The Emergence and Future of Central Counterparties*

Thorsten V. Koeppl
Queen's University

Cyril Monnet
University of Bern and SZ Gerzensee

First Version: September 2009

This Version: July 2013

Abstract

This paper analyzes the impact of central counterparty (CCP) clearing on prices, market size, and liquidity in financial markets with counterparty risk. CCP clearing achieves efficiency for both, standardized financial contracts that are centrally traded and customized ones that trade over-the-counter (OTC). For standardized contracts, CCP clearing provides insurance against counterparty default. With customized contracts, such insurance is not feasible anymore, but CCP clearing can induce traders to take on the socially optimal level of counterparty risk. However, CCP clearing in OTC markets attracts liquidity which depresses prices of standardized contracts and thus causes resistance against extending efficient clearing arrangements.

Keywords: Counterparty Risk, Novation, Mutualization, Over-the-counter Markets, Customized Financial Contracts

JEL Classification: G2, G13, G32, D47

*We thank V.V. Chari, Todd Keister, Ed Nosal, Chris Phelan and Pierre-Olivier Weill for their comments. We also thank the audiences at many conferences and institutions where we presented this paper. Part of this work was completed while Cyril Monnet was a John Weatherall Fellow at the Department of Economics at Queen's University. Thorsten Koeppl acknowledges research funding from SSHRC grant 410-2006-0481 and financial support from the Governor's Award of the Bank of Canada. The views expressed are entirely those of the authors and not necessarily those of the Bank of Canada.

1 Introduction

Research on financial markets has mainly concentrated on understanding trading volume, how prices are determined and what information they incorporate and reveal. Much less effort has been devoted to understand how post-trade arrangements such as clearing and settlement control default risk in financial trading, although one would think that how traders safeguard against the risk that a counterparty defaults influences market prices, liquidity, and the size of a market. To fill this gap, we analyze how clearing arrangements can control counterparty risk and how these arrangements impact the functioning of financial markets. In particular, we show how the benefits from central clearing vary across standardized, centrally traded contracts and customized contracts which are traded over-the-counter (OTC), and that the incentives to move to such clearing differ across these market structures.

After trading, financial markets participants operate back-office services that manage the obligations from trading through what is called clearing and settlement. Clearing manages the trading relationship starting from trade confirmation and continually controlling any risk associated with the trade, while settlement is the fulfillment of the obligations at the end of a trading relationship. These services are necessary since there is always a lag between trading and the fulfillment of the obligations from trading. This lag can be short like in spot transactions or fairly long for term or derivatives transactions where clearing plays a crucial role for a well-functioning market.

Clearing can be arranged in several ways. It can be done bilaterally in which case the original counterparties carry it out among themselves directly. But clearing can also be delegated to a central third party, a clearinghouse. When contracts are centrally cleared, the clearinghouse usually functions as a so-called central counterparty (CCP). Through a process called novation, it replaces all trades by two new, legally binding contracts, one with the seller and another one with the buyer. CCP clearing, therefore, separates the two counterparties to a trade, with the CCP taking on all legal obligations towards the seller and the buyer, respectively. As a consequence, the two original counterparties do not have any legal obligations towards each other anymore, but only towards the CCP. This risk transfer implies however that now the clearinghouse needs to manage any counterparty risk associated with the trade.

The first clearinghouses offering various services for futures trading can be traced back to 18th century Japan (Schaede (1989)). Kroszner (1999) describes how the first clearinghouse emerged in North America – for grain trading in Chicago – and how it evolved into a CCP. The bottom line of these historic accounts is that the role of clearinghouses evolved quickly from merely controlling the quality of the grain traded to insuring its delivery as contractually specified, thus improving counterparty risk in the market. Modern futures exchanges started to emerge as early as the 1920s making central clearing a key organizational feature of futures trading. By now, virtually all major futures, derivatives and spot market exchanges operate with CCP clearing.

With the rise of more specialized financial products, trading, however, has steadily moved away from such centralized trading venues to OTC trading. This poses the question how far CCP clearing can reach beyond centralized markets. Even preceding the recent financial crisis, regulators have contemplated that OTC trades should also be cleared centrally through a CCP. The crisis then made clear that risk exposures in OTC markets are unknown and that the sheer size of potential counterparty risk in these markets makes proper clearing arrangements essential. Notwithstanding, it is commonly asserted (see for example ISDA (2013)) that highly customized OTC derivatives contracts, while necessary for proper hedging, remain outside the scope of central clearing due to the difficulty in assessing the risks associated with such contracts.

Is it feasible to expand central clearing into OTC markets where contracts are often customized? And if so, should it be extended to such markets and what are the obstacles that prevent its introduction? Our paper gives answers to these questions. We first develop a precise explanation for why central clearing is so widely used in centralized markets and then show that – for different reasons – it is also essential for achieving efficiency in OTC trading. Interestingly though, we find that some financial markets participants can have a strong incentive to block CCP clearing for OTC trading.

We set-up a basic general equilibrium model of financial trading with a delay between the time of trading and the time when the trades are settled. While the model is deliberately simple, it captures the two fundamental risks that make clearing meaningful. First, there is price risk so that some traders in the model have an incentive to enter into forward transactions in order to hedge against such risk. Second, there is the risk that a counterparty that offers such hedging defaults on the trade for exogenous reasons. This counterparty risk implies that forward transactions are again partially exposed to price risk and thus that the hedge is imperfect.

We look at two different types of financial contracts. Standardized contracts are traded with a central price mechanism and can be traded among all traders, while customized contracts are uniquely designed for a particular trader and, hence, are negotiated bilaterally. As a consequence, a customized contract cannot be re-traded among other traders. We assume that markets are incomplete, as traders are unable to insure against the risk of default. It is then not surprising that a CCP is able to diversify default risk, as it transfers counterparty risk from all traders to itself. More surprisingly, however, is that the CCP is able to provide such diversification irrespective of the trading protocol (centralized or OTC trading) or the characteristics of the contracts it clears. All that matters is that central clearing can pool counterparty risk. To the contrary, price risk and the ability to assess this risk is not essential for central counterparty clearing at all.[1]

For standardized contracts, we find that it is never optimal for the CCP to fully insure traders against price risk. Rather, the remaining risk should be efficiently allocated among traders ex-ante. Also, an ex-post transfer scheme among traders – mutualization of losses – guarantees that there is no price risk ex-post for traders that try to hedge against it. However, this is not the case for customized contracts, where the price risk is extreme: the absence of a secondary market for such contracts makes any losses from default very hard or even impossible to recover.

The main benefit of CCP clearing for customized contracts arises from the fact that the CCP has access to all the positions taken. The CCP can therefore achieve a better allocation of risk: in OTC markets, the absence of a central price mechanism implies that individuals do not necessarily internalize that some trades have a higher surplus than others. We show that the CCP can induce traders to take more risk exposure in trades with higher surplus and, thus, can substitute for the signal prices provide in centralized exchange. Importantly, all traders prefer such a reallocation of risk ex-ante, before trading takes place.

Why has central clearing then not already been introduced for all trading, i.e. also for OTC trades? Our simple model shows that while there is a clear benefit for all traders when the CCP clears standardized contracts, there will be winners and losers when the CCP clears customized contracts. Diversifying counterparty risk in OTC markets re-shapes the organization of markets – where and what people trade. In our model, trading customized contracts becomes more attractive and, hence, central clearing of such contracts removes liquidity from the market for standardized contracts. As a consequence, prices for standardized contracts fall making some traders worse off. It is thus possible to understand the reluctance of some market participants to move to central clearing for OTC trades.

The academic literature on clearing is new but growing. Pirrong (2011) provides a good survey of the perceived benefits of central clearing and some of the practical issues that can

[1] Hull (2010) also argues that the inability to assess such risk is immaterial for central clearing, albeit for a different reason. A clearinghouse could always request risk assessments from the contracting parties upfront. It would then limit its services to be in line with these assessments.

make formal clearing difficult to be introduced in a particular market. There are several theoretical papers that focus on a particular advantage of central clearing. Leitner (2009) and Acharya and Bisin (2009) study the role of a central counterparty in gathering information on traders' aggregate exposure. Carapella and Mills (2013) argue further that CCP clearing can foster market liquidity by making traders' exposure information insensitive. Duffie and Zhu (2009) look at the benefits from netting exposures when clearing derivatives centrally. All these paper have in common that they emphasize a particular service offered by clearinghouses. These services are not an essential element of central clearing, as they could also be offered independently of the fundamental risk transfer that we have argued is at the core of central clearing.[2]

Above, we have outlined the key benefit and the key impediment of the risk transfer that characterizes CCP clearing. Some recent contributions have made progress in adding additional details to our analysis. Monnet and Nellen (2013) have quantified the gains of clearing some derivatives contracts centrally. Koeppl (2013) uses the framework in this paper to consider the effect of clearing on moral hazard and market discipline as additional limitations to clearing OTC transactions centrally. Finally, Biais et al. (2012) consider limiting the risk transfer involved in central clearing as a key incentive mechanism for controlling counterparty risk in financial markets.

The paper proceeds as follows. In the following section we lay out the environment. In Section 3, we analyze the properties of the equilibrium in the absence of central clearing. We study central clearing in Section 4, for standard as well as customized contracts. Section 5 briefly concludes. The appendices contain all proofs and additional material to show robustness of the results regarding some of our assumptions.

2 The Environment

We develop a model to capture the difference between trading standardized (futures) and customized (forward) contracts in financial markets. We see futures and forward contracts as promises to two different types of goods. A futures contract promises the delivery of a general good valued by all market participants. Hence, futures can be traded in a centralized market where the pricing of contracts is perfectly competitive. To the contrary, a forward contract promises the delivery of a special or "exotic" good that only one agent likes. Here,

[2]Trade repositories for example take on the role of gathering and disseminating information on trading positions and risk exposures. Ring netting and trade compression are alternative arrangements that can net trades and exposures outside clearinghouses.

bilateral negotiation will determine the terms of trade, very much like in an OTC market.

