A Model of Central Clearing for Derivatives Trading*

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Abstract

This paper analyzes the impact of central counterparty (CCP) clearing on prices, market size, and liquidity in derivatives markets. Through novation, CCP clearing achieves diversification of counterparty risk which extends beyond standardized contracts to customized ones that are traded over-the-counter (OTC). When clearing standardized contracts, CCP clearing also provides insurance against counterparty default. With customized contracts, such insurance is not feasible anymore, but CCP clearing is still an essential part of efficient OTC trading. It substitutes for a central price mechanism to induce market participants to achieve a better allocation of risk across trades by setting appropriate clearing fees. However, introducing CCP clearing in OTC markets affects liquidity across markets, so that not all traders benefit from introducing such clearing arrangements for customized contracts.

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

JEL Classification: G2, G13, D53, D82

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1 Introduction

Research on financial markets has mainly concentrated on understanding trading volume, how prices are determined, what information they incorporate and reveal. Little effort has been devoted to understand the consequences of post-trade arrangements on the same variables, although one would think that how traders safeguard against the risk that one of the counterparties defaults impacts market prices, liquidity, and market size. To fill this gap, we analyze how clearing arrangements can control counterparty risk, and how such arrangements can improve the functioning of financial markets. In particular, we study how the benefits from central clearing differ across standardized and customized contracts – which are traded over-the-counter (OTC) –, and what the incentives are to offer such clearing across different 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. Clearing can also be delegated to a third party, a clearinghouse. In this case, 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, legally 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 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 implying a much larger expected cost in case of a default by a counterparty. When traders are unable to insure against the risk of default, it is not surprising that a CCP is able to diversify default risk, as it transfers counterparty risk from all traders to itself. It is more surprising, however, 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 (standardized vs. customized). 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.

For standardized contracts, we find that it is never optimal for the CCP to fully insure traders upfront against price risk. Instead, some of the risk is efficiently allocated among traders ex-post via a transfer scheme among traders which guarantees that there is no price risk for traders that try to hedge against it. We interpret this transfer scheme as mutualization of losses among traders. 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 CCP clearing can induce traders to take more risk in trades with higher surplus, thereby equating the social costs and benefits from trading customized contracts. The absence of a central price mechanism is thus not a serious limitation for the clearing of customized contracts that are traded OTC. To the contrary, it is the very reason why CCP clearing is an important element for OTC markets to substitute for some features of a central price mechanism. 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.

Why has central clearing then not already been introduced for all trading, on exchanges and for OTC trades? We show 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. Hence, it is then possible to understand the reluctance of some market participants to move to central clearing.

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 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 (2012) and Acharya and Bisin (2009) study the role of a central counterparty in gathering information on traders aggregate exposure. Carapella and Mills (2013) argue 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 papers 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.[1]

Above, we have outlined the key benefit and the key impediment of the risk transfer that

[1]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.

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 liquidity 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 in 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 standardized 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 and customized contracts in financial markets. Rather than viewing contracts as mere promises to make transfers in a numeraire, we consider contracts that promise to deliver goods that take time to produce. A standardized contract then promises the delivery of a standard good (the S good) valued by all market participants. This contract is traded in a centralized market with competitive pricing. To the contrary, a customized contract promises the delivery of a customized good (the C good) that only a specific trader likes. Here, bilateral negotiations will determine the terms of trade, very much like in an OTC market.

Viewing financial contracts as being linked to real goods has several advantages. First and foremost, it allows us to capture the distinction between the underlying of a financial contract and the contract itself as well as the link between the nature of the underlying and how easily the contract can be traded. Standard goods can be sold with standardized contracts – think of a forward contract or any plain vanilla derivative – with both goods and contracts being easily retraded among market participants. Customized goods, however, require customized contracts that are directly negotiated – think of an "exotic" derivative –

which are very hard to retrade. It also allows us to distinguish between obligations from the contracts and the payments associated with such obligations. This results in a clear notion for posting collateral and settling the obligations from the contract in the numeraire. Finally, all contracts have real (that is welfare-relevant) costs and benefits associated with them, as actual goods are being produced and sold by contracts. This turns out to be important as we can assess the value of a customized contract relative to a standardized one which is not possible if contracts simply imply zero sum transfers between contracting parties.

The two markets where contracts are traded – which we will call *Forward Market* and *OTC Market* – are incomplete as agents are unable to insure against two sources of risk. The first risk arises from the exogenous default of a trader. The second one arises from aggregate demand shocks that lead to price fluctuations for the standard good. By their very own nature, customized 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 or replacement cost risk associated with the default of a counterparty.

2.1 Model

We consider an economy with two periods and three types of goods: the numeraire which is perfectly storable, standard (S) and customized (C) goods. In the first period, there is a continuum of measure one of sellers who like the numeraire and can produce either S or C goods. There is also a continuum of buyers with measure $1/(1-\delta) > 1$. They can produce the numeraire and like to consume both the S and C goods. Each buyer, however, likes to consume only his specific variety of C goods. Therefore, we index the variety of C good by the name of the buyer $i \in [0, 1/(1-\delta)]$ who likes to consume it and refer to the variety i of the C good as the C_i good. Buyers only live through the second period with probability $1-\delta$, so that in the second period there are as many buyers as sellers. A buyer's death is a random event that we use to introduce the idea of counterparty risk.

Sellers need to specialize in their production of goods and it takes time to produce goods. This introduces a time lag between the trading of goods through contracts and the settlement of the obligations from such contracts. In the first period, they spend q resources to produce the S good or c_i resources to produce a specific C_i good, but not both.[2] Sellers obtain the S or the C_i goods in the second period. For simplicity, we assume that sellers do not die.

The value of the S good 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 seller consumes a possibly uncertain amount of the numeraire $x(\theta, q, c_i)$ in the second period, which depends on θ and on whether he produced some C good for buyer i who is dead or alive. Sellers' preferences are represented by the utility function

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

where expectations are taken over the probability of death of the buyer as well as over the aggregate demand shock for the S good, θ.

