Central Counterparty Clearin: Incentives, Market Discipline and the Cost of Collateral*

Thorsten V. Koeppl
Queen's University

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Abstract

Central counterparty (CCP) clearing – as defined by offering a substitution of counterparty through novation – offers collateral savings by diversifying default risk. It can, however, upset market discipline where reputational concerns ensure a low probability of default in the presence of moral hazard. Such discipline allows to save on costly collateral that is used as an incentive device. Consequently, CCP clearing can lead to an increase in collateral costs, even though unit costs of collateral with such clearing fall and default risk remains unchanged. This is the case whenever CCP clearing decreases liquidity in financial markets sufficiently, so that market participants cannot rely on reputation as an incentive mechanism anymore. I show that CCP clearing offers the largest benefits in situations where reputational concerns matters the least, i.e. when (i) liquidity is large and (ii) moral hazard severe.

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1 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 $1-2trn in derivative exposures are not at all collateralized or "under"-collateralized.[1] The common policy response to this problem is to move these transaction under the umbrella of a clearinghouse that would offer central counterparty (CCP) clearing and ensure that "proper" collateral is posted in these transactions. Large dealer banks were quick to point out that – while the lack of collateralization need not represent an inefficiency – such an omnipresent rise in collateral requirements would lead to a significant increase in the costs of OTC trading while not dramatically improving overall risk exposures.[2]

This paper asks whether CCP clearing – as defined by the process of novation which diversifies counterparty credit risk – (i) leads to an increase in collateral costs and (ii) whether it is indeed beneficial either by reducing risk or by increasing welfare. I start from the premise that clearing through a CCP has two benefits. First, it pools and thereby diversifies counterparty risk by interposing itself as the sole buyer and seller of any contract traded on a financial market (see Koeppl and Monnet (2010)). Second, CCP clearing leads to lower *unit* costs of collateral.[3] Hence, it seems puzzling from this perspective that market participants fear an increase in overall collateral costs.[4]

Consider, however, a situation where a trade occurs with a risk of default. Furthermore, there is moral hazard in the sense that a trading party has a private (and non-contractible) benefit from increasing this risk. Collateral can then have two purposes. First, it can act as a prepayment – essentially insuring against the risk of default. Alternatively, it can provide incentives to not increase the risk of default against the private benefit. I show that when collateral is costly, it can be (privately) optimal for the contracting parties to require low collateral at the expense of a higher default risk. As moral hazard increases, it becomes more and more costly to require collateral to rule out default, making the insurance contract

[1] See for example Cecchetti, Gyntelberg and Hollander (2009) or Singh (2010)).

[2] Singh (2010) gives a back-of-the-envelope calculation of about $220bn in additional collateral requirements. There are other indirect costs if one takes into account other effect such as for example restrictions on rehypothecation.

[3] These savings arise either by introducing multilateral netting or netting across different financial products and by more efficient collateral management (see for example Checcetti, Gyntelberg and Hollander (2009)).

[4] Admmittedly, I omit the issue 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 other reasons.

with low collateral better. Still, low collateral implies a high default risk here. Nonetheless, a CCP will lower collateral costs as long as it does not intend to achieve low or no default risk. Through diversification, it offers a cheap substitute to collateral as an insurance device; collateral will only increase if a CCP mandates low default risk which necessitates high collateral as an incentive device.[5]

I look next at the role of market discipline as a substitute for collateral to provide incentives. Suppose there are trading frictions that make long-term relationships attractive. More specifically, consider a search friction: when losing a trading partner it takes time to engage in a new trade. Thus, this search cost can thus be interpreted as a proxy for how easy it is to transact in the market, which in turn is a function of competition and general liquidity in the market.

With the search cost, the threat of terminating a relationship can be credible whenever these costs are lower than the costs suffered through a default. This allows for short-term contracts that have low collateral *and* low default risk. This is interesting, as now the correlation between low collateral and default risk becomes blurred. In particular, now low collateral postings are not necessarily an indication of large default risk, even if the riskiness of the counterparties is (possibly imperfectly) observable.

Even though it offers again gains from diversification, a CCP might upset the equlibrium structure of contracts. I demonstrate that a fall in market liquidity concurrent with the introduction of a CCP[6] can destroy the reputational equilibrium. As a consequence, collateral requirements need to increase to keep the risk of default constant. Interestingly, whenever moral hazard is large and market liquidity sufficiently high, only small savings in unit costs of collateral are required to make CCP clearing still beneficial for the contracting parties despite the adverse effects on market discipline. Finally, the paper concludes with a look at how liquidity in the market changes endogenously when default risk varies across transaction in response to CCP clearing.

There are several conclusions to be drawn for the current policy discussion. First, zero or low collateral cannot be necessarily interpreted as insufficient risk management. It might be the case that they simply reflect market discipline or a more efficient contract design of the counterparties. Second, introducing a CCP can involve costs and unintended consequence.

[5]We are abstracting here from the issue whether regulators indeed can force trades to be cleared through a central counterparty (see the discussion in Koeppl, Monnet and Temzelides (2011)).

[6]There is some reason to believe that a CCP will decrease liquidity. CCPs set strict membership requirements so that only high quality counterparties have access to it to avoid adverse selection. Moreover, trades outside formal clearing arrangements will face additional costs in the form of capital requirements if new Basle regulation is implemented (see BIS (2011)).