Both markets are incomplete as agents are unable to insure against two sources of risk. The first risk arises from the exogenous default of an agent. The second one arises from aggregate demand shocks that lead to price fluctuations for the general good. By their very own nature, exotic goods cannot be retraded at all upon default, so that this second source of risk can be viewed as being extreme. These features will capture counterparty risk and the so-called price risk associated with the default of a counterparty.

2.1 Model

We consider an economy with two periods and three types of goods: gold which is perfectly storable, wheat and an exotic type of wheat which we will call "Einkorn". In the first period, there is a continuum of measure one of farmers who like gold and can produce wheat. There is also a continuum of bakers with measure $1/(1-\delta) > 1$. They can produce gold and like to consume both wheat and Einkorn. Each baker, however, likes to consume only his specific variety of Einkorn. Therefore, we index the variety of Einkorn by the name of the baker $i \in [0, 1/(1-\delta)]$ who likes to consume it. Bakers only live through the second period with probability $1-\delta$, so that in the second period there are as many bakers as farmers. A baker's death is a random event that we use to introduce the idea of counterparty risk.

Farmers need to specialize in their production. In the first period, they either can plant q units of wheat or s_i units of a single variety of Einkorn, but not both.[3] Farmers harvest wheat or Einkorn in the second period.

The value of wheat is subject to an aggregate demand shock θ in the second period. We assume that θ is drawn from a distribution F with mean 1. Therefore, a farmer consumes a possibly uncertain amount of gold $x(\theta, q, s_i)$ in the second period, which depends on θ and whether he produced Einkorn for baker i who is dead or alive. A farmer's preferences are represented by the following utility function,

$$U(x(\theta, q, s_i), q, s_i) = -q - s_i + E_{\theta,i}[\log x(\theta, q, s_i)], \tag{1}$$

where expectations are taken over the probability of death of the baker as well as over the aggregate demand shock for wheat θ.

Bakers value both wheat and Einkorn and they may consume both in the second period. We

[3] In other words, we impose the restriction that $qs_i = 0$ and $s_i s_j = 0$ for all $i, j \in [0, 1/(1-\delta)]$.

denote a baker's demand for wheat in state θ by $y(\theta)$ and his demand for Einkorn by s_i. His preferences are given by

$$V_i(y(\theta), s_i, x_1, x_2(\theta)) = -\mu x_1 + (1-\delta)E_\theta \left[\theta \log(y(\theta)) + \sigma_i v(s_i) - x_2(\theta)\right], \tag{2}$$

where x_1 and x_2 are the amount of gold produced – or consumed when negative – in the first and second period. We assume that $\mu > 1$ so that prepaying for wheat or Einkorn is costly.

Bakers are ex-ante heterogeneous with respect to their preference for their variety of Einkorn. This is expressed by the parameter $\sigma \in [\underline{\sigma}, \overline{\sigma}]$ which is distributed across bakers according to some distribution G. It is a fixed, observable ex-ante characteristic of a baker and expresses how much a baker likes his variety of Einkorn relative to wheat. The function v is concave, with normalization $v(0) = 0$ and satisfying $v'(0) = \infty$.

2.2 Markets

The sequence of events is depicted in Figure 1. Initially, each farmer is randomly matched with exactly one baker in the forward market. Bakers who are not matched with a farmer move on directly to the futures market. We assume for simplicity that the farmer makes a take-it-or-leave-it offer to the baker. The offer specifies an amount s_i of Einkorn to be delivered and a price p_i to be paid in gold in the second period, as well as an amount of collateral k_i to be delivered in gold in the first period. If the baker rejects the offer, they move on to the futures market for wheat. If the baker accepts the offer, the farmer produces the Einkorn.

The futures market is competitive. Farmers and bakers trade futures contracts that consist of (i) a farmer's promise to deliver 1 unit of wheat to the baker and (ii) the baker giving collateral k in gold to the farmer. Farmers in this market produce plain wheat and they are sellers of a contract that promises the delivery of one unit of wheat in period 2. Bakers as buyers of the contract agree to deliver k units of gold per contract in the first and $p_f - k$ units in the second period. While both farmers and bakers take the price p_f as given, each farmer transacts with exactly one baker who does not yet have a contract for Einkorn.[4]

In the second period, all contracts will be settled if possible through the delivery of wheat, Einkorn, and gold. In the forward market, surviving bakers deliver $p_i - k_i$ units of gold

[4] If there is a measure n of farmers in the futures market, a measure n of bakers is randomly selected to participate in the futures market from those who were not matched with a farmer and those who rejected an offer. This is feasible as there are always more bakers than farmers that do not trade in Einkorn.

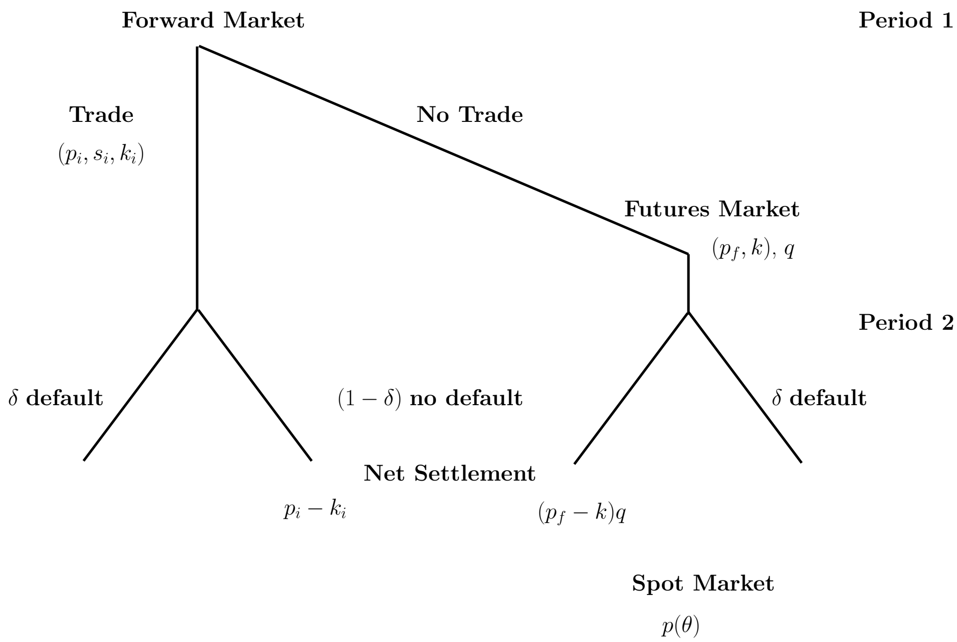


Figure 1: Timing – Forward, Futures and Spot Market

against s_i units of Einkorn. Similarly, in the futures market, bakers deliver $p_f - k$ units of gold against delivery of one unit of wheat. Hence, there is net settlement of contracts, so that pledging collateral acts as a partial prepayment. For contracts where the baker died, there is no settlement and farmers are then not required to honor their obligations. Finally, there is a spot market for wheat. Farmers with futures contracts in default can sell their wheat on this spot market. There is, however, no market for trading Einkorn, since it was produced for a specific baker and is useless to any other baker.

3 Equilibrium Without Central Clearing

3.1 Spot Market

We first solve for a competitive equilibrium on the wheat spot market in the last stage of the economy. When the spot market opens, a measure one of bakers is still alive. Taking the price $p(\theta)$ as given, a baker with wealth ω in terms of gold solves the following problem

$$\tilde{V}(\omega) = \max_{y, x_2} \theta \log(y) - x_2$$

subject to his budget constraint $p(\theta) y \leq x_2 + \omega$. Then, conveniently, the demand of the baker is independent of initial wealth ω and given by

$$y(\theta) = \frac{\theta}{p(\theta)}, \tag{3}$$

while his payment in gold is $x_2(\theta) = \theta - \omega$. Denoting the total amount of wheat by Q, market clearing requires that $\int y(\theta) di = Q$ so that the equilibrium spot price in state θ is simply given by

$$p(\theta) = \frac{\theta}{Q}. \tag{4}$$

3.2 Futures Market

We now analyze trading on the futures market for wheat where only farmers and bakers participate that have not contracted on Einkorn. Consider a baker that purchases q_b units of a futures contract at price p_f. The contract can also specify the posting of collateral k. Then in period 2, the baker has a claim to q_b units of wheat as long as he pays p_f minus collateral k. Since he can also sell wheat on the spot market at price $p(\theta)$, his net wealth is thus given by $\omega = (p(\theta) + k - p_f) q_b$. Using the fact that his demand on the spot market $y(\theta)$ is independent of his wealth position, a baker will choose the number of contracts q_b to maximize his expected revenue, or

$$\max_{q_b} -\mu k q_b + (1-\delta) \int (p(\theta) + k - p_f) q_b dF(\theta), \tag{5}$$

where the first term expresses the additional costs of securing the trade with collateral when purchasing wheat in a futures contract. No-arbitrage pricing then implies that the futures price has to satisfy

$$p_f = \int p(\theta) dF(\theta) - \left(\frac{\mu}{1-\delta} - 1\right) k. \tag{6}$$

Posting collateral implies an effective cost $\mu/(1-\delta) > 1$ which takes into account that collateral has a deadweight cost $\mu > 1$ and is lost for the baker if he dies ($\delta > 0$). No-arbitrage pricing thus implies that bakers are fully compensated for the cost of collateral and, hence, are indifferent between pledging any amount of collateral.

We denote by $n \in [0, 1]$ the measure of farmers who enter the futures market. Farmers are risk averse and use the futures market to insure against the variability in the spot price $p(\theta)$. Therefore a farmer who intends to produce q units of wheat will prefer to sell q futures contracts rather than to wait until period 2 to sell his production on the spot market. Trading on the futures market is competitive and farmers take the price p_f as given.