Buyers value both S and C goods and they may consume both in the second period. We denote a buyer's demand for the S good in state θ by $y(\theta)$ and his demand for the C_i goods by c_i. His preferences are given by

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

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

Buyers are ex-ante heterogeneous with respect to their preference for their variety of the C good. This is expressed by the parameter $\sigma \in [\underline{\sigma}, \overline{\sigma}]$ which is distributed across buyers according to some distribution G. It is a fixed, observable ex-ante characteristic of a buyer and expresses how much a buyer likes his variety of the C good relative to the S good. 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. Note that all payments for goods S or C_i are in the numeraire. Initially, each seller is randomly matched with exactly one buyer in the OTC market where they trade customized contracts. Buyers who are not matched with a seller move on directly to a centralized market where they trade standard contracts competitively.

[2]In other words, we impose the restriction that $qc_i = 0$ and $c_i c_j = 0$ for all $i, j \in [0, 1/(1-\delta)]$.

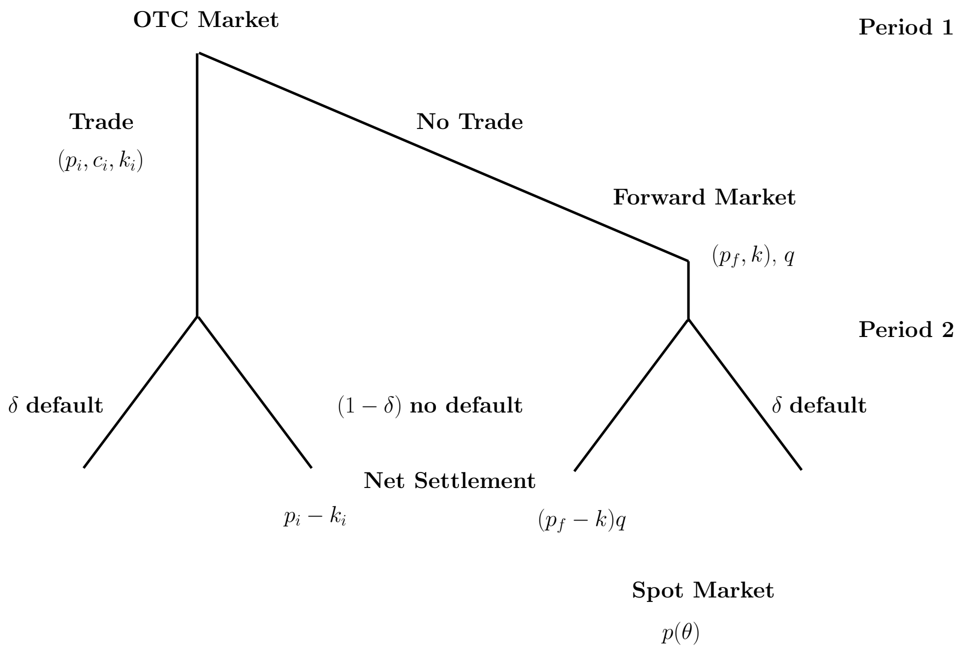

Figure 1: Timing – OTC, Forward and Spot Market

In the OTC market, we assume for simplicity that the seller makes a take-it-or-leave-it offer to the buyer. The offer specifies an amount c_i of the C good to be delivered – which we call *contract size* – and a forward price p_i to be paid in the second period, as well as an amount of collateral k_i to be paid in the first period. If the buyer accepts the offer, the seller produces the C_i good. If the buyer rejects the offer, they move on to the centralized market where they can trade standard contracts.

A standard contract consists of (i) a promise to deliver 1 unit of the S good and (ii) pledging collateral k to the seller of the contract. While both buyers and sellers take the forward price of a standard contract p_f as given, each seller transacts with exactly one buyer who does not yet have a customized contract.[3] In the forward market, sellers thus sell their production of the S good to a specific buyer in the form of contracts that promise the delivery of one unit of the S good in Period 2. In exchange, buyers agree to pay k units per contract in the first and $p_f - k$ units in the second period.

In the second period, all contracts will be settled if possible through the delivery of the

[3]If there is a measure n of sellers in the centralized market, a measure n of buyers is randomly selected to participate in the centralized market from those who were not matched with a seller and those who rejected an offer. This is feasible as there are always more buyers than sellers that do not trade C goods.

S or C goods and payments in the numeraire. In the OTC market, surviving buyers pay $p_i - k_i$ against c_i units of the C good. Similarly, in the centralized market, buyers pay $p_f - k$ against delivery of one unit of the S good. Hence, there is net settlement of contracts, so that pledging collateral acts as a partial prepayment. For contracts where the buyer died, there is no settlement and sellers are not required to honour their obligations. Finally, there is a spot market for the S good. Sellers with standard contracts in default can still sell their S good on this spot market. There is, however, no market for trading customized goods, since the good was produced for a specific buyer and is useless to any other buyer.

3 Equilibrium Without Central Clearing

3.1 Spot Market

We first solve for a competitive equilibrium on the spot market for the S good in the last stage of the economy. When the spot market opens, a measure one of buyers is still alive. Taking the price $p(\theta)$ as given, a buyer with wealth ω in terms of the numeraire 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 buyer is independent of initial wealth ω and given by

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

while his payment is $x_2(\theta) = \theta - \omega$. Denoting the total amount of the S good 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 Forward Market

We now analyze trading for standard contracts where only sellers and buyers participate that have not contracted customized contracts. Consider a buyer that purchases q_b units of a standard contract at price p_f and with a downpayment of k. In period 2, the buyer has a claim to q_b units of the S good as long as he pays p_f minus the downpayment k. Since he can also sell these units 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 buyer will choose the number of contracts q_b that maximizes 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 q_b standard contracts. No-arbitrage pricing then implies that the standard contract 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 buyer if he dies ($\delta > 0$). No-arbitrage pricing thus implies that buyers are fully compensated for this cost and, hence, indifferent between pledging any amount of collateral.

We denote by $n \in [0,1]$ the measure of sellers who enter the forward market. Sellers are risk averse and use the forward market to insure against the variability in the spot price $p(\theta)$. Therefore a seller who intends to produce q units of the S good will prefer to sell q standard contracts rather than wait until Period 2 and sell his production spot. Trading is competitive and sellers take the price p_f as given.

