect market liquidity[5], thereby weakening market discipline. If the ensuing fall in market liquidity is sufficiently large, the seller's threat to terminate a relationship after risk taking by the buyer is not credible anymore. Collateral requirements then need to increase further *for all remaining* transactions, just to keep counterparty risk on all these transactions unchanged.

[5]There might be other reasons to believe that CCP clearing will decrease liquidity. CCPs for example are likely to set strict membership requirements so that only high quality counterparties have access to central clearing. Moreover, trades outside formal clearing arrangements are likely to face additional costs in the form of capital charges, thereby further reducing liquidity in the market (see BIS (2012)).

This paper is the first systematic analysis of what limits CCP clearing that is concerned with minimizing counterparty risk. Earlier contributions have considered what benefits central clearing offers, such as netting (see Duffie and Zhu (2009)), information dissemination (see Archaya and Bisin (2010)) or the segregation of collateral as a commitment device (see Monnet and Nellen (2012)).[6] My analysis here is mainly built on the framework of Koeppl and Monnet (2010) that exhibits as main benefits novation and mutualization of risk for standardized derivatives transactions and an improved risk allocation for customized derivatives.

Moral hazard is a common feature that limits any transfer of risk. Biais et al. (2012a) have studied this relationship in the context of central clearing in financial markets. Their main conclusion is that one needs to limit the risk transfer to keep overall aggregate counterparty risk in financial markets low.[7] To the contrary, I have found here that central clearing can exploit conflicts about risk taking in bilateral transactions to limit moral hazard associated with the risk transfer. This is important, as it points out that – in the context of bilateral trading – moral hazard has to be collusive in order to really matter for transferring risk. Even then, central clearing can control risk taking by setting appropriate collateral requirements, which shifts the emphasis from the feasibility to the costs of such a risk transfer.

My analysis establishes here a novel relationship between clearing, market liquidity and collateral requirements. Once counterparty quality is not observable for a clearinghouse, collateral requirements need to increase at least for some trades which compromises market liquidity as trading costs increase. This channel leads to a further amplification of collateral requirements. There is an emerging literature on how risk management such as setting margins can adversely affect overall market liquidity.[8] While central clearing could take into account such a link in its risk management policies, I have shown here that the problem just reappears in a different form. This finding needs then to be taken into account for any attempts to quantify the actual costs of adequately collateralizing OTC derivatives transactions. The most thorough analysis in this area has been provided by Heller and Vause (2012), which still suffers from the defect that it does not base its estimates on a

[6] Carapella and Mills (2012) link several ideas to show that information insensitivity of securities is a key benefit of CCP clearing. Netting and collateral in the form of a default fund are crucial to achieve these benefits.

[7] In different work, the same authors look at the conflict between risk allocation and risk taking in bilateral transactions. This is interesting, since the authors find that collateral in the form of variation margins can control risk taking incentives which mirrors some features of the framework I have developed here (see Biais et al. (2012b)).

[8] The most related contribution in the literature is Brunnermeier and Pedersen (2009) who investigate the effects of margin calls as a risk management tool on overall market liquidity. See also Garleanu and Pedersen (2008) or Wagner (2010).

formal model of collateral choice for derivatives transactions, instead keeping risk taking incentives and market liquidity constant when considering central clearing.

There are several conclusions to be drawn for the broader policy discussion how to best regulate OTC derivatives markets. First, zero or low collateral cannot be necessarily interpreted as insufficient risk management. It might be the case that low collateral levels simply reflect market discipline or a privately efficient contract design by the counterparties to a trade. Second, I have shown that introducing a CCP can increase collateral costs across all transactions without necessarily improving counterparty risk for all transactions. Third, central clearing reaches its limits when contracting parties have an incentive to collude on increasing counterparty risk. It is conceivable that these incentives are strongest in situations where markets are under stress due to increased uncertainty and general market risk. Forth, even if the social costs of default exceed private ones, the decision whether to introduce a CCP or not must not only consider the impact on the cost of collateral, but also the impact of such a move on market liquidity and trading dynamics. As shown here, a fall in market liquidity can amplify collateral requirements necessary to achieve lower levels of counterparty risk. Fifth, CCP clearing tends to work best in liquid markets where counterparty quality is highly homogeneous across transactions.

The remainder of the paper is organized as follows. Section II describes the model. The next two sections deal with the two limiting factors for CCP clearing – moral hazard in Section III and adverse effects on liquidity in Section IV. The last section concludes by briefly expanding on the implications of this paper for empirical work and financial markets policy. All formal proofs have been relegated to the appendix.

II. Model

I describe a simple, stylized model that formalizes bilateral trading of customized financial contracts. There are two dates $t = 0$ and $t = 1$ and there are two types of people, sellers and buyers, both of measure 1. Sellers produce a specialized good for a particular buyer at $t = 0$ to be delivered at $t = 1$, which captures the nature of a customized financial contract with a term component. Buyers can produce gold in both periods as payment in exchange for the specialized good. Since goods are specifically produced for a buyer, they cannot be retraded; in other words, they are assumed not to be fungible. These features capture the notion of a non-standardized derivative transaction such as a forward contract where replacement costs are large.

Sellers' preferences are described by

$$u_F(q, x) = E[-\theta q + u(x)] \tag{1}$$

where q is the amount of the good produced – either 0 or 1 – and x is the amount of gold consumed in period $t = 1$. For most of the paper, I assume that θ is sufficiently small, so that sellers have an incentive to produce the good for buyers. Buyers' preferences are given by

$$u_B(q, x_1, x_2) = E[-\mu x_1 - x_2 + vq] \tag{2}$$

where v is the valuation of the good. The baker can produce gold either in period 1 (x_1) or 2 (x_2). However, early production of gold implies an additional cost, since we assume that $\mu > 1$.

There are two complications for trading. First, there is counterparty risk. Buyers can die with probability $\epsilon \in [0, 1)$ after $t = 0$. Since a seller has produced a good specifically for a buyer, he will not be able to deliver it against a payment in gold in case of the buyer's death. Second, there is moral hazard. Buyers can engage in an activity that delivers some private benefit $B > 0$ at $t = 0$, but that also increases their probability of dying. We denote this decision by $\lambda_B \in \{0, 1\}$. In particular, I assume that if a buyer realizes his private benefit ($\lambda_B = 1$), his probability of dying increases to $\epsilon + (1 - \epsilon)\rho$, where $\rho \in (0, 1)$. I interpret the variable B as counterparty quality, since it relates counterparty risk to the specific counterparty of a transaction, but not to the transaction itself. To the contrary, the exogenous probability ϵ is constant across transactions and, hence, I interpret it as the common default risk associated with any transaction.

Trading is organized as follows. At $t = 0$, a seller meets a buyer and makes a take-it-or-leave-it offer $(p, k) \in \mathbb{R}_2^+$. The variable p is the price of the transaction, a total payment in gold by the baker upon delivery of wheat in $t = 1$. The variable k describes a prepayment in $t = 0$ when the seller undertakes production. The transaction can thus be interpreted as a forward contract where the seller asks for collateral k to safeguard against the risk that the buyer dies. I assume that the action λ_B is not verifiable for the seller, so that the contract cannot be contingent on it. Finally, if the buyer survives, the contract is settled in period $t = 1$ with the final payment being net of collateral $p - k$. That is the seller delivers the good against the net payment of $p - k$; i.e., there is perfect enforcement of the contract.

To summarize, we have a basic problem of moral hazard where risk taking by a contracting party increases counterparty risk. The private benefit B is valuable for the buyer, but decreases the expected surplus from trading. I assume for reasons of tractability that buyers need to receive at least an expected surplus of $c > 0$ from trading with a seller. Furthermore, I am restricting the range of B to be

$$(1 - \epsilon)\rho v \geq B \geq \rho c. \tag{3}$$

As will become clear later, this restriction ensures that the buyer prefers the private benefit B given the increase in counterparty risk ρ and the surplus c from trading. It also ensures and that any contract will feature a total payment that exceeds collateral postings ($p \geq k$). The latter restriction thus ensures that we indeed have a forward contract with net settlement of contracts not in default. For later reference, I denote the highest and the lowest level of counterparty quality that fulfill these restrictions by $\underline{B}$ and $\bar{B}$.