Each farmer, however, faces counterparty risk, as he trades with a single baker who can die. In this case, the farmer needs to sell the wheat on the spot market. As a consequence, he may require a prepayment or collateral $k > 0$ per futures contract to cover the ensuing price risk. Taking futures prices as given, farmers recognize that they bear the cost of asking for collateral, as the net payment in period 2, $p_f - k$, declines linearly with the discounted cost of collateral $\mu/(1-\delta)$. Notwithstanding, collateral can be useful: if a farmer's counterparty defaults, he keeps the collateral kq and sells his wheat on the spot market. Hence, he obtains a state-dependent revenue equal to $(p(\theta) + k)\,q$, where $p(\theta)$ is the equilibrium spot price. Without default, the farmer obtains a total payment of $p_f q$ from the baker. The farmer's problem in the first period is then to choose production of wheat $q \geq 0$ and a level of collateral $k \geq 0$ to solve

$$\max_{q,k} -q + (1-\delta)\log(p_f q) + \delta \int \log\left((p(\theta) + k)\, q\right) dF(\theta). \tag{7}$$

It follows that farmers supply $q = 1$ units of futures contracts *independent of the collateral policy.*[5] Hence, the spot price is also independent of collateral posted and equal to $p(\theta) = \theta/n$, as the total supply of plain wheat satisfies $Q = n$. This yields the following result.

Proposition 1. *The equilibrium price on the futures market equals the expected spot price minus collateral costs, i.e.*

$$p_f = \frac{1}{n} - \left(\frac{\mu}{1-\delta} - 1\right) k. \tag{8}$$

It is never optimal for farmers to fully insure against default through collateral, $k < p_f$, and, for sufficiently high costs of collateral μ, it is optimal to not require collateral.

Trading on the futures market partially insures farmers against the aggregate price risk of selling wheat on the spot market. The insurance is imperfect, however, as farmers still face the risk that their counterparty defaults with probability $\delta > 0$. Default thus reintroduces aggregate price risk. One way to limit this risk is to require collateral. Somewhat surprisingly, farmers never fully collateralize their trades. But the intuition is simple. In case of default, farmers can still sell their production spot. If farmers were to fully collateralize – i.e., require full prepayment ($k = p_f$) – they would enjoy too much consumption in default

[5]This result holds only for the specific functional form we have assume for preferences. In general, the amount produced depends on the collateral posted, but this additional complication would not influence our main results.

states at the expense of lower consumption in nondefault states. Therefore, they prefer to undercollateralize their exposures. It is easily verified that collateral is decreasing in collateral costs μ, but increasing in counterparty risk δ. Finally, the futures price is decreasing with the number of participating farmers n. This number is determined by the equilibrium in the forward market which we analyze next.

3.3 OTC Market for Forward Contracts

We turn now to the forward market for Einkorn, which we interpret as an OTC market for customized contracts. All farmers are matched with a baker to whom they make a take-it-or-leave-it offer to produce Einkorn. The offer consists of production s_i, a price p_i and collateral k_i. The baker accepts it as long as it is at least as good as trading futures contracts (p_f, k). By no-arbitrage pricing, his expected future wealth from futures trading is given by $\int \omega(\theta)dF(\theta) = 0$ so that he accepts the offer if and only if[6]

$$-\mu k_i + (1-\delta)\left[\sigma_i v(s_i) - (p_i - k_i)\right] \geq 0. \tag{9}$$

If the baker accepts the offer, he needs to pledge collateral k_i in the first period. If he is still alive in the second period, the baker obtains s_i units of Einkorn and pays the remaining $p_i - k_i$ units of gold. If the baker dies, the farmer only gets the collateral, as Einkorn is worthless and he cannot produce wheat anymore. The equilibrium contract for OTC trades is then given by the farmer's take-it-or-leave-it offer which solves

$$\max_{(s_i, p_i, k_i)} -s_i + (1-\delta)\log(p_i) + \delta \log(k_i) \tag{10}$$

subject to the baker's participation constraint (9). The level of production s_i is independent of σ_i and given by some level $\bar{s}$ that satisfies the first-order condition

$$v'(s_i) = v(s_i), \tag{11}$$

for all i. Farmers then extract all the surplus from bakers via the price

$$p_i = (1-\delta)\sigma_i v(\bar{s}), \tag{12}$$

[6]Notice that a baker who accepts a forward offer can still buy wheat in the spot market in period 2. If he rejects the offer, he can buy wheat also on the futures market in period 1. However, the pricing of futures contracts implies that the baker is indifferent between the two options. As a consequence, the gain from trading wheat does not directly influence the surplus from trading Einkorn and, hence, the decision whether to accept the forward contract.

while collateral is given by

$$k_i = \frac{\delta}{\mu - (1-\delta)} p_i. \tag{13}$$

Once again, collateral is an increasing function of the default rate δ and less than the price p_i due to the deadweight cost ($\mu > 1$).

Importantly, the forward contract only depends on the preference parameter σ_i and the fixed amount of Einkorn $\bar{s}$. A farmer will trade forward contracts, whenever he is better off selling Einkorn to a baker with preference σ_i than selling a futures contract for wheat, or

$$-\bar{s} + \log(p_i) + \delta \log\left(\frac{\delta}{\mu - (1-\delta)}\right) \geq -1 + (1-\delta)\log(p_f) + \delta E\left[\log(p(\theta) + k)\right]. \tag{14}$$

The forward price – and, hence, the farmer's pay-off – increases with the baker's preference σ_i for Einkorn. Hence, there is a threshold $\sigma^*(n)$ above which Einkorn is produced.[7] The equilibrium in the forward market can thus be characterized as follows.

Proposition 2. *The forward contract is fixed in size ($s_i = \bar{s}$) with its price being increasing in the valuation of Einkorn ($\partial p_i / \partial \sigma > 0$). Collateral is always positive and set as a fixed percentage of the price.*

Forward transactions take place only for sufficiently high valuations of Einkorn; i.e., there exists a threshold $\sigma^*(n)$ such that forward contracts are traded if and only if $\sigma \geq \sigma^*(n)$.

3.4 Equilibrium and Inefficient Risk Allocation

Based on the previous analysis, an equilibrium for the economy can be summarized by the fraction of farmers $n^* = G(\sigma^*(n^*))$ trading in the futures market. This pins down the lower bound $\sigma^*(n^*)$ such that $1 - G(\sigma^*(n^*))$ farmers have an incentive to produce Einkorn and sell it forward to any baker with $\sigma \geq \sigma^*(n^*)$. It also determines the futures price $p_f(n^*)$ and the spot price $p(\theta)$. An equilibrium exists, is unique and has forward trades in Einkorn, provided we make a simple assumption on the support of G.

Figure 2 summarizes the payoff for farmers in the equilibrium as a function of the potential surplus when trading Einkorn. Below the equilibrium threshold $\sigma^*(n^*)$, farmers produce

[7] The expected payoff from producing wheat increases without bound as n approaches 0. Hence, there are two cases. Either $\sigma^*(n) > \bar{\sigma}$, in which case there is no trade in Einkorn; or the farmer being matched with the highest σ always prefers to produce Einkorn, in which case there is some forward trade.

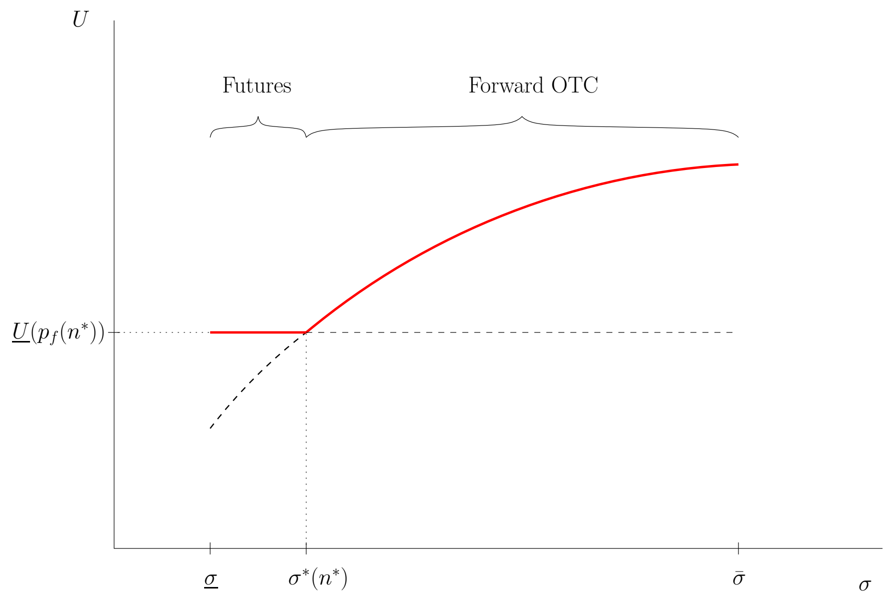


Figure 2: Farmers' Payoff in Equilibrium

wheat and sell it in the futures market to obtain the fixed expected payoff $\underline{U}(p_f(n^*))$ that depends on the equilibrium futures price $p_f(n^*)$. All other farmers produce the same amount $s(\sigma) = \bar{s}$ of Einkorn, but extract increasingly more surplus as the price increases with σ.

The equilibrium, however, is inefficient because the forward market is an over-the-counter market where farmers and bakers trade bilaterally.[8] As trade is bilateral, there is no central price mechanism that can allocate the production efficiently. Given that farmers are risk-averse with respect to their consumption of gold, it is efficient to have a constant payment $\bar{p}$ across farmers. But to maximize surplus from any individual transaction, this implies that for all σ we have

$$\bar{p} = (1 - \delta)\sigma v'(s^*(\sigma)). \tag{15}$$

Therefore the *efficient* quantity of Einkorn $s^*(\sigma)$ strictly increases with the baker's preference for Einkorn. With farmers having all the bargaining power, however, the quantity of Einkorn produced is fixed at $\bar{s}$ and, thus, independent of σ.