Such a policy can increase collateral costs without reducing overall default risk. Third, the decision whether to introduce a CCP or not must not only consider the impact on cost of collateral, but also the impact of such a move on market liquidity and trading dynamics. Hence, we ultimately need a theory that links changes in financial markets infrastructure and risk management to changes in market liquidity and the optimal level of default risk.[7]

My analysis is mainly built on the framework of Koeppl and Monnet (2010) that stresses novation and mutualization of losses as key channels how CCP clearing affects trade and welfare. As such it abstracts from other benefits such netting (see Duffie and Zhu (2009)) or information disemmination (see for example Archaya and Bisin (2010)). A recent contribution by Carapella and Mills (2011) exhibits information insensitivity of securities as a key mechanism of CCP clearing. Most interestingly, this last paper also establishes a link between collateral in the form of margin calls and CCP introduction and design.

2 Model

I follow a simplified version of the set up by Koeppl and Monnet (2010) to formalize bilateral trading of customized financial contracts. The key difference is that there are (i) no aggregate shocks and (ii) that there is no retrading ex-post, but these elements are not essential for this analysis. I add a moral hazard feature along the lines of Holmström and Tirole (1997) where some people can take an action that yields a private benefit which cannot be contracted upon directly.

More formally, there are two dates $t = 0$ and $t = 1$. There are two types of people, farmers and bakers, both of measure 1. There are also two different goods in the economy, wheat and gold. Farmers can produce a specialized type of wheat for a particular baker. They can produce either one unit or none for bakers, and production takes time. The farmer has to produce the wheat in $t = 0$ for consumption by the baker in period $t = 1$. Since wheat is specifically produced for a baker, it cannot be retraded at $t = 1$. Bakers can produce gold in both periods which can be stored across periods.

[7] It is important to understand that a CCP here sets collateral levels that are in accordance with maximizing surplus for some counterparty in the contractual relationship. Hence, in order to justify higher collateral requirements, one must indicate and model reasons why the default risk associated with a transaction is too large from a societal perspective. Here, I model the private incentives to take on default risk and how they are changed with CCP clearing.

Farmers preferences are described by

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

where q is the amount of wheat produced – either 0 or 1 – and x is the amount of gold consumed in period $t = 1$. For most of the paper, we assume that θ is sufficiently small, so that farmers have an incentive to produce the special wheat for a baker. The baker's preferences are given by

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

where v is the (fixed) utility obtained from q units of wheat. The baker can produce gold either in period 1 or 2. However, early production of gold implies an additional cost, since we assume that $\mu > 1$.

There are two complications. First, bakers can die with probability $\epsilon \in [0, 1)$ after $t = 0$. If a farmer has produced specific wheat for a baker, he will not be able to deliver it against a payment in gold. Second, bakers can engage in an activity that delivers some private benefit $B > 0$ at $t = 0$, but increases their probability of dying. We denote this decision by $\lambda_B \in \{0, 1\}$. In particular, we assume that if a baker engages in the activity he will go bust with probability ρ conditional on not dying. Hence, if $\lambda_B = 1$, the probability of dying increases to $\rho(1 - \epsilon) + \epsilon$, where $\rho \in (0, 1)$.

Trading is organized as follows. At $t = 0$, a farmer meets a baker and offers a contract $(p, k) \in \Re_2^+$. The variable p formalizes 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 farmer undertakes production. This allows us to interpret the relationship as a forward contract where the farmer asks for collateral k to safeguard against the risk that the baker dies. The final payment is then net of collateral $p - k$. We assume that the action λ_B is not verifiable for the farmer, so that the contract cannot be contingent on it. Finally, if the baker survives, the contract is settled in net terms in period $t = 1$. That is the farmer delivers wheat 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 that leads to counterparty risk. B is valuable for the baker, but decreases the expected surplus from a trade for a baker. We assume for reasons of tractability that bakers need to receive at least an expected surplus of c from trading wheat with a farmer, where

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

As will become clear later, this restriction ensures that the baker prefers taking on the additional risk given the surplus c from trading with the farmer and that any contract features a payment that exceeds collateral postings ($p \geq k$).

3 Collateral: Incentives vs. Insurance

3.1 Bilateral Clearing

We solve first for the contract when farmers can make a take-it-or-leave-it offer (p, k) to the baker. Interpreting the prepayment k as collateral, it can take on two roles. First, it can be used to provide incentives, with the baker putting up a bond that prevents the farmer from taking on excessive default risk. But it also insures the farmer against the default risk by bakers *independent of* λ_B. Hence, collateral serves a dual role as an insurance and incentive device, while controlling the farmer's default risk.

To make this more precise, the incentive constraint for the baker not to realize the private benefit B is given by

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

or

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

The baker weighs the expected benefit from obtaining the wheat $v - p + k$ 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 settling the contract with the farmer. It is in this sense that collateral provides incentives. The baker 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 is called an *incentive contract.*

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

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

The participation constraint then becomes

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

We call such a contract an *insurance contract.*

A farmer will choose between the two type of contracts to maximize his expected utility which is given (net of production costs) by

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

Since utility is increasing in both p and k, the participation constraint will be binding for both type of contracts. The incentive constraint is then given by

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

whereas the insurance constraint yields

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

As a result, collateral posted in an insurance contract is always lower than in an incentive contract.

The trade-off between the two contracts is then clear for the farmer. Offering a contract with incentives has two benefits. First, it lowers the default probability to ϵ. Second, it increases the expected surplus from the contract for the baker, thereby enabling the farmer 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 farmer can require for his special wheat. The cost arises from the fact that $\mu > 1$. Hence, when the risk-weighted private benefit B/ρ is sufficiently high, the farmer might find it optimal to forego the incentives and offer an insurance contract. Of course, with an insurance contract, the farmer allows the baker to engage in the risky activity B. But such a contract might help to save on collateral costs. This is formalized in the next proposition.

