Be Careful What You Wish For: Cost of Collateral, Liquidity and Incentives with Central Counterparty Clearing*

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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 contracts where either collateral is used or market discipline is applied to 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 matter 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 be 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.

Consider, however, a situation where a trade occurs with the 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 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 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 require low default risk. Through diversification, it

[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)).

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.[4]

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. Then, the threat of terminating a relationship can be credible whenever these search costs are lower than the costs suffered through a default. This allows for short-term contract that have low collateral *and* low default risk. A CCP can again help as an insurance device – unless it changes the equlibrium structure of contracts. I demonstrate that a fall in market liquidity concurrent with the introduction of a CCP[5] can destroy the reputational equilibrium. As a consequence, collateral requirements will have 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 beneficial for the contracting parties. The reason is that in such situations the gains from market discipline are small.

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. Second, introducing a CCP can involve costs and unintended consequence. Such a policy can increase collateral costs without reducing overall default. 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.

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 interestinly, this last paper also establishes a link between collateral in the form of margin calls and CCP introduction and design.

[4]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)).

[5]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)).

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.

Farmers preferences are described by

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

where q is the amount of wheat produced – 0 or 1 – and x is the amount of gold consumed in period $t = 1$. 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 sell the wheat. 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 B is not observable 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 $p - k$.

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 a trading wheat with a farmer, where

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

This restriction ensures that the baker prefers taking on the additional risk if there is no collateral ($k = 0$) given the surplus c from trading with the farmer and, as will become clear later, that the contract features a price that exceeds collateral ($p \geq k$).

3 Collateral: Incentives vs. Insurance

3.1 Bilateral Clearing

Farmers will make a take-it-or-leave-it offer (p,k) to the baker that maximizes their expected utility. 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 insurance and incentive device, while controlling the farmer's default risk.

To make this more precise, the incentive constraint for the baker 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

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

Rewriting the incentive constraint we obtain

$$k \geq \frac{1}{\mu}\left(\frac{B}{\rho} - c\right). \tag{7}$$

Any contract that satisfies these two constraint is called an *incentive contract*.

Alternatively, the contract could violate the incentive constraint (7). This would imply that the baker takes excessive risk ($\lambda_B = 1$). The participation constraint becomes then

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

Using this constraint, collateral needs to be sufficiently low so that the baker has an incentive to set $\lambda_B = 1$, or

$$v - p + k \leq \frac{B(1-\rho)}{\rho}. \tag{9}$$

We call such a contract an *insurance contract*.

Collateral is costly so that requiring it reduces the total amount of gold p that farmer can require for his special wheat. The cost arises from the fact that $\mu > 1$. Collateral, however, has two benefits. First, it sets incentives not to choose B. This is reflected that a higher level of collateral relaxes the incentive constraint. Second, it provides for insurance, as the collateral will be retained by the farmer in case of a default.

The trade-off for the farmer is thus clear. 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. It might, however, be very costly to provide incentives through collateral. 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. 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 $\bar{k}(B)$ for $B \in [B^*, \rho v(1-\epsilon)]$.*

The optimal insurance contract is given by an increasing level of collateral 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. $k^0(B) < \max\{k^*, \bar{k}(B)\}$.

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

$$p = v - \frac{c}{1-\epsilon} - k\left(\frac{\mu}{1-\epsilon} - 1\right). \tag{10}$$

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

$$\epsilon u'(k) + (1-\epsilon)u'(p)\left(1 - \frac{\mu}{1-\epsilon}\right) + \lambda\mu = 0, \tag{11}$$

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

$$u'(k)\left(\epsilon + (1-\epsilon)\rho\right) - u'(p)\left(\mu - (1-\epsilon)(1-\rho)\right) + \lambda_{NN} - \lambda_{IC} = 0, \tag{12}$$

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

$$\begin{aligned} k &\geq 0 && (13) \\ k &\leq \frac{1}{\mu}\left(\frac{B(1-\rho)}{\rho} - c\right), && (14) \end{aligned}$$

respectively.

Inspection of the two constraints implies immediately that $k = 0$ for low values of B, then 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 summarizes this result. Optimal collateral policies for incentives and insurance contracts are driven by the incentive 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 $B/\rho = v(1 - \epsilon)$.