In our set-up, farmers can always decide to trade futures instead of forward contracts. This limits how much surplus can be redistributed across trades in the forward market. Therefore,

[8] We formally characterize efficient allocations in the appendix. We also demonstrate in the appendix, that the inefficiency is not associated with the distribution of bargaining power, but with bargaining per se. The distribution of bargaining power only matters for the size of the inefficiency. Consequently, one cannot remedy the inefficient allocation of risk by simply changing the bargaining power in the market. Furthermore, the inefficiency does not depend on our log-linear preference structure.

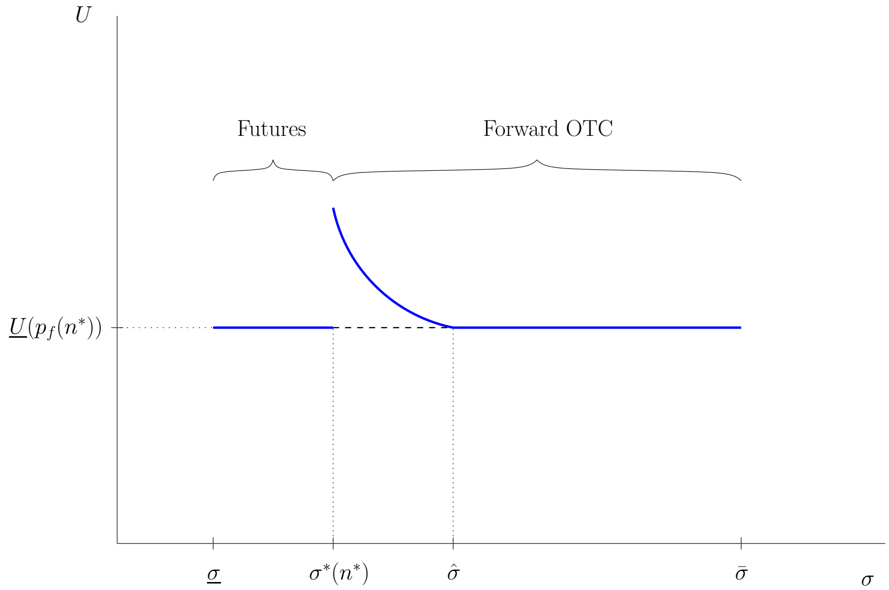


Figure 3: Farmer's Payoff in the Constrained Efficient Allocation

one should compare the equilibrium to the *constrained efficient* allocation that holds the size of the two markets – forward and futures – constant, but recognizes the possibility for farmers to trade futures contracts. Figure 3 shows the farmer's pay-off in the constrained efficient allocation for Einkorn, holding fixed the size of the futures market at the equilibrium level n^*. Above the threshold $\sigma^*(n^*)$, forward contracts take place. In the efficient allocation, a farmer's payoff is decreasing in σ as farmers have to produce more to receive the same payment $\bar{p}$. For high σ, however, the farmer's payoff in the efficient allocation would fall below the value of his outside option of trading wheat in the futures market. This drives a wedge into the efficient allocation, where for high σ, farmers would only produce an amount of Einkorn such that

$$\log\big((1-\delta)\sigma v'(s(\sigma))\big) - s(\sigma) = \underline{U}(p_f(n^*)), \tag{16}$$

where $\underline{U}(p_f(n^*))$ is the utility a farmer obtains from trading on the futures market. As a consequence, farmers must be rewarded with higher payments for the production of Einkorn, even though it is still efficient to have the production of Einkorn increasing with σ. Still, comparing with Figure 2, the equilibrium is not even constrained efficient.

We can interpret the inefficiency of equilibrium in terms of the allocation of default risk across OTC trades. Each farmer producing Einkorn faces the risk that his counterparty defaults, in which case he does not receive compensation for his production. Moreover, the more he produces, the more risk he faces. It is *socially* efficient that farmers take on more default risk the larger the surplus from Einkorn is; i.e., the contract size s should increase with σ. However, in equilibrium, farmers *privately* have an incentive to hold default risk fixed across transactions, although the transactions differ in surplus. This is a result of the bargaining friction in OTC trades, where one agent, here the farmer, can extract surplus through a larger premium p_i when taking on any fixed quantity of default risk.

4 Central Counterparty Clearing

A central counterparty (CCP) is commonly defined as a third party that intermediates clearing and settlement of all trades between market participants. To do so, CCPs resort to a legal instrument called *novation*, whereby the CCP becomes the buyer to every seller and the seller to every buyer. More precisely, the original contract between a farmer and a baker is superseded by two contracts: one between the farmer and the CCP and one between the CCP and the baker. This means that farmers and bakers are now facing only the CCP in the second period when settling a contract. By taking on settlement obligations, the CCP needs to manage counterparty risk through its collateral policy, but it can also provide insurance against it. One particular insurance scheme is known as the *mutualization of losses* whereby the CCP uses transfers to distribute the losses from default among its surviving members.

In the remainder of the paper, we analyze how CCP clearing affects the equilibrium outcome. We will take novation and mutualization as given, as we do not aim at explaining why a CCP uses these instruments rather than other ones. We model novation as follows. Once a trade has been agreed upon, the CCP is responsible for collecting all payments from bakers, be it collateral or the final payment. Similarly, in period 2, it collects all wheat from farmers and delivers it to bakers against payment. The CCP also sells wheat in the spot market that was supposed to be delivered to bakers that died. Its total revenue is then paid out to farmers.[9] Mutualization takes the form of a transfer – on top of the agreed payment – from (to) surviving bakers to (from) the CCP in period 2. We should stress here that while the CCP takes the terms of trade and the market structure as given, it will affect outcomes by modifying the trading environment through its collateral policy, novation and mutualization. We show next that by doing so CCP clearing achieves efficiency for *both* standardized and

[9] Novation is thus not a guarantee. In order for it to be a guarantee, we would have to require that the CCP satisfies a solvency constraint. In other words, the CCP would guarantee to settle all trades at the original price at which farmers sold wheat forward. For the guarantee to be credible, this would necessitate a specific collateral requirement, again influencing the price. Our approach is more general, since a guarantee is just one possibility for a CCP to set its collateral policy.

customized financial contracts.

Without loss of generality, we make two assumptions. First, we assume that the CCP exclusively sets collateral requirements when it clears trades. Farmers and bakers take these collateral requirements as given when negotiating their trades. Second, a CCP operates either in the futures market or the forward market, but not in both markets simultaneously. We will first introduce a CCP in the futures market and then – taking as given central clearing in this market – we consider the introduction of a separate CCP for trading forward contracts in the OTC market.[10]

4.1 CCP Clearing of Futures – Efficient Risk Sharing

Consider first a CCP for the futures market. The CCP offers novation and runs a transfer scheme $\phi(\theta)$ that specifies additional payments by bakers depending on the aggregate demand shock for wheat θ. Its revenue in period 2 is given by

$$R(\theta) = \Big(k + (1-\delta)\left(p_f^{CCP} - k\right) + \delta p(\theta) + (1-\delta)\phi(\theta)\Big)Q. \tag{17}$$

where we denote the new futures price by p_f^{CCP}. Given the CCP cleared Q futures contracts, the first term in (17) is the collateral that the CCP collects from bakers in the first period. The second term is the overall gold payments – net of collateral postings – made by bakers still alive in period 2. In exchange, the CCP delivers a total of $(1-\delta)Q$ units of wheat and sells the remaining δQ units on the spot market at price $p(\theta)$. The state-dependent transfer per futures contract associated with mutualization is the final term in (17).

We now analyze the futures market equilibrium with CCP clearing. Taking aggregate production Q as given, farmers receive a share of the CCP's revenue that is proportional to their own production. Hence, they choose their production to maximize

$$\max_q -q + E\log\left(R(\theta)\frac{q}{Q}\right), \tag{18}$$

which again yields $q = 1$. Hence, if n farmers produce wheat, total supply is again given by $Q = n$ in equilibrium. Since the spot market price is unaffected by CCP clearing, by no

[10]Koeppl, Monnet and Temzelides (2009) consider the problem of a CCP operating on two different platforms and possibly cross-subsidizing its operations.

arbitrage pricing, the futures price is

$$p_f^{CCP} = \frac{1}{n} - \left(\frac{\mu}{1-\delta} - 1\right)k - \int \phi(\theta)dF(\theta). \tag{19}$$

Therefore, in state θ, each farmer receives

$$\frac{R(\theta)}{n} = (1-\delta)\frac{1}{n} + \delta\frac{\theta}{n} - (\mu-1)k + (1-\delta)\left(\phi(\theta) - \int \phi(\theta)dF(\theta)\right) \tag{20}$$

from trading futures.

Farmers obtain the average payments across all trades for any level of collateral k and any transfer scheme $\phi(\theta)$. This implies immediately that it is optimal for the CCP to not require collateral, or equivalently, to set $k = 0$. The intuition for this result is straightforward. Collateral is costly to produce, and these costs have to be borne entirely by farmers. In other words, collateral is a costly insurance device against counterparty risk. The CCP can diversify against counterparty risk by simply pooling all farmers and paying them the average payoff for all futures transactions. Requiring collateral would just lower the revenue in all states without providing any additional insurance, either against idiosyncratic default risk or against the aggregate price risk. A farmer cannot replicate this result as he would have to enter into too many contracts in the first period to fully diversify against counterparty risk. Novation is resolving this market incompleteness.