Each seller in this market, however, faces counterparty risk, as he trades with a single buyer who can die. If this is the case, the seller needs to sell the S good on the spot market. The seller thus may again require a downpayment (or collateral) $k > 0$ per standard contract to cover the ensuing price risk. Taking prices as given, sellers 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 $\mu/(1-\delta)$. Nonetheless, collateral can be useful: If a seller's counterparty defaults, he keeps the collateral kq and sells his S goods 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. Otherwise, the seller obtain $p_f q$ from the buyer. The seller's problem in the first period is then to choose production of the S good $q \geq 0$ and a level of collateral $k \geq 0$ to solve

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

It follows that sellers supply $q = 1$ units of standard contract independent of the collateral policy.[4] Hence, the spot price is also independent of collateral posted and equal to $p(\theta) = \theta/n$ as the total supply of S goods satisfies $Q = qn = 1$. This yields the following result.

Proposition 1. *The equilibrium forward price for standard contracts equals the expected spot price of the S good minus collateral costs*

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

It is never optimal for sellers 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.

A forward contract partially insures sellers against the aggregate price risk of selling the S good on the spot market. The insurance is imperfect, however, as sellers still face the risk that their counterparty defaults with probability $\delta > 0$. Default thus reintroduces aggregate price risk. One way to limit these risks is to require collateral. Somewhat surprisingly, sellers never fully collateralize their trades. But the intuition is simple. In case of default, sellers can still sell their production spot. If sellers were to fully collateralize – i.e., require full prepayment ($k = p_f$) – they would enjoy too much consumption in default 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 forward price is decreasing with the number of participating sellers n which is determined by the equilibrium in the forward market which we now analyze.

[4]This result holds only for our preference specification. For other specifications of preferences, the amount produced generally depends on the collateral posted.

3.3 OTC Market for Customized Contracts

We turn now to the OTC market for customized contracts. All sellers are matched with a buyer to whom they make a take-it-or-leave-it offer to produce the C good. The offer consists of production c_i, a price p_i and collateral k_i. The buyer accepts it as long as it is at least as good as trading standard contracts $\left(p_f^k, k\right)$. By no-arbitrage pricing, his expected future wealth from trading standard contracts is given by $\int \omega(\theta)dF(\theta) = 0$ so that he accepts the offer if and only if[5]

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

If the buyer accepts the offer, he needs to pledge collateral k_i in the first period. If he is still alive in the second period, the buyer obtains c_i units of C_i goods and pays $p_i - k_i$ units. If the buyer dies, the seller only gets the collateral, as the C_i good is worthless and he cannot produce the S good anymore. The equilibrium customized contract in the OTC market is then given by the seller's take-it-or-leave-it offer which solves

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

subject to the buyer participation constraint (9). The level of production c_i is uniquely pinned down at some level $\bar{c}$ independently of σ_i, as the first-order conditions yield

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

for all i. Sellers then extract all the surplus from buyers via the price

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

while collateral is given by

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

[5]Notice that a buyer who accepts a forward offer can still buy S goods in the spot market in Period 2. If he rejects the offer, he can buy also standard contracts in the forward market in Period 1. However, the pricing of such contracts implies that the buyer is indifferent between the two options. As a consequence, the gain from trading S goods does not directly influence the surplus from trading C goods and, hence, the decision whether to accept a customized contract.

Collateral is an increasing function of the default rate δ. Also, it is only less than the price if it bears a deadweight cost ($\mu > 1$). Otherwise, sellers would ask for full pre-payment, or $k_i = p_i$, in Period 1.

Importantly, customized contracts only vary with σ_i across buyers which captures the valuation of a buyer for C goods. Sellers will only sell a customized contract to a buyer with a sufficiently high valuation σ_i, as only then it is more profitable than just selling a standard contract. This implies that

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

Hence, there is a lower bound $\sigma^*(n)$ from which the C good is produced. [6] The equilibrium in the OTC market can thus be characterized as follows.

Proposition 2. *Any customized contract is fixed in size ($c_i = \bar{c}$) with the forward price being increasing in the valuation of the C good ($\partial p_i/\partial\sigma > 0$). Collateral is always positive and set as a fixed percentage of the price.*

OTC trades take place only for sufficiently high valuations of the C good; i.e., there exists a threshold $\sigma^*(n)$ such that customized 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 sellers $n^* = G(\sigma^*(n^*))$ trading standard contracts. This pins down the lower bound $\sigma^*(n^*)$ such that $1 - G(\sigma^*(n^*))$ sellers have an incentive to package customized contract to any buyer with $\sigma \geq \sigma^*(n^*)$, as well as the forward price $p_f(n^*)$ and the spot price $p(\theta)$. The equilibrium exists and is unique, with a simple assumption on the domain of G guaranteeing that there are trades of customized contracts.

Figure 2 summarizes the payoff in the equilibrium allocation for sellers as a function of the potential surplus when trading customized contracts. Below the equilibrium threshold

[6] The expected payoff from producing S goods 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 C goods. Or the seller being matched with the highest σ always prefers to produce C goods, in which case there is some trade in them.