Proposition 1. *The optimal incentive contract is given by a fixed level of collateral k^* for $B \in [c\rho, B^*]$ and an increasing level of collateral $k^{INC}(B)$ for $B \in [B^*, \rho v(1-\epsilon)]$.*

The optimal insurance contract is given by an increasing level of collateral $k^{INS}(B)$ for $B \in [c\frac{\rho}{1-\rho}, B^{**}]$ and a constant level of collateral k^0 for $B \in [B^{**}, \rho v(1-\epsilon)]$.

The collateral posted in any incentive contract is strictly higher than in any insurance contract, i.e. $k^{INS}(B) \leq k^0 < k^* \leq k^{INC}(B)$.

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

$$p = v - \frac{c}{1-\epsilon} - k\left(\frac{\mu}{1-\epsilon} - 1\right). \tag{12}$$

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

$$\epsilon u'(k) + (1-\epsilon)u'(p)\left(1 - \frac{\mu}{1-\epsilon}\right) + \lambda\mu = 0, \tag{13}$$

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

$$u'(k)\left(\epsilon + (1-\epsilon)\rho\right) - u'(p)\left(\mu - (1-\epsilon)(1-\rho)\right) + \lambda_{NN} - \lambda_{IC} = 0, \tag{14}$$

where $p = v - \frac{c}{(1-\epsilon)(1-\rho)} - k\left(\frac{\mu}{(1-\epsilon)(1-\rho)} - 1\right)$ and the Lagrange multipliers are on the constaints

$$k \geq 0 \tag{15}$$
$$k \leq \frac{1}{\mu}\left(\frac{B(1-\rho)}{\rho} - c\right), \tag{16}$$

respectively.

Inspection of the two constraints implies immediately that $k = 0$ for low values of B, then collateral increases according to the second constraint and finally stays constant at some k^0 that satisfies the first-order condition with $\lambda_{NN}\lambda_{IC} = 0$. Hence, there exists a cut-off point B^{**} such that k^0 is the solution if and only if $B \geq B^{**}$.

For the last statement it suffices to show that $k^0 < k^*$. We can directly compare the solutions of the unconstrained problems for an incentive and an insurance contract. Suppose to the contraty that $k^* < k^0$. Then, $p^0 < p^*$ to satisfy the participation constraint. This implies that the marginal rate of substitutions has decreased. A contradiction with the unconstrained first-order conditions. □

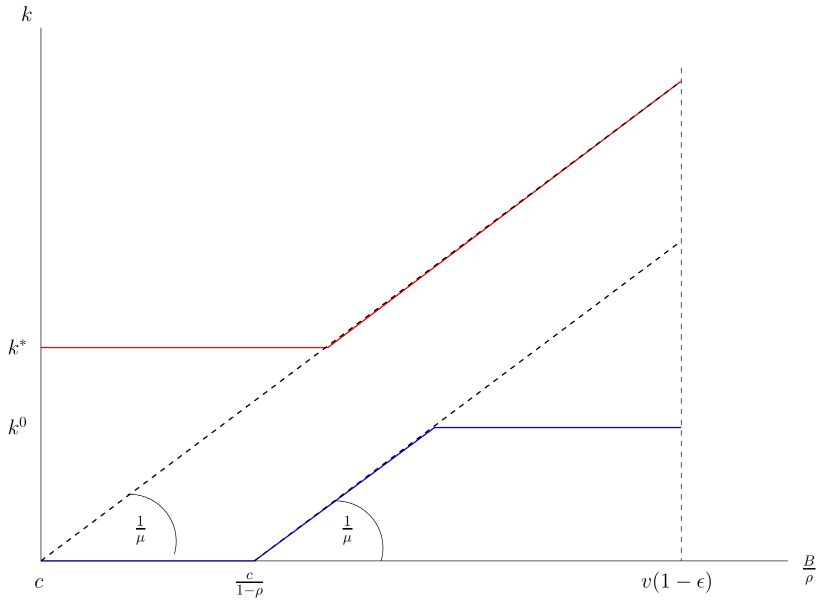

Figure 1: Optimal contract in terms of risk-weighted private benefit B/ρ

Figure 1 summarizes this result. Optimal collateral policies for incentives and insurance contracts are driven by the incentive and insurance constraints. The slope of these constraints reflect the cost of collateral $\mu > 1$. As long as these constraints are not binding, the contract chooses the optimal level of collateral that equates the farmer's marginal utility for default and no default by the baker. For low levels of B, the only feasible choice of collateral in an insurance contract is $k^{INS} = 0$. When moral hazard is severe (i.e. B/ρ is large), the optimal level of collateral in an insurance contract becomes incentive feasible and remains insensitive to the degree of moral hazard. To the contrary, an incentive contract features first a constant level of collateral which is the unconstrained optimal level given the exogenous default probability ϵ. As the moral hazard becomes more severe, we have that the collateral must be increased to prevent it. Eventually, collateral becomes so high that $p = k$, a situation of complete prepayment at $B/\rho = v(1-\epsilon)$.

The choice of contract for the farmer is then driven by the collateral costs of the contract. With an incentive contract, for low levels of moral hazard, the utility for the farmer is independent of B/ρ, while it decreases as collateral begins to rise. For an insurance contract the opposite is the case. As collateral cannot be too high, insurance against default by the baker is not at its optimal level. Hence, the farmer's utility rises as moral hazard becomes more severe eventually leveling out at some level. This is summarized as follows.

Corollary 2. *The farmer prefers an incentive contract if and only if the level of moral hazard B is sufficiently low.*

In conclusion, low levels of collateral go hand-in-hand with contracts where farmers optimally insure against moral hazard. Hence, my framework predicts that low collateral levels lead to higher default risk. Nonetheless, this is fully efficient from the perspective of the two parties writing the contract.