With novation, the CCP's revenue depends however on the spot price, so that farmers are still exposed to the aggregate price risk. But the CCP can offer a transfer schedule $\phi(\theta)$ such that (i) transfers are revenue neutral ex-ante; i.e. $\int \phi(\theta)dF(\theta) = 0$, and (ii) farmers are fully insured against aggregate risk; i.e., $R(\theta) = 1$. Since the fee schedule is revenue neutral, bakers are as well off ex-ante as without the fee schedule. Setting $R(\theta) = 1$ and $k = 0$, we obtain

$$\phi(\theta) = \frac{\delta(1-\theta)}{1-\delta}. \tag{21}$$

This transfer schedule implies that for $\theta < 1$ bakers who have not defaulted pay more than the agreed futures price, while they pay less whenever $\theta > 1$. Since there is no *expected* transfer between bakers and farmers, the futures price does not change and equals the expected spot price

$$p_f^{CCP} = \int p(\theta)dF(\theta) = \frac{1}{n}. \tag{22}$$

Hence, mutualization of losses guarantees a fixed payment to farmers who are thus also perfectly insured against aggregate price risk.

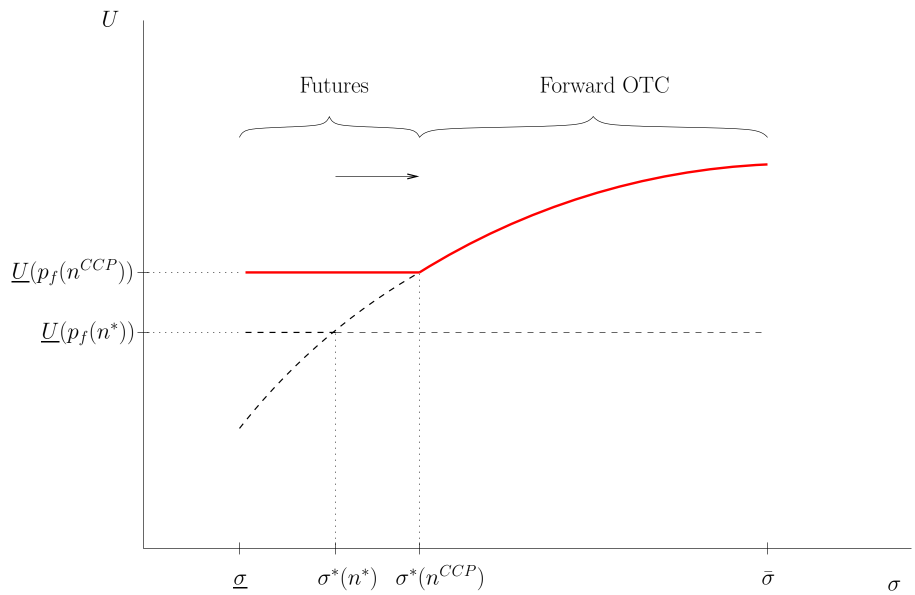


Figure 4: Equilibrium with CCP Clearing of Futures

Proposition 3. *Novation perfectly diversifies counterparty risk, and together with mutualization implements an efficient allocation on the futures market. Trade will shift from forward to futures markets ($n^{CCP} > n^*$), so that all farmers and bakers are ex-ante better off when there is CCP clearing in the futures market.*

This result explains why modern futures markets always operate with central clearing by a CCP. With such clearing, trade shifts away from Einkorn so that the cut-off point σ^* will increase (see Figure 4)[11], but the farmers' payoffs from the remaining trades of Einkorn are unaffected. Bakers get zero surplus from any trade in futures markets in the first period. With more wheat being produced, however, their welfare increases as the expected spot price for wheat declines. Still, farmers producing wheat are better off, since they fully reap the benefits from eliminating the deadweight costs of collateral while also being fully insured. As a result, all market participants have an incentive to introduce central clearing in futures markets where contracts are standardized. Better insurance against default benefits both parties – the one who causes default risk and the one who tries to insure against it.

[11]The impact of central clearing on the futures price is ambiguous. On the one hand, central clearing eliminates the deadweight costs associated with collateral. On the other hand, the number of traders in the futures market also increases.

4.2 CCP Clearing of OTC Contracts – Efficient Risk Allocation

Suppose now that – in addition to the CCP clearing futures – there is also a CCP for clearing forward contracts. We assume that the CCP can observe the surplus σ of each forward trade in Einkorn and that it can force all trades to clear centrally. These two assumptions are crucial for the results in this section as we will discuss later. We structure central clearing as in the futures market.

Therefore, taking the terms of a forward contract (p, s) as given, the CCP novates the trade: it specifies a collateral requirement $k(p, s)$, a payment schedule $m(p, s)$, as well as an additional fee $\phi(\sigma)$ on bakers who are still alive in period 2.[12] Once the trade has been novated, farmers have the obligation to produce s and deliver it to the CCP against payment $m(p, s)$. Bakers post collateral k in period 1 and, if they are still alive in period 2, they also pay $p - k$ and the additional fee $\phi(\sigma)$.

Forward contracts only take place for $\sigma \geq \sigma^*(n^0)$, where n^0 is the fraction of farmers that trade futures after CCP clearing has been introduced in the forward market. Hence, the CCP's revenue is given by

$$R^{OTC} = \int_{\sigma^*(n^0)}^{\bar{\sigma}} (1-\delta)(p(\sigma) + \phi(\sigma)) + \delta k(p(\sigma), s(\sigma)) dG(\sigma). \tag{23}$$

An important difference between central clearing of forward and futures contracts is that Einkorn has only value for the baker who bought it. The CCP thus faces extreme price risk, as it cannot raise additional revenue from selling the Einkorn on a spot market in case a baker dies. We call a payment schedule m and a fee ϕ *feasible* if

$$\int_{\sigma^*(n^0)}^{\bar{\sigma}} m(p(\sigma), s(\sigma)) dG(\sigma) = R^{OTC} \tag{24}$$

and

$$\int_{\sigma^*(n^0)}^{\bar{\sigma}} \phi(\sigma) dG(\sigma) = 0. \tag{25}$$

Hence, the fee charged to bakers needs to be purely redistributive across forward trades. Since the CCP cannot prevent farmers from trading futures instead of forward contracts, the payment schedule $m(p, s)$ must also be *incentive compatible*. Hence, we require that for

[12] The CCP does thus not employ a direct mechanism – except for the fee ϕ – where it specifies the terms of trade as a function of σ. Instead, it takes as given the bargaining problem between the farmer and the baker. Notwithstanding, in equilibrium, the terms of trade (p, s) are a function of σ, so that m and k are also a function of σ.

every $\sigma \geq \sigma^*(n^0)$, the payment schedule $m(p, s)$ is such that we have

$$-s + \log(m(p, s)) \geq -1 + \log\left(\frac{1}{n^0}\right) \tag{26}$$

where it is understood that $(p, s) = (p(\sigma), s(\sigma))$ are the terms of the forward contract for a baker with a particular σ. Note that the outside option of trading on the futures market will also depend on CCP clearing in the forward market, as this will influence the fraction of farmers n^0 that trades futures in equilibrium.

Novation with zero collateral maximizes surplus in forward trades and therefore is again optimal. Set $\phi(\sigma) = 0$ and set $m(p, s)$ to the expected payment associated with any specific contract (p, s) that is traded on the forward market

$$m(p, s) = (1 - \delta)p + \delta k(p, s). \tag{27}$$

This payment schedule is clearly feasible. Hence, novation is able to fully diversify counterparty risk in forward contracts, even though Einkorn cannot be traded in the spot market so that the price risk is extreme. Again, as before collateral involves a deadweight cost so that it is optimal to set $k(p, s) = 0$ for all contracts. This leads to the following result.

Proposition 4. *CCP clearing can perfectly diversify counterparty risk on the forward market through novation. The size of the forward market increases ($n^0 < n^{CCP}$) so that futures prices also increase, making all farmers better off, but all bakers worse off.*

With zero collateral and novation, a farmer still extracts all the baker's surplus by setting a fixed contract size $\bar{s}$ and charging a price equal to

$$p(\sigma) = \sigma v(\bar{s}). \tag{28}$$

Note that the payment schedule m given in equation (27) ensures that the farmer obtains the (expected) payment of the bilateral contract independent of default by the baker. As Figure 5 shows, with novation, a farmer's payoff from a forward contract shifts upward. As a consequence, less wheat is produced thus increasing its expected spot price as well as its futures price. Hence, *all* farmers gain from introducing a CCP on the forward market, independent of whether they trade on this market. However, bakers are worse off. They expect to pay more for wheat on the spot market, while getting no surplus from Einkorn.

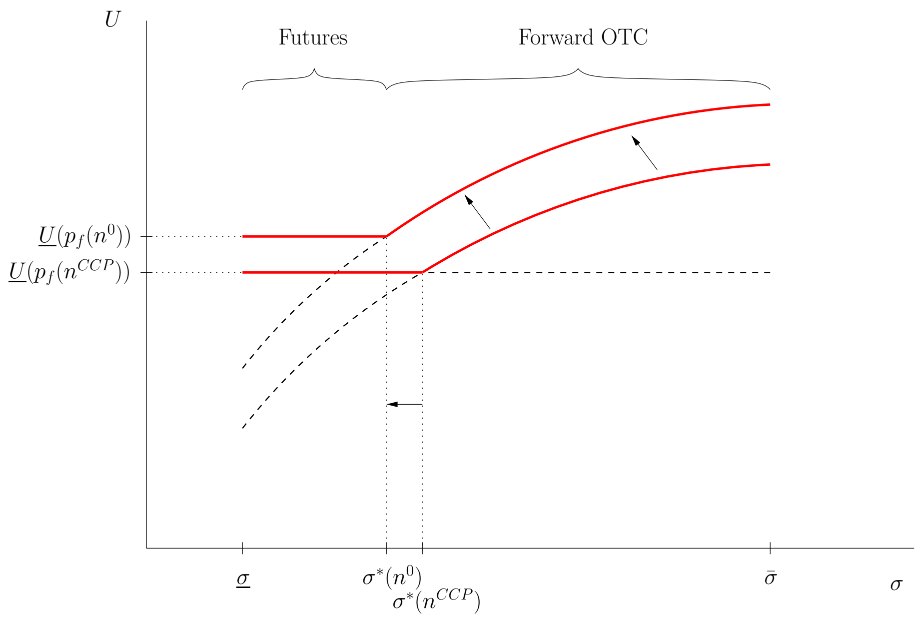


Figure 5: Equilibrium with CCP Clearing of Forward Contracts

This creates a conflict of interest for introducing CCP clearing in the forward market[13], where the opposition comes from the originators of counterparty risk. Hence, our model sheds some light on why some market participants want to resist the introduction of CCP clearing in OTC markets.