III. CCP Clearing and Unobservable Counterparty Risk

A. *Collateral Choice with Bilateral Clearing*

Collateral in the form of a prepayment k can serve two different roles. First, it can be used to provide incentives, with the buyer putting up a bond that prevents him from taking on excessive risk. But collateral also insures the seller against counterparty risk independent of the buyer's decision to take on additional risk. Hence, collateral serves a dual role as an insurance and incentive device, while controlling the default risk a seller faces.

To make this more precise, the incentive constraint for the buyer not to engage in risk taking is given by

$$-\mu k + (1 - \epsilon)(v - p + k) \geq -\mu k + B + (1 - \rho)(1 - \epsilon)(v - p + k) \tag{4}$$

or

$$(1 - \epsilon)(v - p + k) \geq \frac{B}{\rho}. \tag{5}$$

The buyer weighs the expected benefit from obtaining the good $v - p + k$ against the gain from obtaining the (risk-weighted) benefit B. Note that when making a decision about B, collateral k is sunk. Hence, an increase in collateral k relaxes the constraint, as it increases the benefit from surviving and settling the contract with the seller. It is in this sense that collateral provides incentives. The buyer also needs to receive a minimum expected surplus from the contract given by

$$-\mu k + (1-\epsilon)(v - p + k) \geq c. \tag{6}$$

Any contract that satisfies these two constraint I call an *incentive contract*, since collateral provides incentives against risk taking.

Alternatively, the contract could violate the incentive constraint (5). In order for the buyer to have an incentive to increase risk ($\lambda_B = 1$) it must be the case that

$$(1-\epsilon)(v - p + k) \leq \frac{B}{\rho}. \tag{7}$$

The participation constraint then becomes

$$-\mu k + (1-\epsilon)(1-\rho)(v - p + k) \geq c, \tag{8}$$

where the surplus from the transaction is adjusted for the lower probability of settling the transaction. Note that I assume here that the seller cannot extract the additional surplus B from the buyer through the contract terms (p, k). Hence, sellers are never in favor of the buyer taking on risk, because they can extract part of the private benefit B from the buyer.[9] In other words, moral hazard is *not collusive*, an assumption I will change below. Still sellers might be in favor of higher counterparty risk, if preventing moral hazard through collateral leads to deadweight costs that are too high. I call such a contract an *insurance contract*, since collateral only serves as insurance in case of a counterparty default.

A seller will choose between the two types of contracts to maximize his expected utility which – neglecting production costs – is given by

$$\Big(\epsilon + (1-\epsilon)\rho\lambda_B\Big)u(k) + \Big(\epsilon + (1-\epsilon)(1-\rho\lambda_B)\Big)u(p). \tag{9}$$

The participation constraint will be binding for both type of contracts. The reason is straightforward. If the participation constraint was not binding for an incentive contract, the seller could increase collateral k. This relaxes the incentive constraint and increases utility. For an insurance contract, the seller could increase p which also relaxes the reverse incentive

[9] One can interpret the private benefit B to be independent of the transaction itself. Hence, collateral only serves as a way to control for general risk taking by buyers unrelated to the transaction.

constraint. We thus have a single constraint which for an incentive contract is given by

$$k \geq \frac{1}{\mu}\left(\frac{B}{\rho} - c\right) \tag{10}$$

and for an insurance contract by

$$k \leq \frac{1}{\mu}\left(\frac{B(1-\rho)}{\rho} - c\right). \tag{11}$$

Hence, given any level B of counterparty quality, collateral is lower in insurance contracts than in incentive contracts implying higher counterparty risk. Furthermore, an insurance contract will only be feasible if $B \geq c\rho/(1-\rho)$.

The trade-off between the two contracts is straightforward. The seller has in principle any incentive to control counterparty risk. First, an incentive contract keeps the default probability at ϵ. Second, it increases the expected surplus from the contract for the buyer, thereby enabling the seller to charge a higher price p. An incentive contract, however, requires collateral to be posted. Collateral is costly here as requiring it reduces the total amount of gold p that a seller can charge for his good. The cost arises from the fact that there is a deadweight cost for posting collateral ($\mu > 1$). Hence, when the risk-weighted private benefit B/ρ is sufficiently high, the seller might find it optimal to save on collateral, forego incentives and offer an insurance contract instead. While such a contract increases the counterparty risk for the seller, it will help save on collateral costs. This is formalized in the next proposition.

Proposition 1: *For any given level of counterparty quality, lower collateral implies higher counterparty risk.*

The optimal incentive contract has a fixed level of collateral for $B \in [\underline{B}, B^*]$ *and an increasing level of collateral for* $B \in [B^*, \bar{B}]$.

The optimal insurance contract has an increasing level of collateral for $B \in [\underline{B}/(1-\rho), B_0]$ *and a fixed level of collateral for* $B \in [B_0, \bar{B}]$.

Figure 1 summarizes this result. Optimal collateral policies for incentive contracts need to have sufficiently high levels of collateral, while for insurance contracts collateral needs to be sufficiently low in order for the buyer to engage in risk taking. The slope of the constraints reflects the marginal cost of collateral for the buyer. As long as these constraints are not binding, the optimal contract equates the seller's marginal utility across the default and the

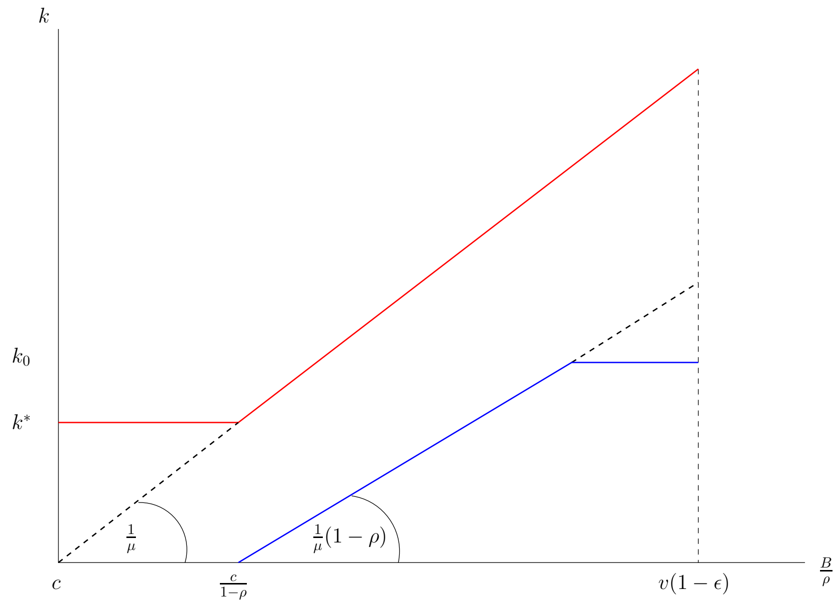

Figure 1: Optimal one-period contracts in terms of risk-weighted private benefit B/ρ

no default states. An incentive contract features first a constant level of collateral as the seller seeks insurance against the exogenous default probability ϵ. As the counterparty quality becomes worse, collateral needs to be increased in order to prevent risk taking. Eventually, at $\bar{B}$, collateral becomes so high that the entire contract is prepaid ($p = k$) which is equivalent to a spot transaction on the seller's side. To the contrary, for low levels of B, an insurance contract is not feasible. Then, collateral starts to increase, until the counterparty quality is sufficiently bad (i.e., B/ρ is large), so that the first-best level of collateral in an insurance contract becomes feasible.

The choice of contract for the seller is driven by collateral costs. With an incentive contract, for good counterparty quality, the utility for the seller is first independent of B/ρ, while it decreases as collateral begins to rise. For an insurance contract exactly the opposite is the case. Utility for the seller first increases when counterparty quality gets worse and then stays constant once insurance against default is at its optimal level. Hence, incentive contracts are optimal if and only if counterparty quality is sufficiently good. This yields the following implication.