3.2 CCP Clearing

We introduce CCP clearing along the lines of Koeppl and Monnet (2010). We assume here throughout that the level of moral hazard B/ρ is fixed across transactions. The CCP announces a collateral policy k^{CCP} for all trades. Farmers make a take-it-or-leave-it offer to bakers in terms of p taking as given the collateral policy k^{CCP}. The CCP then pools all payments made from bakers in the form of collateral k at $t = 0$ and net settlement $p - k$ at $t = 1$. It pays out a share of its revenue to all farmers that is proportional to the value of the contract, but *independent* of their default experience.

Let $p(i)$ be the value of the contract written by farmer i and $\int p(i)di$ be the total value of contracts written by all farmers. The CCP's revenue is given by

$$R^{CCP} = (\epsilon + (1-\epsilon)\rho\lambda_B)\, k^{CCP} + ((1-\epsilon)(1-\rho\lambda_B)) \int p(i)di. \tag{17}$$

Farmer i's pay-off is increasing in the value of the contract $p(i)$, as he receives a fixed payment equal to

$$\frac{p(i)}{\int p(i)di} R^{CCP} \tag{18}$$

independent of the default by individual bakers. In their decision, farmers take the total value of contracts written, the collateral policy and the total expected revenue of the CCP as given. Hence, the only variable they maximize over is the price for the contract. We show next that the CCP can induce any form of contract – incentive and insurance – through its collateral policy.

Proposition 3. *If $k^{CCP} \geq \frac{1}{\mu}\left(\frac{B(1-\rho)}{\rho} - c\right)$, the only feasible contract is an incentive contract. If $k^{CCP} \leq \frac{1}{\mu}\left(\frac{B(1-\rho)}{\rho} - c\right)$, the insurance contract yields a higher payoff, i.e. $p^{INS}(k^{CCP}) > p^{INC}(k^{CCP})$.*

Proof. If k^{CCP} satisfies the first condition, there is no positive price p that fulfills both the participation and insurance contract constraints. Hence, the only feasible contract is an incentive contract.

Suppose next that $k^{CCP} \leq \frac{1}{\mu}\left(\frac{B(1-\rho)}{\rho} - c\right)$. Then, for an incentive contract the highest price that can be charged is given by the binding incentive constraint

$$p^{INC}(k^{CCP}) = v + k^{CCP} - \frac{B}{\rho(1-\epsilon)}. \tag{19}$$

With an insurance contract, we have that the price is given by the binding participation constraint or

$$p^{INS}(k^{CCP}) = v + k^{CCP} - (c + \mu k^{CCP})\frac{1}{(1-\epsilon)(1-\rho)}. \tag{20}$$

Hence, $p^{INS} > p^{INC}$ for the given level k^{CCP}. $\square$

We assume now that the CCP sets collateral requirements to maximize the famer's utility.[8] All farmers will select the same price for a given collateral requirement k^{CCP}. Hence, a CCP will simply maximize total revenue R^{CCP} subject to the original constraints.

If the CCP wants to select an incentive contract, it is straightforward to verify that the CCP sets collateral requirements to

$$k^{INC} = \frac{1}{\mu}\left(\frac{B}{\rho} - c\right) \tag{21}$$

for all B. The revenue of a CCP in case of an incentive contract is then given by

$$R^{INC} = \epsilon k^{INC} + (1-\epsilon)\left(v - \frac{c}{1-\epsilon} - k^{INC}\left(\frac{\mu}{1-\epsilon} - 1\right)\right), \tag{22}$$

where the second term has used the optimal price charged by a farmer. CCP clearing thus reduces collateral requirements, as farmers need not self-insure against the idiosyncratic default risk. If moral hazard is relatively high, however, the collateral requirements remain unchanged when moving from bilateral clearing to CCP clearing.

Turning to an insurance contract, it is immediately clear that the solution to the CCP's

[8] This assumption is innocuous here. The CCP could simply set minimum collateral requirements, but allow farmers to charge more collateral. If farmers prefer and incentive over an insurance contract, they simply could write such a contract by charging $k = \frac{1}{\mu}\left(\frac{B}{\rho} - c\right) - k^{CCP}$ in addition. Similarly, when $k^{CCP} \in [\frac{B(1-\rho)}{\rho} - c, \frac{B}{\rho} - c)$, farmers would charge more collateral, as this would increase the price they can charge to bakers. The assumption, however, rules out redistribution from bakers to farmers that would be feasible with binding or maximum collateral requirements.

problem is $k^{INS} = 0$ which clearly satisfies the constraint (7). The CCP's revenue is given by

$$R^{INS} = (1-\epsilon)(1-\rho)\left(v - \frac{c}{(1-\epsilon)(1-\rho)}\right), \tag{23}$$

where we again have used the optimal price charged by the farmer. Not surprisingly, since collateral is costly and used to insure against risk, it is optimal to economize on it as soon as there is a possibility to diversify such risk. Collateral is an imperfect and costly substitute to pooling idiosyncratic default risk. It is now straightforward to compare incentive and insurance contracts under CCP clearing.

Proposition 4. *The optimal contract with CCP clearing has lower collateral requirements than without CCP clearing for any level of B. It is an incentive contract if and only if*

$$v(1-\epsilon) \geq \frac{\mu - 1}{\mu\rho}\left(\frac{B}{\rho} - c\right).$$

For the optimal collateral policy, both the severity of the moral hazard problem and the cost of collateral matter. Independent of collateral cost, if moral hazard is sufficiently small, we have that an incentive contract is better. However, for any given level of moral hazard, once collateral becomes sufficiently costly, it becomes optimal to forgive incentives and purely insure against the default risk. As a consequence, however, collateral posted drops to zero – arguably an artefact of the absence of aggregate risk – and default risk increases. But these effects are not different from clearing bilaterally.