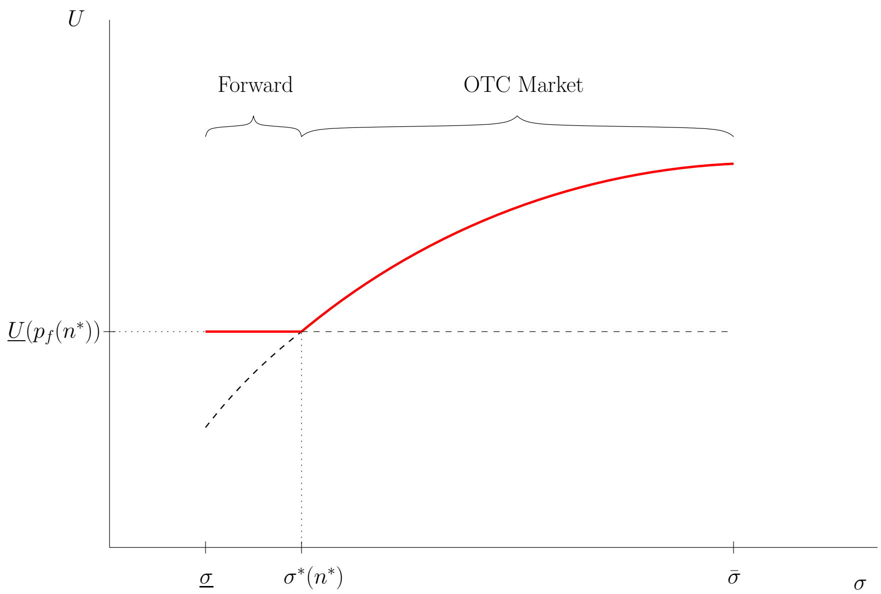

Figure 2: Seller's Payoff in Equilibrium

$\sigma^*(n^*)$, sellers sell only standard contracts to obtain the fixed expected payoff $\underline{U}(p_f(n^*))$ that depends on the equilibrium forward price $p_f(n^*)$. All other sellers sell customized contracts of a fixed size $c(\sigma) = \bar{c}$. However, they extract increasingly more surplus as the price increases with σ.

The equilibrium, however, is inefficient because sellers and buyers trade bilaterally on the OTC market.[7] As trade is bilateral, there is no central price mechanism that can allocate the trading of customized contracts across different valuations efficiently. Given that sellers are risk-averse with respect to payments in the numeraire, it is efficient to have a constant payment $\bar{p}$ across sellers. But to maximize surplus from any individual transaction, this implies that for all σ we have

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

Therefore the *efficient* quantity of the C good $c^*(\sigma)$ increases strictly with the buyer's preference for the C good. With sellers having all the bargaining power, however, the quantity

[7]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.

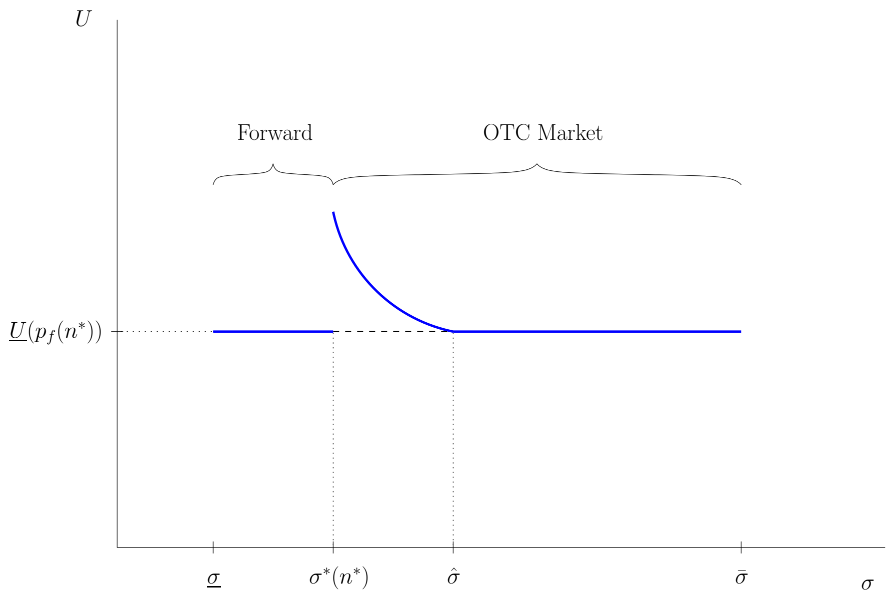

Figure 3: Seller's Payoff in the Constrained-Efficient Allocation

produced is fixed at $\bar{c}$ and, thus, independent of σ.

In our set-up, the existence of a perfectly competitive forward market also limits the redistribution of surplus. Therefore, one should compare the equilibrium to the *constrained-efficient* allocation that holds the size of the two markets – OTC and forward market – constant. Figure 3 shows the sellers' pay-off in the efficient allocation for customized contracts holding fixed the size of the market for standard contracts at the equilibrium level n^*. Above the threshold $\sigma^*(n^*)$, customized contracts are traded OTC. In the efficient allocation, a seller's payoff is decreasing in σ as sellers have to produce more to receive the same payment $\bar{p}$. For high σ, however, the seller's payoff in the efficient allocation would fall below the value of his outside option of trading standard contracts. This drives a wedge into the efficient allocation, where for high σ, sellers would only trade customized contracts such that

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

where $\underline{U}(p_f(n^*))$ is the utility a seller obtains from trading standard contracts. As a consequence, sellers must be rewarded with higher payments for trading customized contracts, even though it is still efficient to have the size of a customize contract 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 seller of customized contracts 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. Now, it is socially efficient that sellers take on more default risk for larger surplus; i.e., the contract size c should increase with σ. However, in equilibrium, sellers privately have an incentive to hold the default risk fixed across transactions although they differ in surplus. Again this is a result of the bargaining friction in OTC trades, where one contracting party – here the seller – can extract a larger premium p_i for taking on a fixed quantity of default risk.

4 Central Counterparty Clearing

A central counterparty (CCP) is usually 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 seller and a buyer is superseded by two contracts: one between the seller and the CCP and one between the CCP and the buyer. This means that sellers and buyers 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, but can also provide insurance against it. One particular insurance scheme is known as the *mutualization of losses* whereby the CCP uses transfers to distributes 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 CCP use those instruments rather than others. We model novation as follows. Once a trade is agreed, the CCP is responsible for collecting all payments from buyers, be it the posting of collateral or the final payment. Similarly, in Period 2, it collects all the S goods from sellers and delivers it to buyers against payment. The CCP also sells the S good in the spot market that was supposed to be delivered to buyers that died. Its total revenue is paid out to sellers.[8] Mutualization takes the form of a transfer – on top of the agreed payment – from (or to) surviving buyers to (or 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 clearing policies. We show next that by doing so, the CCP will help achieve an efficient allocation.

Without loss of generality and for simplicity, we make two assumptions. First, we assume that the CCP exclusively sets collateral requirements when it clears trades. Sellers and buyers take these collateral requirements as given when negotiating their trades. Second, a CCP operates either in the OTC market or the forward market, but not in both markets simultaneously. We will first introduce a CCP in the centralized market and then – taking as given central clearing in this market – we consider the introduction of a separate CCP for trading customized contracts in the OTC market.[9] The main result in this section is that CCP clearing achieves efficiency for both standardized and customized financial contracts.