Corollary 2: *If the level of counterparty quality in a transaction is unobservable, an outside* *observer cannot necessarily infer the counterparty risk of the transaction from the collateral level alone.*

To understand this result, one has to realize that it can be *efficient* for both counterparties to incur higher counterparty risk. Collateral is never set "too low" from the perspective of the counterparties once they take into account that collateral is costly. As a consequence, collateral can be low in transactions, because either counterparty quality is good or because counterparty quality is so low that sellers optimally save on collateral costs. For example, set $\epsilon = 0$. Collateral in incentive contracts ranges then from 0 to $\frac{1}{\mu}(v - c)$, but collateral levels for all feasible insurance contracts also fall into this interval independent of B. More generally, if the upper bound on optimal collateral levels for insurance contracts exceeds the lower bound for incentive contracts – as shown in in Figure 1 – one cannot deduce default likelihoods from collateral levels alone. Hence, one must conclude that any empirical work or policy discussion cannot deduce the likelihood of default – or, equivalently, the counterparty risk – from exclusively looking at levels of collateralization without assessing the quality of the counterparties in a transaction.

B. Minimizing Counterparty Risk with Minimal Collateral Costs

If counterparty risk in individual transactions is not observable for a CCP, at what cost can the CCP control such risk? When clearing a transaction, the CCP imposes collateral requirements, but takes the terms of trades of any transaction as given. To be more specific, the CCP can only observe the price of a transaction, but not the level of counterparty quality B associated with the transaction. Its policy is to set collateral $k(p)$ as a function of the transaction price.[10]

I assume that a CCP engages in novation of trades; i.e., it assumes all obligations from financial trading, becoming the buyer and the seller to every transaction. For any collateral policy $k(p)$ the revenue of the CCP associated with transactions at price p is given by

$$R(p) = (\epsilon + (1 - \epsilon)\rho\lambda_B)\, k(p) + ((1 - \epsilon)(1 - \rho\lambda_B))\, p, \tag{12}$$

where $\rho\lambda_B$ expresses the additional default risk associated with transactions at price p –

[10] I do not allow the CCP to use a direct mechanism, where it sets both the price and the collateral for a transaction. Such a mechanism would directly determine the terms of trade and, thus, would go beyond clearing. Also, I do not allow trading parties to make a choice about clearing bilaterally or centrally (see for example Koeppl et al. (2011)) which would put further restrictions on central clearing.

a slight abuse of notation. The CCP receives payments in the form of collateral $k(p)$ at $t = 0$ from all buyers and net settlement $p - k(p)$ at $t = 1$ from all surviving buyers. The CCP pools all payments associated with a transaction price p and pays out its revenue as an average payment of $R(p)$ to sellers that have written contracts at that particular price p. Similarly, it collects all goods from sellers and delivers them to buyers. Such novation allows the CCP to diversify counterparty risk across transactions.[11]

Sellers take the collateral policy $k(p)$ as given and make a take-it-or-leave-it offer to a buyer in terms of the price p. Hence, when negotiating an offer both parties are aware of what collateral will be requested for the transaction by the CCP. I show next that the CCP can set up a collateral schedule that fully reveals counterparty quality B and simultaneously controls for counterparty risk in the cheapest possible way.

Proposition 3: *The linear collateral schedule*

$$k(p) = \left(\frac{(1-\epsilon)}{\mu - (1-\epsilon)}\right)(\bar{p} - p)$$

where $\bar{p} = v - c/(1-\epsilon)$ implements the cheapest incentive contracts for all B; i.e., given this policy there exists a unique, strictly decreasing function $p(B) : [\rho c, \rho v(1-\epsilon)] \longrightarrow \mathbb{R}_+$ such that for all levels of counterparty quality transactions are incentive contracts with price $p(B)$ and default only occurs with probability ϵ in all transactions.

The intuition for this result is as follows. Sellers would like to get the highest payment from the CCP. As long as the revenue function $R(p)$ is strictly increasing, they would like to transact at the highest price. The collateral schedule simply mirrors the participation and incentive constraints when sellers quote the price for the efficient incentive contract associated with the level of counterparty quality B they are facing. Sellers of course would like to misrepresent the level of quality B in the transactions and quote a higher price, as this signals better counterparty quality and lowers collateral. However, this is not feasible

[11]The CCP could alternatively pool *all* payments it receives and make payments proportional to the value p of a contract. The CCP's revenue is then given by

$$R = (\epsilon + (1-\epsilon)\rho\lambda_B) \int k(p(i))di + ((1-\epsilon)(1-\rho\lambda_B)) \int p(i)di,$$

with payouts equal to

$$\frac{p(i)}{\int p(i)di} R.$$

While payouts are still strictly increasing in p, this would allow for cross-subsidization between low and high surplus transactions which is not relevant for my analysis here.

for a subtle reason. At the higher price, collateral required by the CCP would be too low to prevent a buyer with quality B from engaging in risk taking. But then the buyer would not receive enough expected surplus from entering into the contract and, thus, declines the offer. Hence, sellers cannot overstate their counterparty's quality.[12]

This conflict of interest between seller and buyer allows the CCP to minimize counterparty risk for all transactions very cheaply – i.e, with the cheapest incentive contract. The cost of doing so, however, is that the CCP cannot implement insurance contracts anymore that have high counterparty risk, but low collateral costs. To be more precise, consider an insurance contract for any given value of B. CCP clearing pools counterparty risk and, thus, diversifies it. For an insurance contract, it is then optimal not to require collateral anymore ($k_0(B) = 0$ for all B), since collateral is a costly and an imperfect substitute to diversifying counterparty risk. Hence, with CCP clearing, the payoff from any insurance contract would be given by

$$R_0 = (1-\epsilon)(1-\rho)p_0 = (1-\epsilon)(1-\rho)\left(v - \frac{c}{(1-\epsilon)(1-\rho)}\right), \tag{13}$$

where we have used the optimal price charged by the seller for such a contract when it is cleared through a CCP. As a consequence, insurance contracts become even more attractive for sellers relative to incentive contracts for low levels of counterparty risk. Similarly, diversification lowers collateral costs for incentive contracts, but only below some threshold for B (see Figure 1). This yields the following result.

Proposition 4: *Suppose $\mu(1-\rho) > 1$. There is no collateral policy that simultaneously implements optimal incentive and insurance contracts for all levels of counterparty quality B.*

With CCP clearing, insurance contracts however are optimal for the contracting parties whenever

$$B > \rho\left(\bar{B}\frac{\mu}{\mu-1} + c\right).$$

The unique price of an optimal insurance contract with CCP clearing conincides with a price that is also associated with an optimal incentive contract for some quality B. Observing only this price, the CCP cannot determine whether the transaction stems from an insurance contract for high counterparty risk or from an incentive contract with low counterparty risk,

[12]Note that collateral is negatively related with transaction prices which seems counterintuitive. But this is due to transactions having different levels of counterparty quality. Holding quality constant, the incentive constraint still implies that prices and collateral move in the same direction.

which require different collateral policies. As a consequence, when counterparty risk is not observable, the CCP needs to decide between implementing *either* incentive contracts *or* insurance contracts; it cannot do both.

If the CCP wants to minimize counterparty risk, it of course needs to opt for incentive contracts only. Such a policy would prevent insurance contracts from being chosen, even though such contracts would potentially offer more expected surplus for sellers in exchange for high counterparty risk. CCP clearing would thus preclude transactions from taking place when counterparty quality is too low, as collateral costs would be too high – given production costs θ – to render a positive surplus from the transaction. I call this effect a reduction in market liquidity and I will investigate it further in Section IV below.

C. CCP Clearing and Collusive Moral Hazard

So far, sellers were not in favor of buyers engaging in risk taking. I now change my framework slightly and assume that buyers can realize their private benefit B only if they have a transaction with a seller. This implies that sellers can hold up buyers and, therefore, can extract additional surplus from buyers when these realize their private benefit B. Insurance contracts are now more attractive to sellers, since the surplus for buyers on those contracts is now higher, yielding the participation constraint

$$-\mu k + (1-\epsilon)(1-\rho)(v - p + k) + B \geq c. \tag{14}$$

Sellers might now prefer larger counterparty risk because this enables them to extract the private benefit B from buyers by quoting a larger price p. Importantly, the incentives for increasing counterparty risk are thus aligned and moral hazard is *collusive* with incentives for risk taking being larger when counterparty quality becomes worse. The buyer still needs incentives to increase counterparty risk, so that the incentive constraint remains

$$k \leq \frac{1}{\mu}\left(\frac{B}{\rho} - c\right), \tag{15}$$

where I have already taken into account that the participation constraint will again bind for the optimal insurance contract. To the contrary, incentive contracts are identical to the previous analysis, since buyers have no incentive to realize the private benefit B. We then have the result that for a sufficiently high private benefit, there is collusion to increase counterparty risk.