More importantly, for intermediate levels of moral hazard, the introduction of CCP clearing can make insurance contracts more attractive relative to incentive contracts. While incentive contracts remain unchanged, the costs associated with insurance contracts falls as no collateral is required due to diversification, making them more attractive. Hence, introducing a CCP leads to an increase in default risk. Note however, that this is fully efficient in the sense that it increases surplus for farmers.

Turning to collateral costs, for sufficiently low unit costs oof collateral ($\mu \to 1$) we get that an incentive contract always dominates *for all* feasible levels of B. Suppose now CCP clearing leads to a fall in unit costs of collateral, i.e. $\mu_{CCP} < \mu$. For incentive contracts, the degree of moral hazard, B/ρ determines only the overall cost of collateral, μk. Hence, a fall in unit costs is exactly compensated by an increase in collateral requirements with the consequence that overall collateral costs cannot increase with CCP clearing, but need not necessarily fall either. Finally, a CCP policy aimed at minimizing counterparty risk will weakly increase collateral requirements and total collateral costs. Such a policy – in our framework – is misguided, as it might impose an inefficient contract on farmers.

4 Dynamics: The Role of Market Discipline

The previous section has demonstrated that it is not necessarily optimal to increase collateral requirements with CCP clearing. Indeed, once CCP clearing is introduced, market participants might have an incentive to select contracts that *save on collateral costs*. This is the case whenever the CCP offers cheap insurance against counterparty default. Of course this result was efficient when taking into account the costs associated with collateral to prevent counterparty default. We turn now to the question under what circumstances CCP clearing necessitates an increase in overall collateral costs.

4.1 Search Costs and Repeated One-Period Contracts

Consider a dynamic version of the economy. Farmers and bakers are randomly matched. When matched, they stay together and contract until either the baker dies or the farmer terminates the relationship. When a baker dies, he is replaced by a new baker. We restrict attention again to one period (static) contracts where the farmers agrees to produce the one unit of wheat in exchange of a contract $(p.k) \in \Re^2_+$ that specifies an upfront payment or collateral and the price for the wheat. The future is discounted at a rate $\beta \in (0, 1)$. To simplify the analysis further, we also assume in the dynamic economy that $\epsilon = 0$. Hence, if there is no moral hazard, there will be no default. This shuts down the channel of novation for incentive contracts. Consequently, CCP clearing adds direct value through novation only for insurance contracts.

The timing in each period is as follows. First, all matched farmers make a take-it-or-leave-it offer to bakers. Next, the bakers chose their action λ_B. Then the farmer makes a decision to terminate the relationship or not, expressed as $\lambda_F \in \{0, 1\}$. If he does so ($\lambda_F = 1$), he and the baker conditional on surviving are matched with new counterparties next period with probability σ. If he does not ($\lambda_F = 0$) and the baker dies, he is not matched with a baker next period. Finally, bakers die or survive and the contract is executed for the period.

I first assume that the baker's decision to realize the private benefit B is not observable for the farmer. As a consequence, the farmer's decision cannot depend on the realized value of λ_B. However, the baker will anticiapte the decision of the farmer whether to continue the relationship or not and accordingly choose λ_B. We again require that the expected surplus from the contractual relationship is c for the baker so that the participation constraint for the baker becomes now

$$-\mu k + (1-\rho\lambda_B)\left[(v-p+k) + \beta\left(\lambda_F V_0^B + (1-\lambda_F)V_1^B\right)\right] \geq c \tag{24}$$

where V_i^B is the value function for the baker when he is in a match ($i = 1$) or not ($i = 0$) next period. Furthermore an incentive contract has to satisfy the incentive constraint

$$\rho\left[(v-p+k) + \beta\left(\lambda_F V_0^B + (1-\lambda_F)V_1^B\right)\right] \geq B. \tag{25}$$

Using the participation constraint this can again be written more compactly as

$$k \geq \frac{1}{\mu}\left(\frac{B}{\rho} - c\right). \tag{26}$$

Similarly, an insurance contract needs again to satisfy the constraint

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

To summarize, the constraints remain unaltered with respect to the static analysis and – since we are restricting ourselves to static contracts – the optimal level of collateral is identical to the static problem with $\epsilon = 0$.

To charcterize the subgame-perfect Nash equilibria, take the contract (p, k) as given. Since the contracts term are sunk, the farmer will continue the relationship as long as

$$(1-\rho\lambda_B)\beta V_1^F + \rho\lambda_B\beta V_0^F \geq V_0^F \tag{28}$$

where V_i^F is the value function for the farmer. Hence, the farmer compares the expected value from continuing the relationship and potentially postponing the search for a counterparty by one period with searching immediately. The value function of being without a match at the end of the period is given by

$$V_0^F = \beta\left(\sigma V_1^F + (1-\sigma)V_0^F\right) \tag{29}$$

or

$$V_0^F = \frac{\beta\sigma}{1-\beta(1-\sigma)}V_1^F = \beta\chi V_1^F < \beta V_1^F \tag{30}$$

since upon having terminated the relationship, the farmer will be in a match next period only with probability σ again. Rewriting the condition for the farmer to continue the relationship, we obtain

$$[(1-\rho\lambda_B)-\sigma]\,\beta\left(V_1^F - V_0^F\right) \geq 0. \tag{31}$$

This yields the following proposition.