3.2 CCP Clearing and Novation

We introduce CCP clearing along the lines of Koeppl and Monnet (2010). The CCP pools all payments made from bakers in the form of collateral k at $t = 0$ and net settlement $p - k$ at $t = 1$ and pays out an equal share of its revenue to all farmers *independent* of the their default experience. We assume here throughout that the level of moral hazard B/ρ is fixed across transactions.

For an incentive contract, the revenue of a CCP is given by

$$R^{INC} = \epsilon k^{INC} + (1 - \epsilon)\left(v - \frac{c}{1 - \epsilon} - k^{INC}\left(\frac{\mu}{1 - \epsilon} - 1\right)\right) \tag{15}$$

where the second term is the next settlement received by the CCP in the second period. The farmer will now chose collateral so as to maximize the fixed revenue subject to the incentive

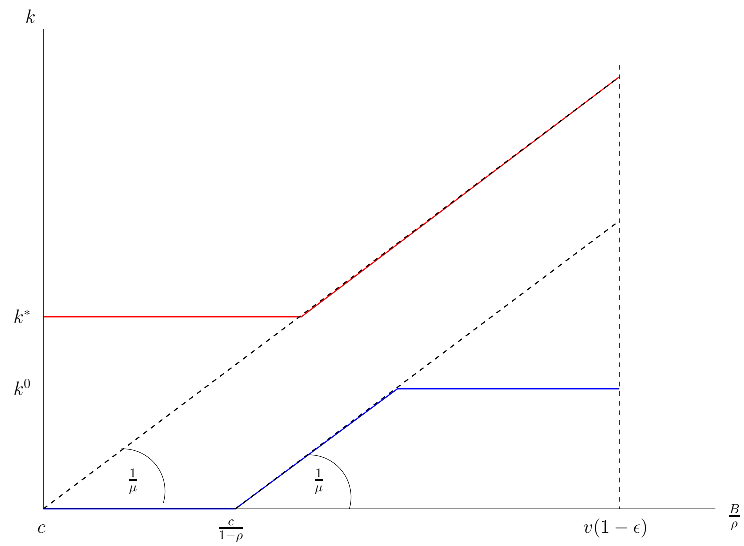

Figure 1: Optimal contract in terms of risk-weighted B

constraint (7). It is straighforward to verify that the constraint is always binding and we have

$$k^{INC} = \frac{1}{\mu}\left(\frac{B}{\rho} - c\right). \tag{16}$$

This implies that CCP clearing reduces collateral requirements, as farmers need not self-insure against the exogenous default risk. If moral hazard is relatively high, however, the collateral requirements remain unchanged.

Turning to an insurance contract, the CCP's revenue given by

$$R^{INS} = (1-\epsilon)(1-\rho)\left(v - \frac{c}{(1-\epsilon)(1-\rho)}\right). \tag{17}$$

It is immediate that the solution to this problem is $k^{INS} = 0$ which clearly satisfies the constraint (9). 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. It is now straightforward to compare incentive and insurance contracts under CCP clearing.

Proposition 2. *The optimal contract with CCP clearing is an incentive contract if and only if*

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

Holding constant the unit cost of collateral μ, any optimal contract with CCP clearing has lower collateral requirements than without CCP clearing.

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. Of course, this can imply that default risk increases with CCP clearing – but this is efficient.

Most interestingly, we can have a situtation where the introduction of CCP clearing will increase counterparty risk simply by inducing market participants to change the nature of contracts. In particular, market particiapants will substitute insurance contracts for incentive contracts. Note, however, that this is fully efficient: CCP clearing allows to save on collateral for insurance purposes. This will occur for intermediate levels of moral hazard when collateral costs are sufficiently. Collateral costs for incentive contracts will remain unchanged, while collateral falls to zero for insurance contracts once CCP clearing takes place.