Proposition 5: *There exists a level of counterparty quality $\hat{B} \in [\rho c, \rho v(1-\epsilon))$ such that sellers prefer insurance contracts with high counterparty risk if and only if $B \geq \hat{B}$.*

Consider again a CCP that chooses a collateral policy $k(p)$ to minimize counterparty risk, but is not able to observe the counterparty quality B, only transaction prices. The collateral policy of Proposition 3 is now not incentive compatible anymore. When CCP revenue $R(p)$ is increasing in the price, the seller has an incentive to charge the highest price, $\bar{p} = v - c/(1-\epsilon)$, at which the collateral policy requires zero collateral. Since buyers can obtain benefit B only when they are in a trade, they will accept this higher price as it gives them higher expected utility than their outside option c. Hence, collusion about increasing counterparty risk prevents the CCP from implementing the best incentive contracts. Indeed, I find that such collusion forces the CCP to implement the most expensive collateral policy when minimizing counterparty risk.

Proposition 6: *When moral hazard is collusive, for minimizing counterparty risk the CCP needs to employ the most costly collateral policy given by*

$$k(p) = k(\bar{B}) = \frac{1}{\mu}\left(v(1-\epsilon) - c\right) \tag{16}$$

for all p.

Collusion about increasing counterparty risk thus forces a CCP to clear all trades at collateral levels that are set for the worst counterparty quality $\bar{B}$. The difference with the previous section is now that buyers can realize their private benefit only when they are in a contract with a seller. Sellers can now offer a contract with a higher price (and lower collateral) that induces buyers to increase counterparty risk. Buyers are willing to accept these terms of trade, as they can realize their private benefit B only when contracting with a seller. A CCP therefore needs to employ a collateral policy $k(p)$ so that there is no contract $(k(p), p)$ that would give incentives to raise counterparty risk *for any* level of counterparty quality B. As a consequence, the lowest level of counterparty quality $\bar{B}$ determines the entire collateral policy.

CCP clearing then raises costs of OTC transactions in two ways. First, as before it precludes insurance contracts by forcing collateral to be high enough so that buyers do not engage in risk taking. But now there is a second channel where the necessity to provide incentives against collusive risk taking increases collateral costs *on all* incentive contracts. Indeed, CCP clearing treats every transaction as one where counterparty risk is at the highest level, thereby forcing all incentive contracts to take place at the highest costs with the lowest surplus. Furthermore, the better the counterparty quality is in a transaction the larger is the increase in costs.

This is in stark contrast to my earlier result where there was no increase in collateral costs for transactions with high counterparty quality when sellers had an interest to control counterparty risk in the first place. As extreme as this result is, it demonstrates how damaging collusion about risk taking is for the effectiveness of central clearing. As collateral costs increase, some transactions might again not be viable anymore and, thus, liquidity in the market will be adversely affected. In the next section, I analyze a different amplification channel on collateral costs that works off such a fall in liquidity. For this channel to work, however, collusive moral hazard is *not* a necessary feature, so that I revert back to my earlier setting where the private benefit B cannot be extracted from the buyer.

IV. CCP Clearing and Market Liquidity

A. Search Costs and Repeated One-Period Contracts

To obtain a notion of market liquidity, I extend the static framework without collusive moral hazard to a dynamic one. Sellers and buyers are randomly matched. When matched, they stay together and contract until either the buyer dies or the seller terminates the relationship. I restrict attention to one-period (static) contracts,[13] where the seller agrees to produce one unit of the good in exchange for a contract (p, k). The future is discounted at a rate $\beta \in (0, 1)$ and I assume that $\epsilon = 0$ to facilitate the analysis. Hence, if buyers do not realize their private benefit ($\lambda_B = 0$), there is no counterparty risk.

The timing in each period is as follows. First, all sellers matched with a buyer make a take-it-or-leave-it offer. Next, buyers chose whether to introduce counterparty risk into the relationship (λ_B). After observing the buyer's choice,[14] the seller makes a decision to terminate the relationship or not, expressed as $\lambda_S \in \{0, 1\}$. If he does so ($\lambda_S = 1$), he and the buyer (conditional on surviving) are matched with new counterparties for trading

[13]This assumption is mainly made for tractability, but is reasonable when thinking about financial trades as shorter term transactions in which the same set of counterparties enters repeatedly.

[14]The analysis for the case where λ_B cannot be observed by the seller in the match is straightforward and is available upon request. I could also allow the seller to pay a fixed cost $q_M > 0$ in order to observe the decision λ_B. This cost would simply increase the upfront costs of entering a contract.

next period with probability $\sigma \in (0,1)$ which I treat as exogenous for now. If he does not ($\lambda_S = 0$) and the buyer dies, he will have to wait one period before he is matched again with a buyer which happens with probability σ. Finally, buyers die or survive and the contract is executed for the period.

I first treat the probability of finding a new counterparty σ as exogenous and consider a single, fixed level of couterparty risk B. To characterize the subgame-perfect Nash equilibria of the game between sellers and buyers, I first look at the decision for sellers to terminate a relationship with a buyer. Denote V_i^S as the value function for the seller depending on whether he is in a match ($i = 0$) or not ($i = 1$). Since the terms of the current one-period contract (p, k) are sunk, the seller will continue the relationship as long as

$$(1 - \rho\lambda_B)\beta V_1^S + \rho\lambda_B\beta V_0^S \geq V_0^S. \tag{17}$$

The left-hand side shows the value for the seller of continuing the relationship. Depending on λ_B – i.e., whether the buyer takes on risk or not – he will either have a transaction next period (V_1^S) or none (V_0^S), in which case he has to wait one period for potentially being matched again. The right-hand side expresses the value for the seller of terminating the relationship immediately. In that case, the seller will be in a match next period with probability σ again. Hence, his value function of being without a match at the end of the period is given by

$$V_0^S = \frac{\sigma}{1 - \beta(1 - \sigma)}\beta V_1^S \left(\equiv \beta\chi V_1^S\right), \tag{18}$$

where $\chi < 1$. Hence, the seller continues the relationship if and only if

$$\left[(1 - \rho\lambda_B) - \sigma\right]\beta\left(V_1^S - V_0^S\right) \geq 0. \tag{19}$$

Whether the relationship is maintained depends on the search cost, $1 - \sigma$, and the risk of default, ρ. The seller will ensure to have the highest probability of trading next period *independent* of the type of the contract. When there is default and the seller has not terminated the relationship and searched for a new counterparty, he will not have a transaction next period for sure. The alternative is to search immediately for having a chance at a trade next period.

When search costs are large ($\sigma < 1 - \rho$), only long-term contractual relationships take place, since continuing the relationship ($\lambda_S = 0$) is a strictly dominant strategy for the seller independently of whether there is counterparty risk or not. The analysis is then identical to the static framework with one-period incentive and insurance contracts. If search costs are small, however, the seller's decision whether to terminate the relationship or not will depend on the buyer's decision to increase counterparty risk. I show next that the threat of terminating the relationship can act as a cheap substitute for collateral to provide incentives.[15]

B. *Market Discipline and Collateral Choice*

Assume that $\sigma \geq 1 - \rho$. Taking his strategy $\lambda_S(\lambda_B)$ as given, a seller will again choose between an incentive and an insurance contract. With an insurance contract the seller bears counterparty risk, so that his best response is to terminate the relationship $\lambda_S = 1$ after one period. For an incentive contract, however, the continuation decision for the seller can now depend directly on the observed action λ_B. It follows immediately from condition (19) that the seller will continue the relationship if and only if there is no counterparty risk, or

$$\lambda_S(\lambda_B) = \begin{cases} 1 & \text{if } \lambda_B = 1 \\ 0 & \text{if } \lambda_B = 0. \end{cases} \tag{20}$$

Hence, with an incentive contract the seller can credibly threaten to terminate the relationship whenever the buyer increases counterparty risk. The reason is simple. When continuing, the farmer faces an increased default risk $\rho > 0$ which outweighs the risk of not finding a new counterparty for next period. I call a subgame-perfect Nash equilibrium that uses this punishment strategy *market discipline*.