Proposition 5. *Suppose risk taking (λ_B) is not observable. If $\sigma \leq 1-\rho$, a long-term relationship is always maintained independent of moral hazard and the contract choice. For $\sigma > 1-\rho$ whether the relationship is maintained depends on the form of the contract: for incentive contracts it is, but for insurance contracts it is not.*

Whether the relationship is maintained or not depends on the search costs – the probability of not finding a counterparty – vs. the risk of default. This is intuitive. When there is default and the farmer has not terminated and searched for a new counterparty, he will not have a transaction next period. Hence, he will make a choice that gives him the highest probability of having a match next period *independent* of the type of contract. Hence, when search costs are large (σ is low) one would see long-term contractual relationships. Interestingly, when search costs are relatively low, we find that insurance contracts take place in short-lived relationships, while collateral is used as an incentive device in long-term relationships.[9]

We turn now to a discussion of the optimal choice of contract (p,k). The analysis is identical to the one for the static problem. Note first that the value for an unmatched baker is given by

$$V_0^B = \frac{\beta\sigma}{1-\beta(1-\sigma)}V_1^B = \beta\chi V_1^B. \tag{32}$$

Since the participation constraint for the baker is always binding, we have that

$$\begin{aligned}
V_1^B &= \mu k + (1-\rho\lambda_B)\left[(v-p+k)+\lambda_F V_0^B + (1-\lambda_F)\beta V_1^B\right] \\
&= -\mu k + (1-\rho\lambda_B)\left[(v-p+k)+\left(\lambda_F\chi + (1-\lambda_F)\right)\beta V_1^B\right] \\
&= \frac{1}{1-(1-\rho\lambda_B)\beta\left(\lambda_F\chi+(1-\lambda_F)\right)}\left[-\mu k + (1-\rho\lambda_B)(v-p+k)\right] \\
&= \frac{1}{\delta_B(\lambda_B,\lambda_F)}\left[-\mu k + (1-\rho\lambda_B)(v-p+k)\right].
\end{aligned} \tag{33}$$

[9] Introducing an exogenous default probability $\epsilon > 0$ would yield an additional region such that for $\sigma \in (1-\epsilon, 1)$ all relationships are short-term.

Hence for any level of collateral k, we have then that the contract price is given by

$$p = v - \frac{c}{(1-\rho\lambda_B)}\delta_B(\lambda_B,\lambda_F) - k\left(\frac{\mu}{(1-\rho\lambda_B)} - 1\right). \tag{34}$$

The optimal contract is qualitatively the same as in the static environment. The choice of collateral and type of contract again maximizes the farmer's expected utility subject to giving bakers an expected life-time utility of c. The additional term $\delta_B(\lambda_B,\lambda_F)$ takes the role of an (endogenous) discount factor for bakers that summarizes the impact of the decisions by the baker and the farmer on how long the relationship will last.

Similarly, we have for the farmer's utility

$$\begin{aligned} V_1^F &= ((1-\rho\lambda_B)u(p) + \rho\lambda_B u(k)) + \lambda_F V_0^F + (1-\lambda_F)\beta\left((1-\rho\lambda_B)V_1^F + \rho\lambda_B V_0^F\right) \\ &= ((1-\rho\lambda_B)u(p) + \rho\lambda_B u(k)) + \left[\lambda_F\beta\chi + (1-\lambda_F)\beta\left((1-\rho\lambda_B) + \rho\lambda_B\beta\chi\right)\right]V_1^F \\ &= \frac{1}{1-\beta\left[\lambda_F\chi + (1-\lambda_F)\left((1-\rho\lambda_B) + \rho\lambda_B\beta\chi\right)\right]}((1-\rho\lambda_B)u(p) + \rho\lambda_B u(k)) \\ &= \frac{1}{\delta_F(\lambda_B,\lambda_F)}((1-\rho\lambda_B)u(p) + \rho\lambda_B u(k)), \end{aligned} \tag{35}$$

where $\delta_F(\lambda_B,\lambda_F)$ is again an endogenous discount factor. Since the constract structure remains the same, it follows immediately that the analysis from the static environment carries over here. In particular from the incentive and insurance constraint, we have that – for a given level of moral hazard – collateral is lower in an insurance contract. The next proposition characterizes the choice of collateral further, especially its interaction with the search cost.

Proposition 6. *For all σ and B, we have that $k^{INS}(B) < k^{INC}(B)$, that is incentive contracts have more collateral.*

The value of the insurance contract for the farmer decreases with the search cost, i.e. $\partial V_1^F(INS)/\partial\sigma \geq 0$.

If $\sigma > (1-\rho)$, we have that optimal collateral decreases with the search cost in an insurance contract, i.e. $\partial k^{INS}(B)/\partial\sigma \geq 0$.

Proof. The first result follows directly, since we have that

$$k^{INS}(B) \leq \frac{B(1-\rho)}{\rho} - c < \frac{B}{\rho} - c = k^{INC}(B)$$

when $\epsilon = 0$.

For the second result, observe that the value of an incentive contract for the farmer is independent of the search friction σ, since $\lambda_F = 0$ for such a contract. The value of an insurance contract, however, is given by

$$V_1^F(INS) = \frac{1}{\delta_F(\lambda_B, \lambda_F)} \left((1-\rho)u(p) + \rho u(k)\right).$$

Suppose first that $\sigma < (1-\rho)$. We then have that

$$\begin{aligned}\delta_B(1,0) &= 1 - \beta\Big(1-\rho\Big) \\ \delta_F(1,0) &= 1 - \beta\Big(1 - \rho(1-\beta\chi)\Big)\end{aligned}$$

with the price being independent of σ

$$p = v - \frac{c}{1-\rho}\Big(1 - \beta(1-\rho)\Big) - k\left(\frac{\mu}{1-\rho} - 1\right).$$

Since $\partial\chi/\partial\sigma > 0$, the result follows for this case.