Turning to collateral costs, the critical value for which the insurance contract with CCP clearing dominates is decreasing in the unit costs of collateral μ. For sufficiently low costs ($\mu \to 1$) we get nonetheless that an incentive contract always dominates *for all* feasible levels of B.[6] Consider next a fall in the unit cost of collateral with CCP clearing, i.e. $\mu_{CCP} < \mu$. For incentive contracts, the degree of moral hazard, B/ρ only determines 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 simply remain unaltered. Finally, a 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 imposes an inefficient contract on market participants whenever moral hazard is severe.

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 we have obtained this result in a framework where both counterparty default *and* the cost

[6]This should be the empirically relevant case. On the one hand, CCPs are likely to only cover institutions with good governance and unit costs of collateral are fairly low.

of collateral matter for efficiency. 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

We present now 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. 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. Only when there are insurance contracts does CCP clearing add direct value through novation.[7]

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

Suppose first that the baker's decision to realize B is not observable for the farmer. Then 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

$$-\mu k + (1 - \rho\lambda_B)\left[(v - p + k) + \beta\left(\lambda_F V_0^B + (1 - \lambda_F)V_1^B\right)\right] \geq c \tag{18}$$

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

$$\rho\left[(v - p + k) + \beta\left(\lambda_F V_0^B + (1 - \lambda_F)V_1^B\right)\right] \geq B. \tag{19}$$

[7] We can justify this assumption in two ways. First, outright default for exogenous reasons is a rare event beyond possibly "technical" default where a party does not settle even though it is able to do so. This either leads to penalties or renegotations between the parties. Second, one could interpret ϵ as an aggregate event which is also a small event. Novation would not provide less value here, since there are no gains from diversification.

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

$$k \geq \frac{1}{\mu}\left(\frac{B}{\rho} - c\right). \tag{20}$$

To the contrary, an insurance contract needs to satisfy the constraint

$$k \leq \frac{1}{\mu}\left(\frac{B}{\rho}(1-\rho) - c\right). \tag{21}$$

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

$$(1-\rho\lambda_B)\beta V_1^F + \rho\lambda_B\beta V_0^F \geq V_0^F \tag{22}$$

where V_i^F is the value function for the farmer. The value function of being without a match at the end of the period is given by

$$V_0^F = \beta\left(\sigma V_1^F + (1-\sigma)V_0^F\right) \tag{23}$$

or

$$V_0^F = \frac{\beta\sigma}{1-\beta(1-\sigma)}V_1^F = \chi V_1^F < V_1^F \tag{24}$$

since upon having terminated the relationship, the farmer will be in a match next period with probability σ again. Rewriting the condition for $\lambda_F = 0$, we obtain

$$\left[(1-\rho\lambda_B) - \sigma\right]\beta\left(V_1^F - V_0^F\right) \geq 0. \tag{25}$$

This yields the following proposition.

Proposition 3. *If $\sigma \leq 1-\rho$ then independent of moral hazard, the long-term relationship is maintained. 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.*

Hence, liquidity on the market matters for the optimal contract structure. 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. Intuitively, when markets are more liquid (higher σ) one would see less long-term contractual relationships. Interestingly, with search costs relatively high, we find that insurance contracts take place in short-lived relationships, while collateral is used as an incentive device in long-term relationships.[8]

We turn now to a discussion of the optimal choice of contract (p, k). Note that the decision to carry on with the relationship depends on the contract choice only for low search costs $(\sigma > 1 - \rho)$. The analysis is identical to the static problem where the pricing function has the same functional form, given by

$$p = v - \frac{c}{(1-\rho\lambda_B)}\alpha(\lambda_B, \lambda_F) - k\left(\frac{\mu}{(1-\epsilon)(1-\rho\lambda_b)} - 1\right) \tag{26}$$

where $\alpha(\lambda_B, \lambda_F)$ summarizes the impact of the decisions by the baker and the farmer on the price. This implies that the optimal contract is qualitatively the same as in the static case and given by a choice of $k \geq 0$ that maximizes utility subject to the incentive or insurance constraints. The next proposition characterizes the choice of collateral further.

Proposition 4. *For all σ and B, we have that $k^0 < \bar{k}(B)$, that is incentive contracts have more collateral.*

If $\sigma > 1 - \rho$, the value of the insurance contract for the farmer increases with liquidity, i.e. $\partial V_1^F / \partial\sigma \geq 0$, and so does collateral k^0.