With market discipline (see Equation (20)), the baker's incentive constraint is given by

$$-\mu k + (v - p + k) + \beta V_1^B \geq -\mu k + B + (1 - \rho)\left((v - p + k) + V_0^B\right), \tag{21}$$

where V_1^B is the value function for the baker when he is in a match next period and V_0^B is the value of being without a match at the end of the period, since the relationship has been terminated by the seller. The buyer has then again a chance σ to find a new trade next period. Hence, the buyer will choose $\lambda_B = 0$ as long as

$$\rho\left((v - p + k) + \beta V_1^B\right) + (1 - \rho)\left(\beta V_1^B - V_0^B\right) \geq B. \tag{22}$$

The second term on the right-hand side expresses the effect of market discipline on the in-

[15]Introducing an exogenous default probability $\epsilon > 0$ would yield an additional third region where for $\sigma \in (1 - \epsilon, 1)$ all relationships are short-term, while the cut-off value for the other regions would change to $(1 - \epsilon)(1 - \rho)$.

centives of buyers to realize their benefit B through risk taking. The participation constraint is given by[16]

$$V_1^B = -\mu k + \left[(v - p + k) + \beta V_1^B\right] \geq c. \tag{23}$$

Since $V_0^B = \beta\chi V_1^B = \beta\chi c$, a seller making a take-it-or-leave-it-offer for an incentive contract now faces the incentive constraint

$$k \geq \max\left\{0, \frac{1}{\mu}\left(\frac{B}{\rho} - c - \left(\frac{1-\rho}{\rho}\right)(1-\chi)\beta c\right)\right\}. \tag{24}$$

The last term in this expression is positive since $\chi < 1$ and reflects that a credible threat to punish risk taking can relax the incentive constraint, so that it is possible to save on collateral. With insurance contracts, the buyer will engage in risk-taking. Hence, it is optimal for the seller to terminate the relationship after a single trade. This gives the buyer also the chance to find a new seller again next period. Given the value of the buyer at the end of the period, V_0^B, the constraints for an insurance contract are now given by

$$V_1^B = -\mu k + (1-\rho)\left[(v - p + k) + V_0^B\right] \;\geq\; c \tag{25}$$

$$\rho\left[(v - p + k) + V_0^B\right] \;\leq\; B. \tag{26}$$

This yields the corresponding incentive constraint for insurance contracts

$$0 \leq k \leq \frac{1}{\mu}\left(\frac{B(1-\rho)}{\rho} - c - \left(\frac{1-\rho}{\rho}\right)(1-\chi)\beta c\right). \tag{27}$$

Figure 2 summarizes the optimal incentive and insurance contracts in terms of the collateral choice with market discipline. Prices are set by the seller such as to extract all surplus – up to the constant c – from the buyer. Compared to the static environment (see Figure 1), collateral requirements shift down in the presence of market discipline for any level of counterparty quality B. Since there is no exogenous default risk anymore, it is optimal to set collateral in incentive contracts as low as possible. As a consequence, with sufficiently low levels of counterparty risk, we get that collateral is also low – here $k = 0$. This yields the following result.

Proposition 7: *Suppose $\rho > 1 - \sigma$. Incentive contracts are used in long-term trading relationships, while insurance contracts are used in short-term ones. If counterparty quality is sufficiently high, the optimal contract is an incentive contract and optimal collateral is*

[16] To facilitate comparison with the static framework, I set the value of the buyer's outside option c in units of life-time expected utility.

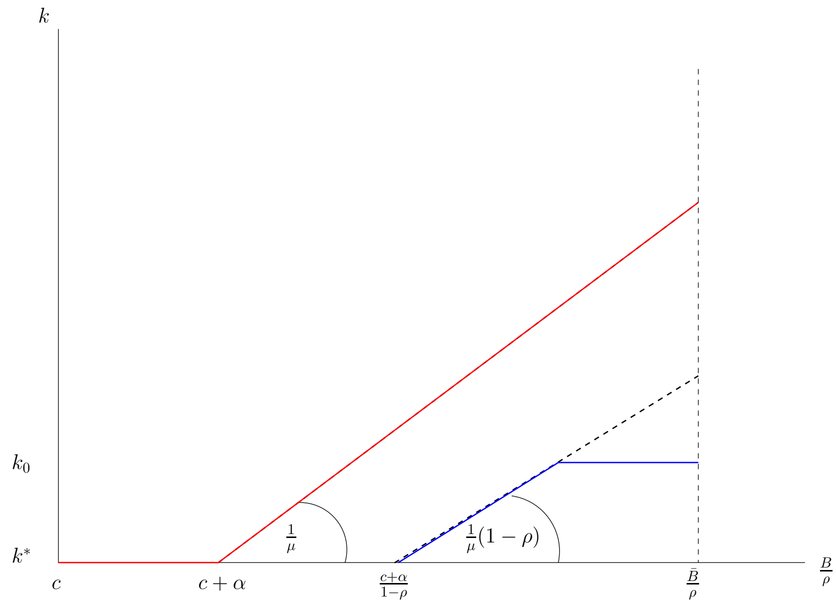

Figure 2: Optimal contracts with market discipline for risk-weighted private benefit B/ρ

$k = 0$.

Higher market liquidity necessitates higher collateral for incentive contracts and makes taking on counterparty risk more attractive.

This is interesting for two reasons. First, for sufficiently high market liquidity, punishment is a credible (and cheap) incentive mechanism making short-term insurance contracts less likely. As a consequence, we can have again a positive correlation between collateral and counterparty risk as in the static problem analyzed earlier. But here, transactions over a range of counterparty quality B can be free of counterparty risk even though no collateral has been posted.

Second, lower liquidity strengthens market discipline, as the potential punishment in the form of a short-term relationship for the buyer is more severe. Hence, market discipline is stronger in markets that are less liquid allowing the seller to require less costly collateral to safeguard against counterparty risk. However, if market liquidity is too low ($\sigma < 1 - \rho$), market discipline will not work any longer, as the seller's threat to break off the trading relationship is not credible anymore. Consequently, the relationship between market liquidity and the incentives to take on counterparty risk is non-monotonic.

C. CCP Clearing and Endogenous Market Liquidity

I investigate next whether CCP clearing can have a detrimental effect on market liquidity. A CCP again sets collateral requirements as a function of prices, as it cannot observe counterparty quality B in the transactions. I assume further that counterparty quality is now distributed according to some distribution function $F(B)$ on the support $[\underline{B}, \bar{B}]$.[17] To render the distribution of counterparty quality time invariant, any buyer that dies is replaced by a new buyer with exactly the same characteristics as the one that died.

Denote $\mathcal{B} \subset [\underline{B}, \bar{B}]$ the set of counterparty qualities such that a seller has an expected benefit from a transaction that exceeds the production cost θ. The value function of a seller searching for a counterparty is given by

$$\begin{aligned} V_0^S &= \beta\sigma\mathcal{P}(B \in \mathcal{B})E_{\mathcal{B}}[V_1^S(B)] + \beta(1-\sigma\mathcal{P}(B \in \mathcal{B}))V_0^S \\ &= \frac{\tilde{\sigma}}{1-\beta(1-\tilde{\sigma})}\beta E_{\mathcal{B}}[V_1^S(B)] = \chi\beta E_{\mathcal{B}}[V_1^S(B)], \end{aligned} \tag{28}$$

where $E_{\mathcal{B}}$ is the expectation over counterparty quality conditional on the set $\mathcal{B}$ and $\tilde{\sigma} = \sigma\mathcal{P}(B \in \mathcal{B})$ is now the endogenous probability of finding a new profitable transaction. We then have the following generalization of the seller's decision to continue a trading relationship with a buyer.