Suppose next that $\sigma > (1-\rho)$. Then, we get

$$\begin{aligned}\delta_B(1,1) &= 1 - \beta(1-\rho)\chi \\ \delta_F(1,1) &= 1 - \beta\chi\end{aligned}$$

with the price of the optimal insurance contract depending on σ according to

$$p = v - \frac{c}{1-\rho}\Big(1 - \beta(1-\rho)\chi\Big) - k\left(\frac{\mu}{1-\rho} - 1\right).$$

The result follows then from the envelope theorem, as the discount factor $\delta_F(1,1)$ is decreasing in σ and the price p is increasing in σ.

Finally, recall the first-order condition for the optimal collateral choice in an insurance contract is given by

$$-\Big(\mu - (1-\rho)\Big)u'(p) + \rho u'(k) = 0$$

whenever the insurance constraint does not bind and $k^{INS}(B) > 0$. Using the expression for p when $\sigma > (1-\rho)$ and applying the implicit function theorem delivers the final result. $\square$

The intuition for this result is straightforward. When search costs decline (σ increases), the implicits cost for farmers of engaging in short term relationships are small, as it is easy to find a new transaction. However, for $\sigma > (1 - \rho)$, there is a second effect. Low search costs allow the farmer to extract more resources from the baker, as trading frictions have declined. This is reflected in larger collateral postings and – on the margin – a higher price for the contract. The reason is, however, a bit an artefact of our set-up. In order to provide a fixed surplus c to the baker, the per period surplus needs to be higher when there is a risk of not having a transaction next period. Hence, with lower search frictions, one needs to provide less surplus. As a consequence, one can require more collateral despite its deadweight cost.

One can interpret the probability of matching, σ, as a parameter reflecting liquidity and competition in the market. Hence, the last result links the costs of collateral to market liquidity and default risk. Suppose the default risk ρ is sufficiently large relative to liquidity as summarized by σ. On the one hand when markets are not liquid, the attractiveness of an insurance contract is small – unless the costs of collateral are large. On the other hand, less liquid markets can see lower collateral postings if the optimal contract structure does not rule out default. Hence, when insurance contracts are preferred over incentives ones, low liquidity in markets leads to low levels of collateral postings.

4.2 Market Discipline

So far, we have not recovered the notion that collateral in an optimal contract without default can be low. We now assume that the farmer can observe the baker's action λ_B[10] in order to capture the flavor of market discipline: farmers continue the relationship until they discover moral hazard; then, they terminate the relationship. Of course such a situation must correspond to a subgame perfect Nash equilibrium as well; in other words, the threat to terminate a relationship upon observing moral hazard needs to be credible.

We again solve backwards. Recall first condition (31). It is clear that for $\sigma < 1-\rho$, continuing the relationship ($\lambda_F = 0$) is a strictly dominant strategy for the farmer independently of the contract choice (p, k). Hence, we assume that $1 > \sigma > 1 - \rho$ for this section.

Note first that in an insurance contract, we get $\lambda_F = 1$. For an incentive contract, the continuation decision for the farmer can now depend directly on λ_B. It follows immediately

[10]We could interpret this framework as allowing the farmer to pay a fixed cost $\chi > 0$ in order to observe the decision λ_B. This cost would simply increase the production cost from θ to $\theta\chi$. Hence, participation of the farmer is not an issue for the analysis and the only question would be whether there is an incentive to monitor.

from condition (31) that *in an incentive contract* the farmer will continue the relationship if and only if there is no engaging in moral hazard, or

$$\lambda_F(\lambda_B) = \begin{cases} 1 & \text{if } \lambda_B = 1 \\ 0 & \text{if } \lambda_B = 0. \end{cases} \tag{36}$$

Hence, the farmer can credibly threaten to terminate the relationship with an incentive contract whenever there is moral hazard. 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 this punishment strategy *market discipline.*

I show next that market discipline is a substitute to collateral, as it relaxes the incentive constraint. Using the punishment strategy $\lambda_F(\lambda_B)$, the baker's incentive constraint is now given by

$$-\mu k + (v - p + k) + \beta V_1^B \geq -\mu k + B + (1-\rho)\left((v - p + k) + V_0^B\right). \tag{37}$$

Hence, the baker will choose $\lambda_B = 0$ as long as

$$\rho\left((v - p + k) + \beta V_1^B\right) + (1-\rho)\left(\beta V_1^B - V_0^B\right) \geq B. \tag{38}$$

Using the participation constraint on the equilibrium path where there is no default,[11] one obtains

$$\begin{aligned} k^{MD} &\geq \frac{1}{\mu}\left(\frac{B}{\rho} - c - \left(\frac{1-\rho}{\rho}\right)\left(\beta V_1^B - V_0^B\right)\right) \\ &= \frac{1}{\mu}\left(\frac{B}{\rho} - c - \left(\frac{1-\rho}{\rho}\right)(1-\chi)\beta c\right) \end{aligned} \tag{39}$$

where we have used the fact that

$$V_0^B = \beta\chi V_1^B = \beta\chi c. \tag{40}$$

Hence, credible punishment as reflected by $(1-\chi) > 0$ can relax the incentive constraint with the result that it is possible to save on collateral in an incentive contract. The value of

[11] We do not consider social norms here, where a one-time deviation is followed by a global punishment in newly formed matches with the particular baker who deviated.

an incentive contract with market discipline for the farmer is then given by

$$V_1^F = \frac{1}{1-\beta} u(v - c(1-\beta) - \frac{\mu}{\mu - 1} k^{MD}). \tag{41}$$

This leads to the following result.