4.1 CCP Clearing of Standard Contracts – Efficient Risk Sharing

Consider first a CCP for standard contracts. The CCP offers novation and runs a transfer scheme $\phi(\theta)$ that specifies additional payments by buyers depending on the aggregate demand shock for the S good θ. Its revenue in Period 2 is given by

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

where we now denote the standard contract price by p_f^{CCP}. Given the CCP cleared Q standard contracts, the first term in (17) is the collateral that the CCP collects from buyers in the first period. The second term is overall payments – net of collateral postings – made by buyers still alive in Period 2. In exchange, the CCP delivers a total of $(1-\delta)Q$ units of the S

[8]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 sellers sold a contract. 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.

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

good and sells the remaining δQ units on the spot market at price $p(\theta)$. The state-dependent transfer associated with mutualization is the final term in (17).

We now analyze the equilibrium in the market for standard contracts with CCP clearing. Taking aggregate production Q as given, sellers receive a share of the CCP's revenue that is proportional to the number of contracts they sell. Hence, they choose the number of contracts to maximize

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

which again yields $q = 1$ and, hence, $Q = n$ in equilibrium. Since the spot market price is unaffected by CCP clearing, by no arbitrage pricing, the forward price is now given by

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

Therefore, in state θ each seller receives

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

Sellers obtain the average payments across all trades for any level of collateral k and any transfer scheme $\phi(\theta)$. So it is optimal 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 sellers. Hence, collateral is a costly insurance device against counterparty risk. Requiring collateral would just lower the revenue in all states without providing any additional insurance neither against idiosyncratic default risk, nor against the aggregate price risk. The CCP circumvents this cost by imposing $\phi(\theta)$ onto all buyers alive in Period 2, when payments are cheaper. A seller cannot replicate this result as he would have to enter into too many contracts in Period 1 to fully diversify against counterparty risk. Novation is resolving this market incompleteness.

Of course, the conclusion that $k = 0$ is at odd with observed CCP practices. But it is a consequence of our simple set-up where the default risk is exogenous. When the default risk is endogenous, Monnet and Nellen (2013) or Koeppl (2013) have shown in slightly different contexts that a CCP optimally requires a positive amount of collateral. However, while endogenizing default would give us a positive collateral level, this complicates our analysis beyond what is necessary to make the main point of the paper, namely that introducing a CCP moves the market structure toward efficiency.

With novation, the CCP's revenue depends on the spot price, so that sellers 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, that is $\int \phi(\theta) dF(\theta) = 0$ and (ii) sellers are fully insured against aggregate risk, that is $R(\theta) = 1$. Since the fee schedule is revenue neutral, buyers 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 $\theta < 1$ buyers who have not defaulted pay more than the agreed price, while they pay less whenever $\theta > 1$. Since there is no expected transfers between buyers and sellers, the forward price for standard contracts is unaffected by mutualizing losses and equals the expected spot price, or

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

Hence, mutualization guarantees a fixed payment to sellers who are thus perfectly insured against the aggregate price risk.

Proposition 3. *Novation perfectly diversifies counterparty risk, and together with mutualization implements an efficient allocation of standard contracts. Trade will shift from customized to standard contracts ($n^{CCP} > n^*$), so that all sellers and buyers are ex-ante better off with CCP clearing in the market for standard contracts.*

We provide a formal argument in the appendix for this result which explains why markets for standard contracts generally operate with central clearing. With CCP clearing, trade shifts away from customized contracts so that the cut-off point σ^* will increase (see Figure 4)[10], with the sellers' payoffs from trading customized contracts being unaffected. Buyers get zero surplus from trading any contracts in the Period 1. With more standard contracts being traded, however, their welfare increases as the expected spot price for the S goods declines. Still sellers producing the S good are better off, since they fully reap the benefits

[10] The impact of central clearing on the forward price is ambiguous, since central clearing eliminates the deadweight costs associated with collateral.

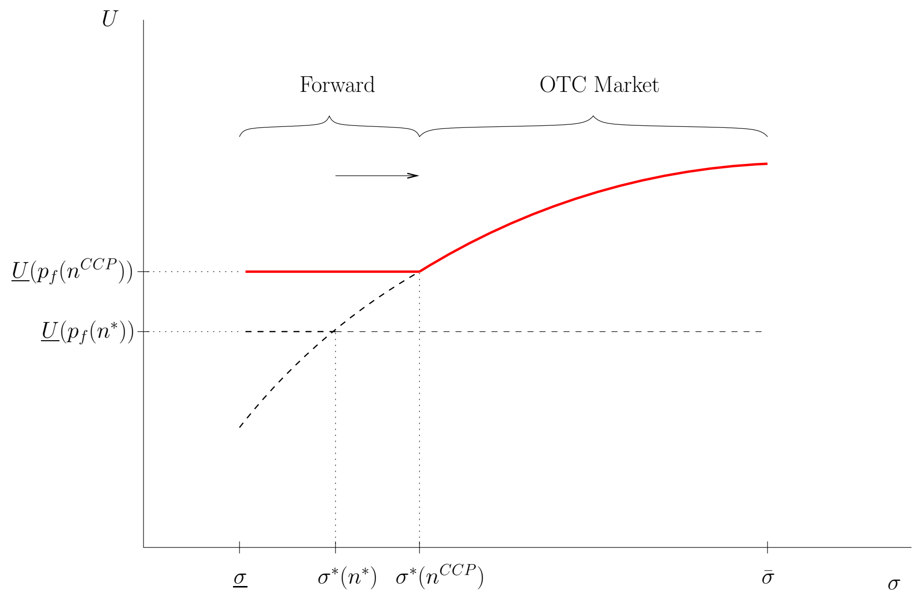

Figure 4: Equilibrium with CCP Clearing on Forward Market

from eliminating the deadweight costs of collateral. As a result, all market participants have an incentive to introduce central clearing in 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.