Lemma 8: *The seller's optimal strategy is given by*

$$\begin{aligned} \lambda_S &= 0, \text{ if } \frac{V_1^S(B)}{E_{\mathcal{B}}[V_1^S(B)]} \geq \alpha(1) \\ \lambda_S &= 0 \text{ iff } \lambda_B = 0, \text{ if } \alpha(1) \geq \frac{V_1^S(B)}{E_{\mathcal{B}}[V_1^S(B)]} \geq \alpha(0) \\ \lambda_S &= 1, \text{ if } \alpha(0) \geq \frac{V_1^S(B)}{E_{\mathcal{B}}[V_1^S(B)]}, \end{aligned}$$

where

$$\alpha(\lambda_B) = \left(\frac{1-\rho\beta\lambda_B}{1-\rho\lambda_B}\right)\chi.$$

When the current counterparty quality B is sufficiently good relative to the average quality of a new trading partner, it is a strictly dominant strategy for the seller to continue the

[17] Note that the values of $\underline{B}$ and $\bar{B}$ differ from the static environment and are now endogenous. The former expresses the threshold of the private benefit B for buyers to be willing to take on risk. The latter is the threshold of B where incentives can only be provided through a forward contract with full prepayment ($p = k$).

relationship independent of the one-period contract being used. The opposite is true if the current quality is too low. In the intermediate region, we again obtain market discipline: the seller breaks off the relationship if and only if the buyer engages in risk taking. In this region, the one-period contract choice by the seller – insurance or incentive contract – once again determines the continuation decision.

I now construct a simple example where CCP clearing amplifies collateral requirements due to a fall in market liquidity. In this example, there are only two levels of counterparty quality $B_L < B_H$ and – in the absence of CCP clearing – the optimal contracts for the two levels of counterparty quality are an incentive contract governed by market discipline and an insurance contract, respectively. Throughout the example, I assume again that $\rho > 1 - \sigma$.

Proposition 9: *Suppose that there are only two levels of counterparty quality. If $1 - \sigma$ and ρ are sufficiently close to 0, there exist $B_L < B_H$ such that the optimal contract for B_L features market discipline while the one for B_H is an insurance contract.*

The intuition for this result is as follows. When it is very likely to find a new transaction next period (σ close to 1) and counterparty risk is small (ρ close to 0), insurance contracts are cheap and not very risky. Incentive contracts, however, are expensive whenever counterparty quality is low, since they require a high level of costly collateral. This implies that with bad counterparty quality we have one-period trading with counterparty risk, while with good counterparty quality we have long-term trading with no counterparty risk. To ensure market discipline for the level $B_L < B_H \leq \bar{B}$, it must then be the case that

$$\alpha(1) \geq \frac{V_1^S(B_L)}{V_1^S(B_H)} \geq \alpha(0), \tag{29}$$

since all new trades for sellers will be with buyers of bad counterparty quality B_H. Since $\chi < 1$ and $\rho > 1-\sigma$, one only needs to find some level B_L, where the seller's value for offering an optimal incentive contract to the buyer of high counterparty quality is close enough to the one associated with the insurance contract at B_H. Figure 3 shows the value for incentive and insurance contracts as a function of counterparty quality B assuming market discipline. Note that the value of incentive contracts is decreasing in B, while the value of insurance contracts is strictly increasing. As shown in the graph, as long as insurance contracts are preferred at some level B_H, there must exist some level $B_L < B_H$, where an incentive contract yields the same payoff for sellers. Hence, I can pick the level of counterparty quality B_L such that the inequality (29) is fulfilled.

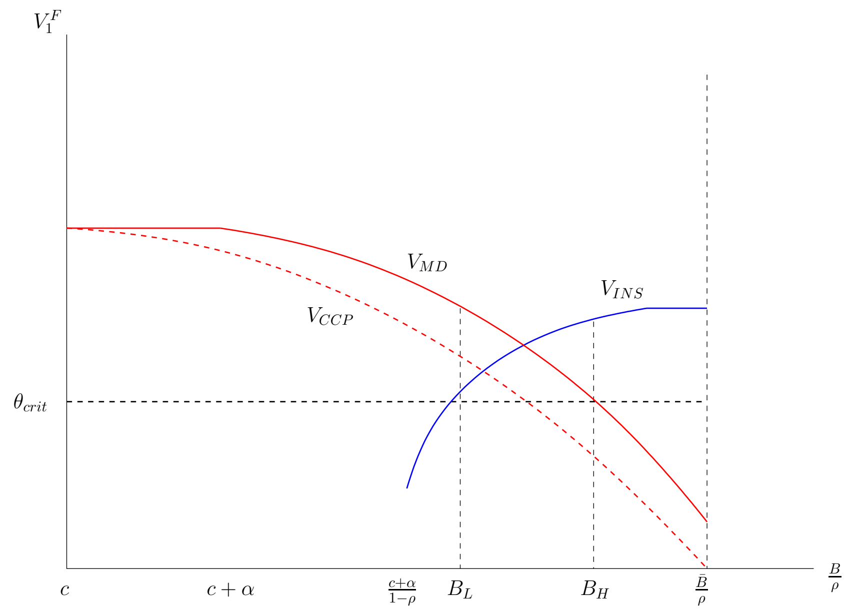

Figure 3: Contract Values for Sellers with Market Discipline, Insurance and CCP Clearing

Consider now again a CCP like in Section III that minimizes counterparty risk and, thus, rules out insurance contracts through its collateral policy. For sellers facing bad counterparty quality B_H, CCP clearing will depress the surplus of trading since the transaction will face higher collateral requirements. If the surplus falls sufficiently, sellers will not have an incentive anymore to engage in trading with buyers of bad counterparty quality. This is shown in Figure 3 by the level of the production cost θ_{crit} where incentive contracts with market discipline become infeasible for B_H.

With only two levels of counterparty quality, this drop in liquidity is severe. After terminating a relationship with a buyer, there are no trading opportunities for the seller anymore ($\tilde{\sigma}$ falls to 0), as he will only meet buyers with bad counterparty quality B_H. This renders market discipline infeasible, since threatening to terminate a relationship as a punishment for increasing risk on a transaction is not credible anymore. As a consequence, collateral requirements need to increase also for trades where counterparty quality is B_L.

Corollary 10: *Suppose a CCP minimizes counterparty risk. If the CCP's collateral policy renders transactions at B_H infeasible, market discipline fails and collateral requirements have to increase for transactions at B_L without changing counterparty risk.*

It is difficult to obtain more general analytical results beyond the case where there are only two levels of counterparty quality. The general message, however, remains the same. CCP clearing can prevent transactions with bad counterparty quality to take place by forcing higher collateral requirements on these transactions. The ensuing drop in market liquidity can interfere with market discipline. This has an adverse impact on transactions with good counterparty quality, as the CCP now also needs to increase collateral for transactions that had no counterparty risk in the first place – in other words, CCP clearing amplifies collateral requirements for any given level of counterparty risk.

V. Implications for Market Infrastructure

Much of the discussion about extending central clearing to OTC derivatives trading has focused on collateralizing credit exposures. The presumption is here that low collateral in transactions is a sign of increased counterparty risk which is inefficient. I have shown however that such a correlation is far from perfect. The reason is that counterparties can vary in how risky they are and in their incentives to increase their riskiness as a counterparty. Moreover, presuming that collateral levels are set to maximize the surplus from trading, minimizing counterparty risk is not necessarily efficient for all levels of counterparty risk.

To be more specific, I have demonstrated that observed collateral levels are likely to depend also on two other important variables: the quality of a counterparty as well as the liquidity in the market. Collateral levels will be lower the better the counterparty quality is, whenever market participants take into account both, the likelihood of a default and the loss given a default. Moreover, long-term trading relationships among major market participants can help to control risk taking among counterparties. The effectiveness of market discipline exerted by such relationships depends on how easy it is to replace a counterparty in the market – or in other words, how thick a market is. Hence, any empirical work that does not control for these two elements is likely to uncover a severely misspecified relationship between actual counterparty risk and the use of collateral.

There are many reasons for introducing CCP clearing with the objective to reduce counterparty risk below levels that are privately optimal for any single market participant. Such a reduction would lead to an increase in collateral levels and, thus, trading costs. But there are two channels which could aggravate such costs. When there are incentives to collude on increasing counterparty risk in transaction, the CCP might be forced to set even higher collateral requirements for these transactions. Beyond such moral hazard, a fall in market liquidity due to higher transaction costs could compromise market discipline. Again, any work that quantifies collateral requirements for a given level of counterparty risk is likely to underestimate the total amount of collateral required when not taking into account these two channels.