A CCP can also achieve a better allocation of counterparty risk in the forward market through a transfer scheme that charges additional fees to surviving bakers. Consider any feasible fee schedule, $\phi(\sigma)$. Farmers will make a take-it-or-leave-it-offer according to

$$\max_{(p,s)} -s + \log\left((1-\delta)p\right) \tag{29}$$
$$\text{subject to}$$
$$(1-\delta)\left[\sigma v(s) - p - \phi(\sigma)\right] \geq 0$$

where we have already taken into account that the CCP will use novation to make average payments to farmers without requesting any collateral. Since the participation constraint

[13] Note that this result does not depend on the extreme distribution of bargaining power and will survive for a sufficiently unequal distribution of bargaining power when most bakers derive sufficiently small surpluses from forward trades in Einkorn.

for bakers binds, we obtain that the farmer's offer is given by

$$v(s) - v'(s) = \frac{\phi(\sigma)}{\sigma} \tag{30}$$

$$p(\sigma) = \sigma v'(s). \tag{31}$$

The fee $\phi(\sigma)$ drives a wedge into the choice of the contract size, with no direct influence on the contract price. As v is concave, this wedge makes s an increasing function of the fee $\phi(\sigma)$.[14] Thus, the CCP can influence the contract size across trades. A positive fee will reduce surplus in a match, as the farmer will offer to produce more at a lower price to maintain his surplus. Similarly, a negative fee subsidizes a trade by increasing the surplus. It is now easier for the farmer to extract surplus, and he will produce less at a higher price. This adjusts the contract size to achieve an efficient allocation of risk.

The CCP, however, faces an additional restriction on its fee schedule ϕ, as farmers need to have an incentive to carry out a forward trade in Einkorn. Hence, for the fees to be incentive compatible we need that

$$-s(\sigma) + \log\Big((1-\delta)\sigma v'(s(\sigma))\Big) \geq -1 + \log\left(\frac{1}{n^0}\right), \tag{32}$$

for all $\sigma \geq \sigma^*(n^0)$ where we have used the payment schedule m and the fact that the CCP takes the size of the futures market with novation n^0 as given. Since this restriction simply mirrors the farmer's outside option in the efficient allocation, there exists a fee schedule ϕ^* that implements an efficient allocation of risk across forward trades as shown in Figure 6.

Proposition 5. *CCP clearing with novation together with a revenue-neutral transfer scheme achieves a constrained efficient allocation of risk in the forward market. The optimal fee ϕ^* is increasing in the baker's valuation of Einkorn σ.*

The absence of a central price mechanism is often taken as a serious limitation for clearing customized OTC contracts. However, we have shown that central clearing can give traders incentives to internalize the social costs and benefits of trading customized contract even without this central price mechanism that would otherwise provide incentives. As such,

[14] Requiring collateral can also drive a wedge in the bargaining problem that causes the contract size s to increase with σ. A positive collateral requirement would tax the gains from trade giving incentives to farmers to increase the contract size, while a negative collateral requirement would subsidize a trade, thereby lowering the contract size s. However, as collateral is costly ($\mu > 1$), changing risk allocation through the CCP's collateral policy is always dominated by a purely redistributive fee schedule.

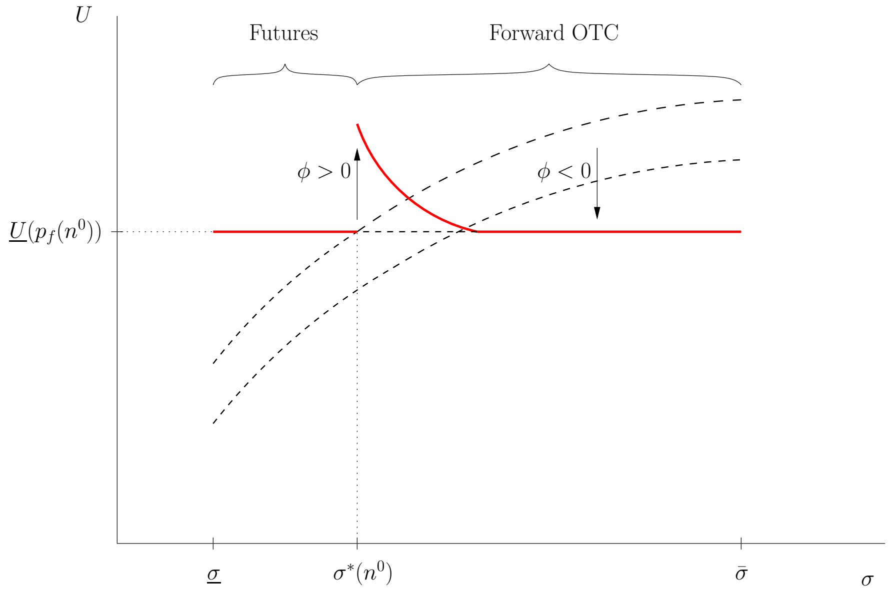


Figure 6: Achieving a Constrained Efficient Allocation in the Forward Market

CCP clearing is a substitute for the central price mechanism that is absent in these markets. This is a new aspect of CCP clearing that has not been explored before making such infrastructure essential for achieving an efficient allocation of counterparty risk in OTC markets. To summarize, the customized nature of the transaction does not prevent CCP clearing from offering welfare gains and in fact makes such clearing necessary to achieve benefits that otherwise would only arise through competitive trading.

4.3 Limits for CCP Clearing in OTC Markets

4.3.1 Private Information

We briefly discuss two limitations for clearing OTC trades.[15] The first one is that the contracting parties usually have private information on the surplus generated by Einkorn. Farmers and bakers may want to misrepresent the true valuation of σ by negotiating a different contract, if this avoids extra fees ϕ. As a consequence, the CCP needs to provide incentives for any trade to reveal the true valuation σ through the terms of the trade; in other words, when setting its transfer schedule ϕ, the CCP needs to solely rely on the information contained in the terms of trade (p, s) to infer the true, but unobservable σ underlying the

[15]For more details, see Koeppl and Monnet (2010).

trade.[16] This imposes a standard truth-telling constraint on the CCP.

For expositional convenience, we consider here a direct mechanism for which the farmer and baker negotiating a trade of Einkorn report the valuation σ directly to the CCP. The CCP then assumes that the terms of trade are given by $(p(\sigma), s(\sigma))$ where

$$p(\sigma) = \sigma v'(s(\sigma)) \tag{33}$$

for all $\sigma \geq \sigma^*(n^0)$ and sets its policy equal to

$$m(\sigma) = (1-\delta)p(\sigma) \tag{34}$$

$$\phi(\sigma) = \sigma[v(s(\sigma)) - v'(s(\sigma))]. \tag{35}$$

for some function $s(\sigma)$.[17] This policy implies that the farmer and the baker can lie only downwards, that is report $\sigma' \leq \sigma$.[18] Since bakers never receive any surplus[19] the truth-telling constraint for any σ is then given by

$$-s(\sigma) + \log(m(\sigma)) \geq -s(\sigma') + \log(m(\sigma')) \text{ for all } \sigma' \leq \sigma. \tag{37}$$

This implies that a farmer's utility must be weakly increasing in σ.

While the policy is still of the same form as when σ is observable, the truth-telling constraint (37) restricts the allocation of Einkorn $s(\sigma)$ across trades that the CCP can achieve. Recall, that it would be efficient to have a lower quantity produced in low surplus transactions relative to high surplus transactions leaving the payment fixed across transactions. In other words, farmers facing low σ would produce small amounts of Einkorn, but for the same payment as trades with a higher surplus σ. This however gives an incentive for other farmers to misrepresent the nature of their trades: they also would produce less for the same payment. The best allocation the CCP can thus achieve is to offer farmers the same utility when they trade Einkorn in the forward market independently of σ, where this utility level strictly

[16]This relates our problem to the literature on Mirleesian taxation, in which a planner taxes labor income with output being observable, but productivity being private information.

[17]Given any σ, the CCP still offers a fixed payment to fully diversify counterparty risk, so that it need not use collateral to insure against such risk.

[18]Suppose a trade with true valuation σ reports σ' instead. It has to be the case that the farmer and baker are at least as well off reporting σ'. For the baker, we have

$$\sigma v(s(\sigma')) - p(\sigma') \geq \sigma v(s(\sigma)) - p(\sigma) = \sigma' v(s(\sigma')) - p(\sigma') = 0, \tag{36}$$

implying that $\sigma' \leq \sigma$.

[19]Similarly, if contracts (p, s) were submitted for clearing rather than a report for σ, farmers would need to extract all the surplus given *some* σ', since otherwise the CCP would learn of a deviation.

exceeds the utility from trading futures, or

$$-s(\sigma) + \log(m(\sigma)) = \bar{u} > u(p_f(n^0)) \tag{38}$$

for all $\sigma > \sigma^*(n^0)$. Still, it is efficient to have a higher production of Einkorn for higher valuation matches. Therefore, this new constrained efficient production of Einkorn $\hat{s}(\sigma)$ is still increasing in σ, but farmers also need to have their payment increase in σ. As a consequence, private information limits how much counterparty risk can be reallocated across trades, but it does not prevent such reallocation entirely.