4.2 CCP Clearing of OTC Contracts – Efficient Risk Allocation

Suppose now that – in addition to the CCP clearing standard contracts – there is also a CCP for clearing customized contracts. We assume the two CCPs operate independently, as we do not to consider the issues of cross-subsidization across markets.[11] We assume that the CCP can observe the surplus σ of each customized contract 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 market for standard contracts.

Therefore, taking the terms of a customized contract (p, c) as given, the CCP novates the trade: it specifies a collateral requirement $k(p, c)$, a payment schedule $m(p, c)$, as well as an additional fee $\phi(\sigma)$ on buyers who are still alive in period 2.[12] Once the trade has been

[11] See Koeppl, Monnet and Temzelides (2011).

[12] The CCP does thus not employ a direct mechanism – except for fee ϕ – where it specifies the terms of

novated, sellers have the obligation to produce c and deliver it to the CCP against payment $m(p, c)$. Buyers make the agreed payments k in period 1, and if they are still alive in period 2, they also pay $p - k$ and $\phi(\sigma)$.

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

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

An important difference between central clearing of customized and standard contracts is that the customized contract – or to be precise the claim to the underlying good – has only value for the buyer who bought it. The CCP thus faces extreme price risk with such contracts if a buyer dies, as it cannot raise additional revenue from selling the C good on a spot market. We call a payment schedule m and a fee ϕ *feasible* if

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

and

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

Hence, the fee charged to buyers needs to be purely redistributive across customized trades. Since the CCP cannot prevent sellers from trading standard instead of customized contracts, the payment schedule $m(p, c)$ must be *incentive compatible*. Hence, we require that for every $\sigma \geq \sigma^*(n^0)$, the payment schedule $m(p, c)$ is such that we have

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

where it is understood that $(p, c) = (p(\sigma), c(\sigma))$ are the terms of the customized contract for a buyer with a particular σ. Note that the outside option of trading standard contracts will also depend on CCP clearing in the OTC market, as this will influence the fraction of sellers n^0 trading standard contracts in equilibrium.

trade as a function of σ. Instead, it takes as given the bargaining problem between the seller and the buyer. Notwithstanding, in equilibrium, the terms of trade (p, c) are a function of σ, so that m and k are also a function of σ.

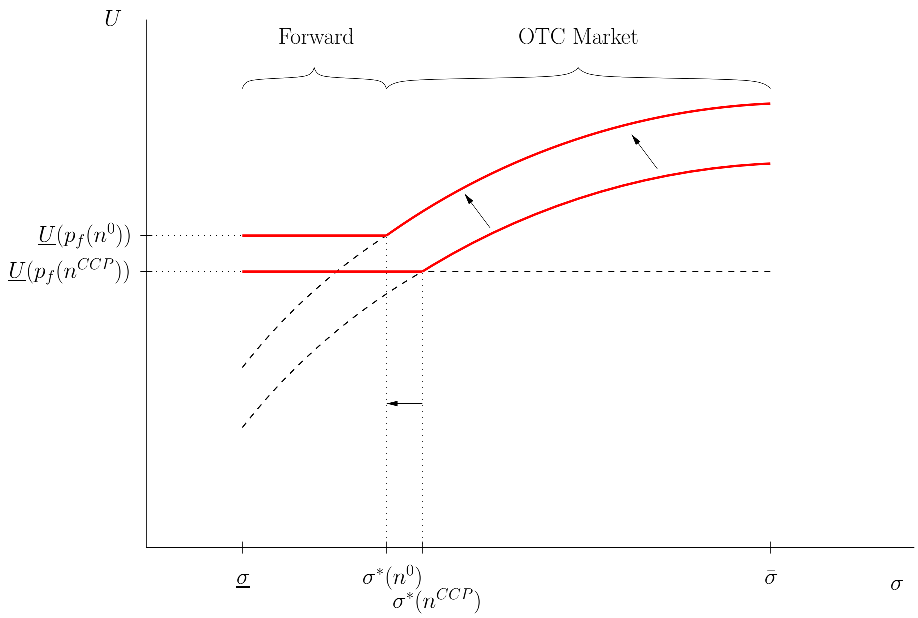

Figure 5: Equilibrium with CCP Clearing on OTC Market

Novation with zero collateral maximizes surplus in OTC trades and therefore is again optimal. Set $\phi(\sigma) = 0$ and set $m(p, c)$ to the expected payments associated with any customized contract (p, c) that is traded OTC, which is given by

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

The payment schedule is clearly feasible. Hence, novation is able to fully diversify counterparty risk in customized contracts, even though the good underlying the contract cannot be traded in the spot market. Due to the deadweight cost of collateral, it is again optimal to set $k(p, c) = 0$ for all contracts. This leads to the following result.

Proposition 4. *CCP clearing can perfectly diversify counterparty risk on the OTC market through novation. The size of the OTC market increases ($n^0 < n^{CCP}$) so that the price for standard contracts increases, making all sellers better off, but all buyers worse off.*

With zero collateral and novation, sellers still extract all the buyers' surplus by setting a fixed contract size $\bar{c}$ and charging a price equal to

$$p(\sigma) = \sigma v(\bar{c}), \tag{28}$$

which ensures that sellers obtain the (expected) payment of a bilateral contract independent of default. As Figure 5 shows, with novation, the sellers' payoff from a customized contract shifts upward. As a consequence, less standard contracts are traded thus increasing its price as well as the expected spot price of the S good. Hence, all sellers gain from introducing a CCP on the OTC market, independent of whether they trade on this market or not. However, buyers are worse off. They expect to pay more for the S good on the spot market, while getting no surplus from customized contracts. This creates a conflict of interest for introducing CCP clearing in the OTC market[13], where the opposition comes from the originators of counterparty risk.

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

$$\max_{(p,c)} -c + \log\left((1-\delta)p\right) \tag{29}$$

subject to

$$(1-\delta)\left[\sigma v(c) - p - \phi(\sigma)\right] \geq 0$$

where we have already taken into account that the CCP will use novation to make average payments to sellers without requesting any collateral. Since the buyer's participation constraint binds, we obtain that the seller's offer is given by

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

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

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 c 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 seller will offer to produce more at a lower price to

[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 buyers derive small surplus from customized contracts.