This raises the question which markets are the most conducive to CCP clearing. I conclude that CCP clearing is likely to be most effective in markets that are sufficiently liquid, where counterparties are homogeneous and the potential for risk taking is not too severe. As I have shown, CCP clearing will need to increase collateral requirements, if it intends to lower counterparty risk relative to what market participants deem privately optimal. But CCP clearing can perform well if the ensuing increase in transaction costs will not affect liquidity very much. Similarly, if counterparty quality does not differ much across market participants, CCP clearing need not worry about idiosyncratic differences in risk, but can assume an overall market-wide assessment of counterparty risk instead.

These features are likely to occur in markets that are "lit" such as formal exchange trading, whereas "dark" markets like OTC markets tend to have the opposite characteristics. Furthermore, certain transactions like derivatives transactions offer much potential for increasing counterparty risk, whereas spot transactions tend to offer smaller possibilities for increased risk taking. Of course, derivatives markets are largely over-the-counter, comprising a large set of heterogeneous institutional participants whose quality as a counterparty can not always be readily observed or assessed. This of course makes market discipline through long-term trading relationships an important element of this market structure. Hence, there seems to be a hint of irony in the push to have derivatives cleared centrally. On the one hand, it is a pressing issue to control counterparty risk in derivative transactions. But on the other hand, based on my findings central clearing seems to be costly and not very effective in derivatives markets for very different reasons that have been pointed out elsewhere.

Finally, my findings indicate that we need to structure central clearing such as to take into account counterparty quality and liquidity when setting collateral levels. Hence, central clearing needs to move away from mechanically applying collateral standards to control replacement cost risk, which basically is the loss for a CCP from a default. It needs to rely more on information concerning the riskiness of a counterparty and how it changes over time[18], as well as take into account the impact of collateral costs on liquidity which are not well understood. Unfortunately, these channels could turn out to be rather damaging for the scope of central clearing in certain markets such as OTC derivatives.

[18] Here information from ratings or from credit default swap data could be useful to reduce the CCP's disadvantage when assessing counterparty quality (see Pirrong (2009)).

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Appendix

Proof of Proposition 1

Consider first an incentive contract. Since the participation constraint must be binding, we have that the price is given by

$$p = v - \frac{c}{1-\epsilon} - k\left(\frac{\mu}{1-\epsilon} - 1\right). \tag{30}$$

It follows that the optimal contract when the probability of default is given by ϵ is described by

$$\epsilon u'(k) + (1-\epsilon)u'(p)\left(1 - \frac{\mu}{1-\epsilon}\right) + \lambda = 0, \tag{31}$$

where λ is the multiplier on the incentive constraint. Denoting k^* the solution to this equation when $\lambda = 0$, it follows directly that there exists a cut-off level B^* such that the incentive constraint is binding if and only if $B \geq B^*$.

For the insurance contract, it must again be the case that the participation constraint is binding. Consider again the first-order condition

$$u'(k)\left(\epsilon + (1-\epsilon)\rho\right) + (1-\epsilon)(1-\rho)u'(p)\left(1 - \frac{\mu}{(1-\epsilon)(1-\rho)}\right) + \lambda_{NN} - \lambda_{INS} = 0, \tag{32}$$

where $p = v - \frac{c}{(1-\epsilon)(1-\rho)} - k\left(\frac{\mu}{(1-\epsilon)(1-\rho)} - 1\right)$ and the Lagrange multipliers λ_{NN} and λ_{INS} are associated with the constraints

$$k \geq 0 \tag{33}$$

$$k \leq \frac{1}{\mu}\left(\frac{B(1-\rho)}{\rho} - c\right) \tag{34}$$

respectively. Note that $\lambda_{NN}\lambda_{INS} = 0$.

Inspection of the two constraints implies immediately that the constraint set is empty for $B < c\rho/(1-\rho)$. Furthermore, if $u'(0)$ is sufficiently small, $\lambda_{NN} > 0$ so that $k = 0$ for all B. Otherwise, collateral is strictly positive for $B > c\rho/(1-\rho)$ and weakly increases with B.

Suppose next that the insurance constraint is binding at $B/\rho = v(1-\epsilon)$ for the optimal insurance contract. Then, we have that $p = k$ and $\lambda_{INS} > 0$. But this contradicts the first-order condition, since $\mu > 1$. Hence, $k < p$ and collateral remains constant for large enough values of B.

Proof of Proposition 3

Fix $B \in [c\rho, v(1-\epsilon)\rho]$. Given the collateral schedule $k(p)$, there exists a unique price p_B such that

$$\begin{aligned}(1-\epsilon)\rho\Big(v - p_B + k(p_B)\Big) &= B \\ (1-\epsilon)\Big(v - p_B + k(p_B)\Big) - \mu k(p_B) &= c,\end{aligned}$$

i.e., there is a unique incentive contract that extracts all surplus for the farmer given B.

Consider a seller facing a buyer with the degree of moral hazard given by B. Suppose revenue $R(p)$ is increasing in p. Note that this is the case if there is no default, since

$$R(p) = \epsilon k(p) + (1-\epsilon)p.$$

and $\mu > 1$. The seller would then like to negotiate the highest price. Consider any price $p > p_B$. The collateral policy $k(p)$ implies that

$$v - p + k(p) < v - p_B + k(p_B) = \frac{B}{(1-\epsilon)\rho}.$$

Hence, the incentive constraint is violated, so that the buyer will take the private benefit and increase counterparty risk. By construction of the collateral policy, we also have that

$$(1-\epsilon)(1-\rho)\Big(v - p + k(p)\Big) - \mu k(p) < (1-\epsilon)\Big(v - p_B + k(p_B)\Big) - \mu k(p_B) = c$$

so that a buyer would never accept such an offer. This implies that the seller cannot offer a price higher than p_B. Since he does not want to offer a price lower than p_B, the collateral policy implements incentive contracts for all levels of B and there is default with probability ϵ only.

It remains to be shown that $R(p)$ is increasing given the collateral policy. Suppose to the contrary, it is decreasing instead. Then, it is straightforward to verify that all sellers independent of B would charge the lowest price with the offer being accepted by buyers. With the collateral schedule $k(p)$, however, there cannot be default beyond ϵ at any price then. As pointed out before, $R(p)$ is then an increasing function, which yields a contradiction.

Proof of Proposition 4

Comparing payoffs across insurance and incentive contracts, the seller prefers the latter if and only if

$$\begin{aligned}
&R(p_B) = \epsilon k(p_B) + (1-\epsilon)p_B \geq R_0 = (1-\epsilon)(1-\rho)p_0 \\
&\epsilon k(p_B) + (1-\epsilon)\left[v + k(p_B) - \frac{\mu}{1-\epsilon}k(p_B) - \frac{c}{1-\epsilon}\right] > (1-\epsilon)(1-\rho)v - c \\
&\rho v(1-\epsilon) = \bar{B} > k(p_B)(\mu - 1).
\end{aligned}$$

Taking into account the collateral policy of Proposition 3, one obtains the condition stated in the proposition.

Let $\bar{B} \geq \left(\frac{\mu-1}{\mu(1-\rho)-1}\right)\rho c$, so that there is some level of B for which a seller prefers an insurance contract. I first show that there is another level of B such that the price associated with an incentive contract is equal to the price p_0.

Using $p_B = p_0 = v - \frac{c}{(1-\epsilon)(1-\rho)}$, the level B associated with such an incentive contract needs to satisfy

$$\begin{aligned}
c &= (1-\epsilon)(v - p_B + k(p_B)) - \mu k(p_B) \\
c &= \frac{c}{1-\rho} - \frac{1}{\mu}\left(\frac{B}{\rho} - c\right)(\mu - (1-\epsilon)) \\
B &= \left[1 + \left(\frac{\rho}{1-\rho}\right)\left(\frac{\mu}{\mu-(1-\epsilon)}\right)\right]\rho c > \underline{B}.
\end{aligned}$$

It is straightforward to verify that $B < \bar{B}$. Hence, whenever farmers prefer the insurance contract for some level of B, there exists a lower, feasible level of moral hazard for which the incentive contract has the same price as the insurance contract.