4.3.2 Bilateral Clearing

We have also assumed that the CCP can enforce mandatory central clearing of forward contracts. The only relevant outside option for farmers is then to trade futures instead. If we drop this assumption, farmers need an incentive to clear forward contracts centrally rather than just bilaterally. Assuming that σ is observable, the CCP has then to design its policy – the payment rule $m(p(\sigma), s(\sigma))$ and the fee $\phi(\sigma)$ – so that farmers not only produce Einkorn, but also that they clear their forward contracts centrally. This adds the constraint

$$-s(\sigma) + \log(m(p(\sigma), s(\sigma))) \geq -\bar{s} + \log\Big((1-\delta)\sigma v'(\bar{s})\Big) + \delta \log\left(\frac{\delta}{(1-\delta)(\mu(\delta)-1)}\right) \tag{39}$$

where the right-hand side is the farmer's payoff from the forward contract when clearing bilaterally. The CCP still takes the terms of the forward contract as given, but offers novation. Bilateral clearing requires costly collateral as a substitute for diversifying risk through novation. The CCP is thus able to use the benefits from novation to extract and again redistribute some of the surplus through its fee schedule $\phi(\sigma)$.

The key difference for the constrained efficient allocation is now that for large values of σ, the outside option is given by bilateral clearing. This follows from the fact that the left-hand side of Equation (39) is increasing in σ. At the optimal fee, matches with high valuations are just indifferent between clearing bilaterally with collateral and clearing through the CCP. The contract size is again increasing with σ, but the CCP can charge a positive fee $\phi(\sigma) > 0$ to trades with high σ, as it taxes away the additional surplus that originates from the diversification of counterparty risk. This revenue can then be transferred to matches with a lower valuation, with the effect of reducing their production of Einkorn. Hence, the option to clear forward trades bilaterally does not prevent redistribution of counterparty risk, but again limits it.

5 Conclusion

We set up a formal model of clearing and find that CCP clearing with novation and mutualization of losses is part of an efficient market structure for standardized financial contracts that are centrally traded on a competitive market. A CCP that clears OTC trades has to take into account, however, that fungibility of contracts is limited. Despite this fact, we have shown that a CCP can still offer novation – albeit not in the form of a guarantee – and that it is precisely these gains from novation that can give incentives for counterparties to formally clear OTC transactions through a CCP. Indeed, our theory goes an important step further by uncovering an inefficient allocation of counterparty risk in OTC markets that a CCP can improve upon through a redistributive transfer scheme across transactions.

These results imply that the discussion about formal clearing of OTC transactions is largely misguided. The discussion has primarily focused on the (im)possibility of netting exposures and on the (in)ability of a CCP to control price risk associated with customized financial contracts. We have pointed out here that CCP clearing is not only feasible in this market, but more importantly it is a crucial element for improving counterparty risk in this market. Hence, future improvements in the infrastructure of financial markets need to concentrate on finding ways how to extend central clearing to OTC markets that offer trading of customized products. Quite interestingly, we also have found that not all market participants are likely to gain from the introduction of CCP clearing for customized products, implying that there will be some resistance in markets to support such a development.

In deriving this conclusion, we have deliberately abstracted from some important issues such as moral hazard. This is clearly pivotal for addressing the optimal collateral structure of a CCP, and we think it deserves particular attention. In this context, it will be necessary to study the optimal scope for CCP clearing in the sense that one creates an institution that potentially causes an overall increase in risk due to a moral hazard problem.[20]

Some of our assumptions are quite strong, but are driven by the desire to derive stark results. One issue is to extend our analysis to cases in which counterparties contemplate default, if it is in their interest. Collateral will then play the role of an incentive device. Also, we have assumed that preferences are represented by log-linear utility. This simplifies the analysis, as there are neither wealth effects from introducing insurance nor distortions from allocating risk. It would be interesting to see how our results fare quantitatively under different preference structures, but this change would not affect the main message of what CCP clearing adds to financial markets and how it differs for OTC traded contracts.

[20] This question is partially addressed in Koeppl (2013).

References

[1] Acharya, V. and Bisin, A. (2009) "Centralized versus Over The Counter Markets," Mimeo, NYU Stern Business School.

[2] Biais, B., Heider, F. and Hoerova, M. (2012) "Clearing, Counterparty Risk and Aggregate Risk," IMF Review, 60, 193-222.

[3] Carapella, F. and Mills, D. (2013) "Information Insensitive Securities: The True Benefits of Central Counterparties, " Mimeo, Board of Governors.

[4] Duffie, D. and Zhu, H. (2009) "Does a Central Clearing Counterparty Reduce Counterparty Risk?," Review of Asset Pricing Studies, 1, pp. 74-95.

[5] Hull, J. (2010) "OTC Derivatives and Central Clearing: Can all Transactions be Cleared?," Financial Stability Review, Banque de France, July, pp. 71-81.

[6] ISDA (2013) "Non-Cleared OTC Derivatives: Their Importance to the Global Economy," International Swaps and Derivatives Association Inc. Report, March.

[7] Koeppl, T. and Monnet, C. (2010) "The Emergence and Future of Central Counterparties," Federal Reserve Bank of Philadelphia, Working Paper 10-30.

[8] Koeppl, T., Monnet, C. and Temzelides, T. (2009) "Optimal Clearing Arrangements for Financial Trades," Journal of Financial Economics, 103, 189-203.

[9] Koeppl, T. (2013) "The Limits of Central Counterparty Clearing: Collusive Moral Hazard and Market Liquidity," Queen's University, Working Paper 1311.

[10] Kroszner, R. (1999) "Can the Financial Markets Privately Regulate Risk? The Development of Derivatives Clearinghouses and Recent Over-the-Counter Innovations," Journal of Money, Credit, and Banking, 31, 596-618.

[11] Leitner, Y. (2009) "Inducing Agents to Report Hidden Trades: A Theory of an Intermediary," FRB Philadelphia Working Paper 09-10, April 2009.

[12] Monnet, C. and Nellen, T. (2013) "The Welfare Effects of Central Clearing," Mimeo, University of Bern.

[13] Pirrong, C. (2011) "The Economics of Clearing in Derivatives Markets: Netting, Asymmetric Information and the Sharing of Derivatives Risk through a CCP," Mimeo, University of Houston.

[14] Schaede, U. (1989) "Forwards and Futures in Tokugawa Period Japan: A New Perspective on the Dojima Rice Market, " Journal of Banking and Finance, 13. pp. 487-513.

Appendix A Proofs

A.1 Proof of Proposition 1

The pricing equation follows directly from no-arbitrage pricing, the optimal choice of production $q = 1$ and spot prices given by $p(\theta) = \theta/n$.

The farmers' choice of collateral is given by the solution of the first-order condition with respect to k

$$(1-\delta)\frac{1}{p_f}\frac{\partial p_f}{\partial k} + \delta \int \frac{1}{p(\theta)+k} dF(\theta) + \lambda = 0$$

where λ is the multiplier on the constraint $k \geq 0$. If the constraint is not binding, the first-order condition reduces to

$$\int \frac{p_f}{p(\theta)+k} dF(\theta) = \frac{(\mu-1)+\delta}{\delta}.$$

Suppose that $k \geq p_f$. Then,

$$\int \frac{p_f}{p(\theta)+k} dF(\theta) < \int \frac{k}{p(\theta)+k} dF(\theta) < 1 < \frac{(\mu-1)+\delta}{\delta},$$

which yields a contradiction.

The optimal level of collateral is decreasing in μ. Taking into account the expression for spot prices, there is a cut-off point $\bar{\mu}$ defined by

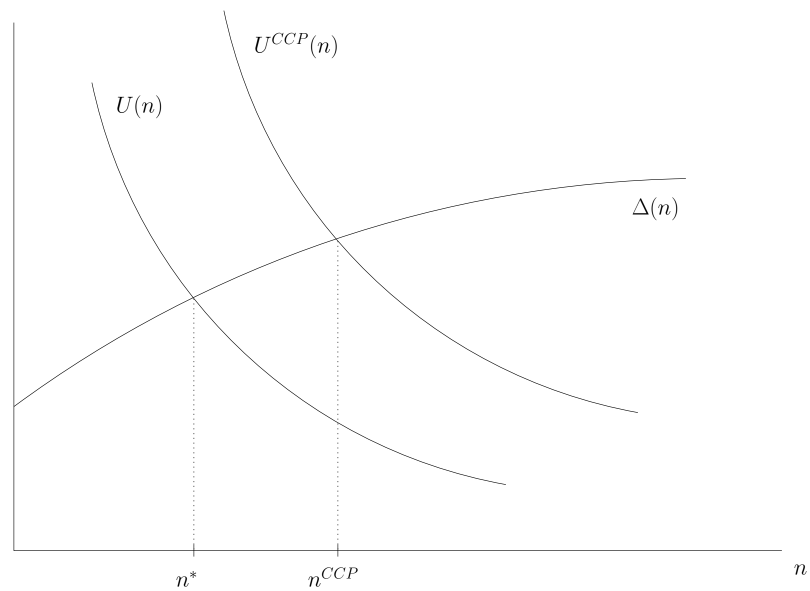
$$\delta \left(\int \frac{1}{\theta} dF(\theta) - 1 \right) = \bar{\mu} - 1$$

such that for all $\mu \geq \bar{\mu}$, we have that $k = 0$. By Jensen's inequality, we have that $\bar{\mu} > 1$, which completes the proof.

A.2 Proof of Proposition 3

We show that $n^{CCP} > n^*$, which implies that farmers are better of with CCP clearing. Without CCP clearing, equilibrium can be described by the unique value n^* that satisfies

$$\Delta(n) = -\bar{s} + log\left((1-\delta)v(\bar{s})\sigma^*(n)\right) + \delta log\left(\frac{\delta}{\mu-(1-\delta)}\right)$$



and

$$U(n) = -1 + (1-\delta)log\left(\frac{1}{n} - (\frac{\mu}{1-\delta} - 1)k\right) + \delta \int log\left(\frac{\theta}{n} + k\right) dF(\theta)$$

With a CCP clearing of futures, the second condition is given by

$$U^{CCP}(n) = -1 + log\left(\frac{1}{n^{CCP}}\right)$$

so that the utility from trading futures increases for every level of n (see Figure A.2).