[14]Requiring collateral can also drive a wedge in the bargaining problem that causes the contract size c to increase with σ. A positive collateral requirement would tax the gains from trade giving incentives to

maintain his surplus. Similarly, a negative fee subsidizes a trade by increasing the surplus. It is now easier for the seller 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 sellers need to have an incentive to package a customized contract. Hence, for the fees to be incentive compatible we need that

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

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 market for standard contracts with novation n^0 as given. Since this restriction simply mirrors the seller'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 and proven in the appendix.

Proposition 5. *CCP clearing with novation together with a revenue-neutral transfer scheme achieves a constrained efficient allocation of risk in the OTC market. The optimal fee ϕ^* is increasing in the buyers' valuation of customized contracts (σ).*

The absence of a price mechanism on the OTC market is often taken as a serious limitation for clearing customized OTC traded contracts. However, we have shown that central clearing is able to set policies so that traders internalize the social costs and benefits of trading such customized products. As such, CCP clearing is a substitute for a 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 financial market.

sellers to increase the contract size, while a negative collateral requirement would subsidize a trade, thereby lowering the contract size c. 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.

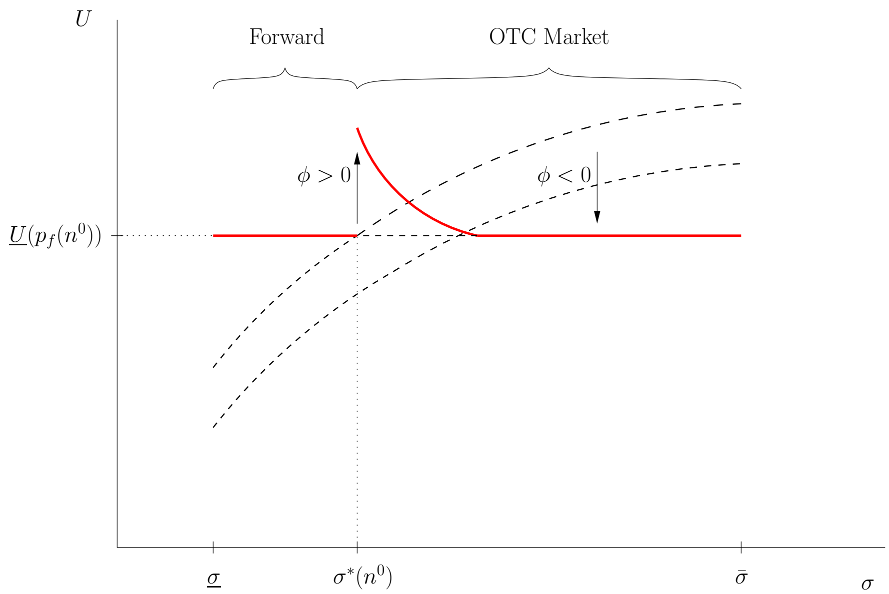

Figure 6: Achieving a Constrained Efficient Allocation in OTC Market

4.3 Limits for CCP Clearing in OTC Markets

4.3.1 Private Information

We briefly discuss two limitations for clearing OTC trades. The first one is that the contracting parties usually have private information on the surplus generated by customized contracts. Sellers and buyers 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, c) to infer the true, but unobservable σ underlying the trade.[15] This imposes a standard truth-telling constraint on the CCP.

For expositional convenience, we consider here a direct mechanism for which the seller and buyer negotiating a customized trade report the valuation σ directly to the CCP. The CCP takes the terms of trade $(p(\sigma), c(\sigma))$ as given where

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

[15]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.

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

$$m(\sigma) = (1-\delta)p(\sigma) \quad (34)$$

$$\phi(\sigma) = \sigma[v(c(\sigma)) - v'(c(\sigma))]. \quad (35)$$

for some function $c(\sigma)$.[16]

This policy implies that the seller and the buyer can lie only downwards, that is report $\sigma' \leq \sigma$.[17] Since buyers never receive any surplus[18] the truth-telling constraint for any σ is then given by

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

This implies that a seller'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 contract size $c(\sigma)$ across trades that the CCP can achieve. 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, sellers facing low σ would offer a small contract size, but for the same payment as trades with a higher surplus σ. This however gives an incentive for other sellers to misrepresent the nature of their trades: they would also a smaller contract size for the same payment. The best allocation the CCP can thus achieve is to offer sellers of customized contracts the same utility independently of σ, where this utility level strictly exceeds the utility from trading standard contracts, or

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

[16]The CCP still has a fixed payment for all sellers across all σ to fully diversify counterparty risk, so that it need not use collateral to insure against such risk.

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

$$\sigma v(c(\sigma')) - p(\sigma') \geq \sigma v(c(\sigma)) - p(\sigma) = \sigma' v(c(\sigma')) - p(\sigma') = 0, \quad (36)$$

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

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

for all $\sigma > \sigma^*(n^0)$. Still, it is efficient to have a larger contract size for higher valuation matches. Therefore, the constrained efficient contract size $\hat{c}(\sigma)$ is still increasing in σ, but sellers also need to have theirpayment increase in σ. As a consequence, private information limits how much counterparty risk can be reallocated across trades, but it does not prevent such a reallocation entirely.[19]

4.3.2 Bilateral Clearing

We have also assumed that the CCP can enforce mandatory central clearing of OTC contracts. The only relevant outside option for sellers is then to trade standard contracts instead. If we drop this assumption, sellers need an incentive to clear customized contracts centrally rather than just bilaterally. Assuming that σ is observable, the CCP has then to design its policy – the payment rule $m(p(\sigma), c(\sigma))$ and the fee $\phi(\sigma)$ – so that sellers not only offer a customized contract, but also clear it centrally. This adds an additional constraint

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

where the right-hand side is the seller's payoff from the customized contract when clearing bilaterally. The CCP still takes the terms of the customized 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 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, trades 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 still 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 trades with a lower valuation, without reducing contract size in those transactions. Hence, the option

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

to clear customized trades bilaterally does not prevent some redistribution of counterparty risk, but again limits it.[20]

5 Conclusion

We set up a formal model of a CCP and of clearing more generally. We 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 uncovered that not all market participants will gain from the introduction of CCP clearing for customized products, implying that not all market participants are likely to support such a development.