I show next that it is always the case that farmers facing moral hazard level B prefer the incentive contract. This is the case if and only if

$$\begin{aligned}
\rho v(1-\epsilon) &\geq k(p_B)(\mu-1) \\
\bar{B} &\geq \left(\frac{\mu-1}{\mu}\right)\left(\frac{B}{\rho}-c\right) \\
\bar{B} &\geq \left(\frac{\mu-1}{\mu}\right)\left(\frac{\rho}{1-\rho}\right)\left(\frac{\mu}{\mu-(1-\epsilon)}\right)c \\
\bar{B} &\geq \left(\frac{1}{1-\rho}\right)\left(\frac{\mu-1}{\mu-(1-\epsilon)}\right)\rho c.
\end{aligned}$$

It is straightforward to verify that this inequality is satisfied given the condition on $\bar{B}$.

Hence, there are at least two different levels of B for which the price negotiated by the seller for an optimal insurance contract and an incentive contract respectively is the same, but who require two different collateral policies, $k(p_0) > 0$ and $k_0 = 0$. This completes the proof.

Proof of Proposition 5

It is straightforward to verify that the value of an incentive contract is weakly decreasing in B, while the value of an insurance contract is weakly increasing in B.

Consider now $B = (1-\epsilon)\rho v$. I show that the seller for this level of B prefers an insurance contract. The incentive contract is given by $k_{ic} = p_{ic}$. Note that the contract $(k_{ic}, p_{ic} + \Delta)$ is a feasible insurance contract for $\Delta > 0$ sufficiently small. Since

$$u(p_{ic}) = (\epsilon + (1-\epsilon)\rho)u(k_{ic}) + (1-\epsilon)(1-\rho)u(p_{ic} + \Delta),$$

the optimal insurance contract must yield a higher utility for sellers.

Proof of Proposition 6

Suppose first that $\frac{\partial R}{\partial p} < 0$ so that collateral needs to decrease with prices. For $\bar{B}$, the only incentive feasible contract has

$$\bar{p} = \bar{k} = \frac{1}{\mu}\left(\frac{\bar{B}}{\rho} - c\right).$$

Note that this contract is feasible for all $B \in [\rho c, (1-\epsilon)\rho v]$ and has the lowest possible price. Hence, all sellers will quote this lowest price, which implies that collateral is at least $\bar{k}$ in all transactions.

Let $\frac{\partial R}{\partial p} > 0$. Consider any collateral policy $k(p)$ that implements incentive contracts for all $B \in [\rho c, \rho v(1-\epsilon)]$. Then, the policy needs to satisfy for all B

$$(1-\epsilon)\rho\left(v - p + k(p)\right) \geq B$$

for all $p > \bar{p}$.

Suppose not. Then, there exists $\tilde{p}$ such that

$$\tilde{B} \leq (1-\epsilon)\rho\left(v - \tilde{p} + k(\tilde{p})\right) < \bar{B}$$

since $(\tilde{p}, k(\tilde{p})$ is a feasible incentive contract for some $\tilde{B}$. But then buyers with counterparty quality $\bar{B}$ will also accept the offer $\tilde{p} > \bar{p}$ from the seller and realize the private benefit, since

$$-\mu k(\tilde{p}) + (1-\epsilon)(1-\rho)(v - \tilde{p} + k(\tilde{p}) + \bar{B} > -\mu k(\tilde{p}) + (1-\epsilon)(v - \tilde{p} + k(\tilde{p}) \geq c$$

where the last inequality follows from the fact that the collateral level $k(\tilde{p})$ implements an incentive contract for some counterparty quality $\tilde{B}$. Since $p > \bar{p}$, any seller facing counterparty quality $\bar{B}$ will also prefer the offer $\tilde{p}$. This is a contradiction, since the collateral policy does then not implement an incentive contract for all B.

This implies that any policy that implements an incentive contract for all B needs to satisfy

$$(1-\epsilon)\rho(v - p + k(p)) \geq \bar{B}.$$

For any $p < \bar{p}$, all sellers will prefer $\bar{p}$ with collateral $\bar{k}$ which is a feasible incentive contract. For $p > \bar{p}$, the contract would require $k(p) > \bar{k} = \bar{p}$ so that the contract is not feasible, which completes the proof as a similar argument holds for the case $\frac{\partial R}{\partial p} = 0$.

Proof of Proposition 7

The first result follows immediately. For the second result, the incentive constraint implies that collateral weakly increases with σ. This implies that the price associated with an incentive contract for any counterparty quality weakly decreases with σ. Finally, recall that

$$\chi = \frac{\sigma}{1-\beta(1-\sigma)}$$

so that $\partial\chi/\partial\sigma > 0$. The value of an insurance contract for the seller is given by

$$V_1^S = \frac{1}{1-\beta\chi}\left(\rho u(k) + (1-\rho)u(p)\right).$$

Since higher σ relaxes the insurance constraint and decreases the adjusted discount factor $\frac{1}{1-\beta\chi}$, the final result follows.

Proof of Proposition 9

I first show that an insurance contract dominates for $\bar{B}$ if σ is sufficiently close to 1. By the definition of $\bar{B}$, the only feasible incentive contract has

$$p^*(\bar{B}) = k^*(\bar{B}) = \frac{1}{\mu}\left(v - (1-\beta)c\right).$$

At $\bar{B}$ an insurance contract is feasible and the optimal insurance contract is weakly better than one with $k_0 = 0$ and $p_0 = v - \frac{c}{1-\rho} + \beta\chi c$. Hence, the price of the insurance contract p_0 is higher if and only if

$$v > \left(\frac{\mu-(1-\rho)}{(\mu-1)(1-\rho)}\right)c - \left(\frac{\chi\mu-1}{\mu-1}\right)\beta c$$

which is the case for $\sigma \to 1$ and $\rho \to 0$, since $v > c$. A sufficient condition for the seller to prefer an optimal insurance contract is

$$\frac{1}{1-\beta\chi}\left[\rho u(k_0) + (1-\rho)u(p_0)\right] \geq \frac{1}{1-\beta}u(p^*(\bar{B}))$$

or

$$1 - \beta(1-\sigma) \geq \frac{u(p^*(\bar{B}))}{(1-\rho)u(p_0)},$$

which holds, whenever σ is large enough and ρ sufficiently small.

Next, I show that the optimal incentive contract for all B_L sufficiently close to $\underline{B}$ = yields a higher utility for the seller than the insurance contract at $\bar{B}$. With market discipline, for B_L sufficiently close to $\underline{B}$, we have that $k = 0$. Then, the price of the incentive contract is given by

$$p^*(B_L) = v - (1-\beta)c > p_0 > k_0$$

where (p_0, k_0) is the optimal insurance contract at $\bar{B}$. Hence,

$$\frac{1}{1-\beta} u(p^*(B_L)) > \frac{1}{1-\beta\chi} \left[\rho u(k_0) + (1-\rho) u(p_0)\right].$$

Finally, I need to verify that the condition for market discipline is satisfied at some B_L, where the incentive contract is preferred by the seller. Since there are only two levels of counterparty quality and transactions at B_H are short-term relationships, punishing risk taking by terminating a relationship causes a permanent switch to transactions with low counterparty quality. Market discipline thus holds if and only if

$$\chi \left(\frac{1-\rho\beta}{1-\rho} \right) \geq \frac{V_1^S(B_L)}{V_1^S(B_H)} \geq \chi.$$

Note that the value of an optimal incentive contract is continuous and decreasing in B, while the value of an optimal insurance contract is increasing in B. Hence, we can choose B_L and B_H such that the ratio $V_1^S(B_L)/V_1^S(B_H)$ is sufficiently close to 1, with the optimal contracts still being an incentive and an insurance contract, respectively. The result then follows from the fact that

$$\chi \left(\frac{1-\rho\beta}{1-\rho} \right) > 1 \text{ if and only if } \rho > 1-\sigma.$$

This completes the construction of optimal contracts at B_H and B_L.