Proof. Solving the participation constraint for p, we obtain the following result for $\alpha(\lambda_B, \lambda_F)$

$$\begin{aligned} \alpha(\lambda_B, 0) &= 1 - (1-\rho\lambda_B)\beta & (27) \\ \alpha(\lambda_B, 1) &= 1 - (1-\rho\lambda_B)\frac{\beta\sigma}{1-\beta(1-\sigma)}. & (28) \end{aligned}$$

Observe that for the same level of collateral, the price p is always larger with $\lambda_B = 1$, the insurance contract. Since $\epsilon = 0$, we have that

$$k^0 \leq \frac{B(1-\rho)}{\rho} - c < \frac{B}{\rho} - c = \bar{k}(B) \tag{29}$$

[8]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.

which gives the first result.

Note that the value of an incentive contract for the farmer is independent of the search friction σ. The value of an insurance contract is given by

$$V_1^F(INS) = \frac{1}{1-(1-\rho)\chi}\left((1-\rho)u(p)+\rho u(k)\right). \tag{30}$$

It is easy to veify that $\partial\chi/\partial\sigma > 0$ and the result follows, since holding the level of collateral fixed the price is increasing in σ. □

Search costs matter for the optimal collateral only if $\lambda_F = 1$, that is in a short-term relationship. With λ_B being unobservable, short-term relationships only occur if liquidity is high in the market *and* if the farmer prefers an insurance contract. In such a case, if liquidity – i.e. the probability of finding a counterparty σ increases –, the optimal collateral requirements in an insurance contract increase weakly. The reason is, however, 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. Hence, the attractiveness of an insurance contract is declining with liquidity. Hence, we should expect that for given costs of collateral, the more liquid markets are the more attractive are insurance contracts. Still, collateral is strictly lower in such contracts than in insurance contracts, making them more attractive the larger the moral hazard problem B/ρ.

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[9] 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.

[9]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 (a multiple of) 1 to $1+\chi$. 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.

We again solve backwards. Recall first the condition (25). It is clear that for $\sigma < 1 - \rho$, continuing the relationship is a strictly dominant strategy for the farmer. Hence, there will be no monitoring and $\lambda_F = 0$. This is independent of the contract choice (p, k). We therefore make the following assumption. Hence, we assume that $\sigma > 1 - \rho$ for this section. It follows immediately that the farmer will continue the relationship if and only if condition (22) holds. Thus, by our assumption, the farmer breaks off the relationship if and only if $\lambda_B = 1$. Hence, the farmer can credibly threaten to terminate the relationship whenever there is moral hazard. The reason is simple. When continuing, the farmer faces an increased default risk which outweighs the risk of finding a new counterparty for next period. We call this punishment strategy *market discipline*.

We show next that market discipline is a substitute to collateral, as it relaxes the incentive constraint. We have for the baker's incentive constraint

$$-\mu k + (v - p + k) + \beta V_1^B \geq -\mu k + B + (1 - \rho)\left((v - p + k) + V_0^B\right). \tag{31}$$

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

$$\rho\left((v - p + k) + \beta V_1^B\right) - (1 - \rho)\left(\beta V_1^B - V_0^B\right) \geq B. \tag{32}$$

Using the participation constraint, one obtains

$$k \geq \frac{1}{\mu}\left(\frac{B}{\rho} - c - \left(\frac{1 - \rho}{\rho}\right)\left(\beta V_1^B - V_0^B\right)\right). \tag{33}$$

We have that

$$V_0^B = \chi V_1^B = \chi c \tag{34}$$

so that the incentive constraint becomes

$$k \geq \frac{1}{\mu}\left(\frac{B}{\rho} - c - \frac{1 - \rho}{\rho}(\beta - \chi)c\right). \tag{35}$$

where we have again used the participation constraint on the equilibrium path for V_1^B.[10] Hence, credible punishment as reflected by $(\beta - \chi) > 0$ can relax the incentive constraint with the result that it is possible to save on collateral in an incentive contract.

This is interesting from two perspectives. First, if the exogenous default probability is low ($\epsilon = 0$), collateral savings are large with the result that collateral requirements could even

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

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. This is summarized as follows.