As $\sigma^*(n)$ is increasing in n, the function $\Delta(n)$ is also increasing in n. Hence, $n^{CCP} > n^*$ and the utility of farmers is higher.

A.3 Proof of Proposition 4

Consider any payment schedule $m(p, s) = (1-\delta)p(\sigma) + \delta k(p, s)$. The payment schedule is feasible and perfectly insures against counterparty risk, since it averages payments across all trades with (p, s).

Suppose now that $k(p, s) \neq 0$. Define a new payment schedule equal to $m(p, s) = (1-\delta)\tilde{p}$, where

$$\tilde{p} = p + \frac{\delta}{1-\delta} k(p, s)$$

and set collateral equal to $\tilde{k}(p, s) = 0$. If a contract (p, s) was feasible given σ, it is still feasible, since

$$\begin{aligned}(1-\delta)(\sigma v(s)-\tilde{p}) &= (1-\delta)(\sigma v(s)-p)+\delta k(p,s) \\ &> (1-\delta)(\sigma v(s)-p)-(\mu-1)k(p,s)+\delta k(p,s) \\ &= 0\end{aligned}$$

where the last inequality follows from the fact that farmers make a take-it-or-leave it offer. Hence, $k(p,s)$ was not optimal.

Finally, it is straightforward to verify that the payment schedule $m(p,s)=(1-\delta)p$ induces the farmer to make the offer

$$\begin{aligned}s &= \bar{s} \\ p &= \sigma v(\bar{s}).\end{aligned}$$

This implies that with novation, the payoff for farmers from OTC trading increases, as

$$-\bar{s}+\log(m(p,s)) > -\bar{s}+\log((1-\delta)\sigma v(\bar{s}))+\delta\log(\frac{\delta}{\mu-(1-\delta)}).$$

Hence, both the cut-off point $\tilde{\sigma}$ for OTC trading and n decrease until

$$-\bar{s}+\log((1-\delta)\tilde{\sigma}v(\bar{s}))=-1+\log(\frac{1}{n^0})$$

with $n^0 < n^{CCP}$ which completes the proof.

A.4 Proof of Proposition 5

Let $(s^*(\sigma), x^*(\sigma))$ be the constrained efficient allocation given by the contract size and payment to farmers, where the planner is restricted by bargaining (see Appendix B). Given the payment schedule $m(p,s)=(1-\delta)p$ and no collateral, the solution to the bargaining problem is given by

$$\sigma v'(s)=p.$$

and the baker's binding participation constraint. Using p from the first-order condition, use the participation constraint to define the fee schedule $\phi(\sigma)$ as

$$\phi(\sigma)=\sigma\left[v(s^*(\sigma))-v'(s^*(\sigma))\right]$$

for all $\sigma \geq \underline{\sigma}$. By strict concavity of v, farmers then make the take-it-or-leave-it offer $s = s^*(\sigma)$ and $p = \sigma v'(s^*(\sigma))$. From the constrained efficient allocation it follows that the payment to farmers equals $(1-\delta)\sigma v'(s^*(\sigma)) = x^*(\sigma)$.

It suffices to show that the resource constraint of the CCP is satisfied by the payment and the fee schedule, or equivalently, that

$$\int_{\sigma \geq \underline{\sigma}} \phi(\sigma) dG(\sigma) = 0.$$

We have

$$\begin{aligned} \int_{\hat{\sigma}}^{\bar{\sigma}} \phi(\sigma) dG(\sigma) &= \int_{\hat{\sigma}}^{\bar{\sigma}} \sigma \left[v(s^*(\sigma)) - v'(s^*(\sigma)) \right] dG(\sigma) \\ &= \int_{\hat{\sigma}}^{\bar{\sigma}} \sigma v(s^*(\sigma)) dG(\sigma) - \int_{\hat{\sigma}}^{\bar{\sigma}} \frac{x^*(\sigma)}{1-\delta} dG(\sigma) = 0 \end{aligned}$$

where the last equality follows from the fact that the constrained efficient allocation is resource feasible.

From the constrained efficient allocation, it follows that $s(\sigma)$ strictly increases in σ. This implies that

$$\frac{\partial \frac{\phi(\sigma)}{\sigma}}{\partial \sigma} = \left[v'(s^*(\sigma)) - v''(s^*(\sigma)) \right] \frac{ds}{d\sigma} > 0.$$

Hence, ϕ needs to be increasing in σ which completes the proof.

Appendix B (For Online Publication) Constrained Efficient Allocations in the OTC Market

We consider a planning problem for OTC trades where one has to respect that farmers make a take-it-or-leave-it offer to bakers and that farmers always have the option to trade on the futures market. It is straightforward to verify that initial payments by bakers are inefficient, since $\mu > 1$. We denote payments from bakers to farmers in period 2 by $x(\sigma)$.

The bargaining friction implies that in any allocation bakers must pay $\sigma v'(s(\sigma))$ in all OTC trades. The planner's problem is then given by

$$\max_{(s(\sigma),x(\sigma))} \int_{\sigma \geq \underline{\sigma}} -s(\sigma) + \log\left(x(\sigma)\right) dG(\sigma)$$

$$\text{subject to}$$

$$\int_{\sigma \geq \underline{\sigma}} x(\sigma) dG(\sigma) \leq (1-\delta) \int_{\hat{\sigma}}^{\bar{\sigma}} \sigma v(s(\sigma)) dG(\sigma)$$

$$-s(\sigma) + \log\left(x(\sigma)\right) \geq \bar{u} \text{ for all } \sigma \geq \underline{\sigma}$$

where $\bar{u} = \underline{U}(p_f(n^0))$ is given by the outside option to trade on the futures market.

The first-order conditions are given by

$$\begin{aligned} x(\sigma) &= \frac{1+\lambda(\sigma)}{\lambda} \\ (1-\delta)\sigma v'(s(\sigma)) &= \frac{1+\lambda(\sigma)}{\lambda}. \end{aligned}$$

where $\lambda(\sigma)$ and λ are the Lagrange multipliers on the constraints. Hence, if the participation constraint is not binding, payments x are constant and the contract size s is increasing in σ.

As a consequence, utility for farmers is decreasing in σ. Therefore, at some level $\hat{\sigma}$, the participation constraint will be binding. From the first-order conditions, we then obtain that

$$-s(\sigma) + \log\left((1-\delta)\sigma v'(s(\sigma))\right) = \underline{U}(p_f(n^0)).$$

Hence, the contract size $s(\sigma)$ and the payment to farmers $x(\sigma)$ both increase in σ whenever $\sigma > \hat{\sigma}$.

To summarize, the constrained efficient allocation is given by

$$(1-\delta)\sigma v'(s(\sigma)) = \hat{x}$$

for all $\sigma < \hat{\sigma}$, and

$$-s(\sigma) + \log\left((1-\delta)\sigma v'(s(\sigma))\right) = \underline{U}(p_f(n^0))$$

for all $\sigma > \hat{\sigma}$. The value of $\hat{x}$ is determined by the binding resource constraint and the first-order condition.

Appendix C (For Online Publication) Inefficient Risk Allocation with Generalized Nash Bargaining

We show here that the contract size is also inefficient in OTC trading with Nash bargaining. For simplicity, we assume that there is novation through a CCP for OTC trades. In any OTC trade, the valuation σ is common knowledge for the trading parties. Suppose there is Nash bargaining where η is the relative bargaining weight of farmers. Define the surplus of farmers and bakers as S_1 and S_2, respectively. We then have

$$\begin{aligned} S_1 &= \log\left((1-\delta)p_i\right) - s_i - \bar{u} \\ S_2 &= (1-\delta)\left[\sigma v(s_i) - p_i\right] - \bar{v}, \end{aligned}$$

where we already have used the payment schedule m under novation. The outside options are participation in the futures market, which offers no expected surplus for bakers ($\bar{v} = 0$), but positive expected utility for farmers ($\bar{u} > 0$). Again, with novation it is not optimal to use collateral and the bargaining problem with no collateral is given by

$$\max_{(s_i,p_i)} S_1^{\eta} S_2^{1-\eta}$$

yielding the following first-order conditions

$$\begin{aligned} p_i &= \sigma v'(s_i) \\ \frac{\eta S_2}{(1-\eta)S_1} &= (1-\delta)\sigma v'(s_i). \end{aligned}$$

The pricing of the OTC contract is independent of the bargaining weights and equates the price to the expected marginal benefit of the transactions for bakers. Hence, there is no inefficiency in the pricing of the OTC contract. Rewriting, we obtain

$$\frac{v(s_i)}{v'(s_i)} - 1 = \frac{1-\eta}{\eta}\left[\log\left((1-\delta)\sigma v'(s_i)\right) - s_i - \bar{u}\right].$$

Since the farmer's outside option $\bar{u}$ of trading futures is constant, for any given $\eta \in (0,1)$, the contract size increases with σ (i.e., $ds_i/d\sigma > 0$). Again, there is a cut-off point with respect to σ – now depending on the bargaining parameter η – such that only matches with a high enough surplus will carry out OTC trades.

For $\eta = 1$, the contract size is independent of σ and given by a constant $\bar{s}$, as shown in the main text. As the bargaining power for farmers decreases, the slope $ds/d\sigma$ becomes positive. For $\eta \to 0$, we reach the maxmimum slope

$$\left.\frac{ds_i}{d\sigma}\right|_{\eta=0} = \frac{1}{\sigma}\left(1 - \frac{v'(s_i)}{v''(s_i)}\right).$$

This is the optimal allocation for a planner that has to respect the distribution of bargaining power, as we have derived in the special case of $\eta = 1$ in Appendix B. For $\eta > 0$, however, we get that the contract size does not increase fast enough with the surplus of the transaction as expressed by the parameter σ. The reason is an externality, where individual bargaining does not take into account the social value of a transaction.