Proposition 7. *Suppose $\sigma > 1 - \rho$ and λ_B is observable. If the degree of moral hazard B/ρ is sufficiently close to 0, the optimal contract features market discipline with optimal collateral being $k = 0$. Otherwise, for a given level of moral hazard, collateral requirements are lower for lower levels of liquidity, i.e. $\partial k^{INS}(B)/\partial\sigma \geq 0$.*

This is interesting from two reasons. First, if the exogenous default probability is low ($\epsilon = 0$), collateral savings are large with the implication that collateral requirements could even drop to 0 for B sufficiently close to ρc. Second, if liquidity is relatively high in the market ($\sigma > 1 - \rho$), punishment is a credible (and cheap) incentive mechanism making short-term insurance contracts less likely. As a consequence, collateral is low, but so is default risk.

What is interesting here is that lower liquidity increases the cost savings associated with market discipline. The reason is straightforward. Lower σ increases the costs associated with punishment in the form of a short-term contract for the baker. Hence, lower liquidity makes market discipline stronger. Still insurance contracts can be better, if the moral hazard problem becomes more severe and μ is relatively large. We now turn to the question how CCP clearing changes the selection of contracts between the farmer and the baker.

The key message to take away from this section is that low collateral posting need not be a sign of the contracting parties incurring larger default risk. Collateral could be low either because reputation achieves incentives or because the parties deliberately incur default risk as collateral is expensive. Again, the choice of contract is entirely efficient for the two contracting parties.

4.3 CCP Clearing and Market Discipline

We have simpified the environment by having no exogeneous default. Hence, introducing novation through a CCP will only make insurance contracts more attractive. Nonetheless, the purpose of this section is to show how CCP clearing can change the selection of contracts when it alters (i) the cost of collateral and (ii) the liquidity in the market. Central clearing will tend to decrease the unit cost of collateral, that is $\mu_{CCP} < \mu$. The reasons are that netting and more efficient collateral management can reduce the costs of collateral posted. Furthermore, introducing a CCP will affect the liquidity in the market. However, it is not a priori clear whether a CCP makes it easier for market participants to transact or not. Liquidity could increase simply because of a standardization of post trading arrangements. But, it could also decrease, especially if membership requirements are stringent and trades outside a CCP are penalized.[12] We reflect this in this section as a possible exogenous shift in the parameter σ_{CCP}.

We again assume that λ_B is observable. As in the static case, with $\lambda_B = 1$, the optimal capital requirement is given by $k^{INS} = 0$ since the CCP diversifies default risk better than individual collateral postings. The per-period value of the contract has thus increased. At the same time, the continuation decision is still governed by condition 31 and remains unchanged as $V_1^F > V_0^F$. Hence, CCP makes insurance contracts again more attractive. Also, as discussed in Proposition 6 before, any increase in liquidity (higher σ) will also make insurance contracts more attractive, leading to larger moral hazard problem and larger default risk with CCP clearing.

I want to consider now the case where CCP clearing leads to a fall in the unit costs of collateral, i.e. $1 < \mu_{CCP} < \mu$, that is accompagnied by a drop in liquidity, specifically $\sigma_{CCP} < (1-\rho) < \sigma$. These changes have two effects on incentive contracts. First, in any incentive contract, the total collateral costs will remain unchanged, but the price p of the contract will increase. Second, liquidity is so low that market discipline is not feasible anymore, since breaking off a trading relationship is not a credible punishment anymore. The next result characterizes when CCP clearing leads to efficiency gains for the contracting relationship.

Proposition 8. *Suppose $\sigma_{CCP} < 1-\rho < \sigma$. If $k^{MD} = 0$ due to market discipline, CCP clearing cannot increase total expected surplus. Otherwise, CCP clearing increases total expected surplus in incentive contracts if and only if*

$$\mu_{CCP} < \mu \frac{\left(\frac{B}{\rho} - c\right)}{A + \left(\frac{B}{\rho} - c\right)}, \tag{42}$$

where $A = (\mu - 1)c\beta\frac{(1-\rho)}{\rho}(1-\chi) > 0$.

[12] It is commonly argued that a CCP would concentrate and limit trading by precluding low quality participants in financial markets from trading. This is often presented as avoiding ex-ante adverse selection when introducing a CCP.

Furthermore, in the latter case the necessary savings in unit costs of collateral are decreasing in the degree of moral hazard (B/ρ) and in the matching probability (σ) before the introduction of the CCP.

Proof. Recall that the expected surplus for bakers is constant at c. Farmers pay-offs from an incentive contract with market discipline are given by

$$V_1^F(MD) = \frac{1}{1-\beta}u(v - c(1-\beta) - \frac{\mu - 1}{\mu}\max\left\{\left(\frac{B}{\rho} - c(1 + (1-\rho)(\beta - \chi)\right), 0\right\}), \quad (43)$$

while the incentive contract with a CCP yields a payoff of

$$V_1^F(INC) = \frac{1}{1-\beta}u(v - c(1-\beta) - \frac{\mu_{CCP} - 1}{\mu_{CCP}}\left(\frac{B}{\rho} - c\right)). \quad (44)$$

Comparing these two expressions yields the conditions in the first part of the proposition.

Finally, note that an increase in liquidity σ lowers the payoff for farmers with market discipline as collateral requirements increase. Hence, costs savings need to be smaller. □

The purpose of this section was to demonstrate that collateral requirements will increase with CCP clearing under two circumstances: (i) a fall in liquidity σ; and (ii) a fall in the unit costs of collateral. Whenever CCP clearing is not compatible with market discipline ($\sigma_{CCP} < 1 - \rho$), from an efficiency perspective unit costs have to drop sufficiently in order for CCP clearing to improve welfare. Still, CCP clearing makes insurance contracts more attractive as before, since it diversifies default risk. Again, paradoxically, optimal collateral requirements might fall with CCP clearing, if there is a switch in the type of contracts selected from an incentive to an insurance contract. We turn next to the task of endogeneousing the matching probability σ with and without CCP clearing.

5 Endogenous Liquidity

[TBA]

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