Proposition 5. *Suppose $\sigma > 1-\rho$ and λ_B is observable. If 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 (B/ρ), collateral requirements are lower for lower levels of liquidity – i.e. lower σ.*

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. Insurance contracts can only be better in the case in the market discipline, 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.

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 that it can have an additional effect by influencing two parameters of the model: (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.[11] We reflect this 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

[11]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.

individual collateral postings. This implies that any insurance contract will have a payoff for the farmer given by

$$V_1^F(INS) = \begin{cases} \frac{1}{1-(1-\rho)\beta\chi} u((1-\rho)v - c(1-(1-\rho)\beta)) & \text{if } \sigma < (1-\rho) \\ \frac{1}{1-(1-\rho)\chi} u((1-\rho)v - c(1-(1-\rho)\chi)) & \text{if } \sigma \geq (1-\rho) \end{cases} \tag{36}$$

where we have used already the optimal strategy λ_F and the price functions $p(\lambda_B, \lambda_F)$. The per-period value of the contract has thus increased, making insurance contracts – and short-term relationships more attractive. Also, as discussed before, any increase in liquidity will also make insurance contracts better, potentially leading to larger moral hazard with CCP clearing.

Consider now a fall in the unit costs of collateral, i.e. $1 < \mu_{CCP} < \mu$. In any incentive contract, the total collateral costs will remain unchanged, but the price p of the contract will increase. Suppose, however, that at the same time liquidity in the market falls as CCP clearing is introduced, i.e. $\sigma_{CCP} < \sigma$. In particular, we look at a situation where $\sigma_{CCP} < (1-\rho) < \sigma$. Hence, the introduction of CCP clearing will change the selection among incentive contracts. This yields the following result.

Proposition 6. *Suppose $\sigma_{CCP} < 1-\rho < \sigma$. If $k^{INC} = 0$ 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*

$$\mu_{CCP} < \mu \frac{\left(\frac{B}{\rho} - c\right)}{A + \left(\frac{B}{\rho} - c\right)}, \tag{37}$$

where $A = (\mu-1)c(1-\rho)(\beta-\chi)$.

Furthermore, in the latter case the necessary savings in unit costs of collateral are decreasing in the degree of moral hazard and in the level of liquidity, 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

$$V_1^F(MD) = \frac{1}{1-\beta} u(v - c(1-\beta) - \frac{\mu-1}{\mu} \max\left\{\left(\frac{B}{\rho} - c(1+(1-\rho)(\beta-\chi)\right), 0\right\}), \tag{38}$$

while the incentive contract with a CCP yields a payoff of

$$V_1^F(INC) = \frac{1}{1-\beta}u(v - c(1-\beta) - \frac{\mu_{CCP}-1}{\mu_{CCP}}\left(\frac{B}{\rho} - c\right)). \tag{39}$$

This 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. Hence, costs savings need to be smaller. □

4.4 Implications for Policy

At this stage, it is useful to summarize our results for the current policy discussion. One main issue is how to account for the effects of the action λ_B, since B is a private benefit, but its cost $\rho > 0$ can be interpreted broadly as being also social costs that go beyond lowering the surplus in the relationship between the farmer and the baker.

The main message of this paper is that novation through a CCP can give incentives for market participants to change the counterparty risk in trades. There are two channels for this. First, contracts that induce moral hazard become cheaper as novation provides (free) insurance. In our model, this corresponds to a shift from an incentive to an insurance contract. Second, whenever CCP clearing depresses market liquidity, the discipline of long-term relationships might be compromised. This is reflected in the model by weakening the threat of breaking up an established trading relationship in the face of moral hazard by one of the contracting parties.

On the surface, the solution seems to entail a requirement of collateral that is commensurate with incentive contracts that prevent moral hazard. But this is costly and it is necessary to weigh the benefits of less default risk against the costs from higher collateral requirements which are not in the *private* interest of financial market participants. The next section attempts such a comparison between collateral costs and social benefits of lower default risk.

5 Example: Welfare Implications

To be completed.

6 Endogenous Liquidity

To be completed.

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