In deriving this conclusion, we abstracted from important issues such as introducing CCP clearing might entail 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

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

institution that potentially causes an overall increase in risk due to a moral hazard problem.[21]

Similarly, some of our assumptions are quite strong, but are driven by the desire to derive stark results. For example we have assumed that the customized good had no resale value in case of a default. But our analysis would go through as long as there is a (possibly large) cost of selling the good in case the buyer defaults. One issue is to extend our analysis to cases in which counterparties contemplate default, if it is in their interest. Collateral will then play a crucial role as an incentive device. Also, we have assumed that preferences are represented by log-linear utility. This simplifies the analysis greatly, as there are neither wealth effects from introducing insurance nor distortions from allocating risk across market participants. It would be interesting to see how our results fare quantitatively under different preference structures, but we doubt that this would affect the main message of what CCP clearing adds to financial markets and how it differs for OTC traded contracts.

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Appendix A Proofs

A.1 Proof of Proposition 1

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

The sellers' 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 first that $k \geq p_f$. Then,

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

a contradiction.

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

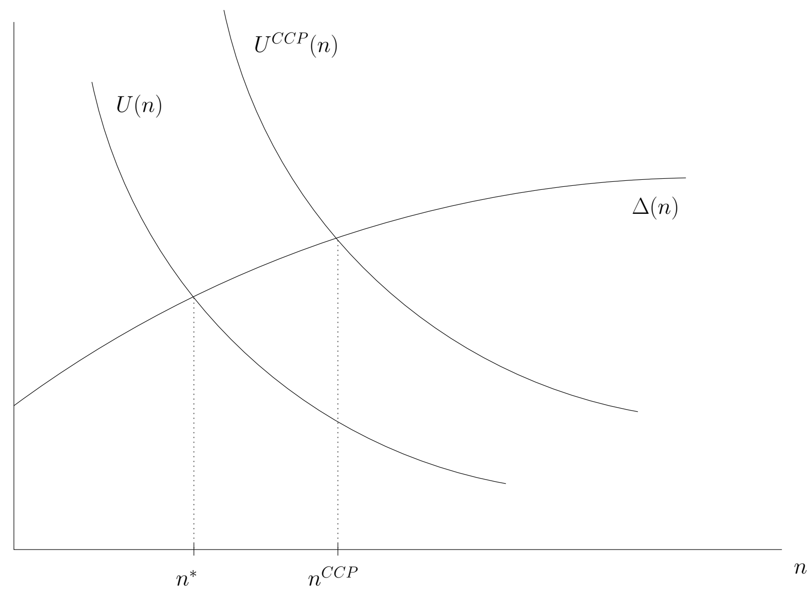
$$\delta \left(\int \frac{1}{\theta} dF(\theta) - 1 \right) = \bar{\mu} - 1$$

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 $n^{CCP} > n^*$ and, thus, that sellers are better of with CCP clearing. Without CCP clearing, equilibrium can be described by the unique value n^* that satisfies

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



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 standardized contracts, the second condition is given by

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

so that the utility from trading standard contracts increases for any level of n (see figure). Also, notice that $U^{CCP}(n) \geq U(n)$ for all n and k. Indeed, using Jensen's inequality we obtain

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

so that integrating and again using Jensen's inequality,

$$U(n) \leq log\left((1-\delta)(\frac{1}{n} - (\frac{\mu}{1-\delta} - 1)k) + \delta(\frac{1}{n} + k)\right)$$

but adding terms this means

$$U(n) \leq log\left(\frac{1}{n} + k(1-\mu)\right)$$

and as $\mu > 1$, we obtain the desired result that for all n and k, $U^{CCP}(n) \geq U(n)$.

Now, recall that in equilibrium, $n = G(\sigma^*(n))$, so that $\sigma^*(n)$ is increasing an increasing function of the equilibrium n. As a consequence, the function $\Delta(n)$ is also increasing in n. Hence, $n^{CCP} > n^*$ and the utility of sellers is higher under the new equilibrium.

A.3 Proof of Proposition 4

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

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

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

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

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

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

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

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

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

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

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

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

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

A.4 Proof of Proposition 5

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

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

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

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

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

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

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

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

From the constrained efficient allocation we have that $c(\sigma)$ strictly increases in σ. We then have that

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

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

Appendix B Constrained Efficient Allocations in the OTC Market

We consider a planning problem for OTC trades where one has to respect that sellers make a take-it-or-leave-it offer to buyers and that sellers always have the option to trade on the market for standard contracts. It is straightforward to verify that initial payments are inefficient. We denote payments to sellers in Period 2 by $x(\sigma)$. The bargaining friction implies that in any allocation buyers must pay $\sigma v'(c(\sigma))$ in all OTC trades.

The planner's problem is then given by

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

subject to

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

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

where $\bar{u} = u(p^f(n^*))$ is given by the outside option to trade on the market for standard contracts.

The first-order conditions are given by

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

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

As a consequence, utility for sellers 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

$$-c(\sigma) + \log((1-\delta)\sigma v'(c(\sigma))) = \bar{u}.$$

Hence, the contract size $c(\sigma)$ and payment to the seller $x(\sigma)$ both increase in σ for $\sigma > \hat{\sigma}$.

The constrained efficient allocation is thus given by

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

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

$$-c(\sigma) + \log\left((1-\delta)\sigma v'(c(\sigma))\right) = u(p_f(n^*))$$

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

Appendix C Inefficient Risk Allocation with Generalized Nash Bargaining

We show here that Nash bargaining in general leads to an inefficient contract size in OTC trading. 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 sellers. Define the surplus of sellers and buyers as S_1 and S_2 respectively. We then have

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

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

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

yielding the following first-order conditions

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

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 buyers. Hence, there is no inefficiency in the pricing of the OTC contract.

Rewriting, we obtain

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

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

As we have shown, for $\eta = 1$, the contract size is independent of σ and given by a constant $\bar{c}$. As the bargaining power for sellers decreases, the slope $ds/d\sigma$ becomes positive. As $\eta \to 0$, we reach the maximum slope

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

This is the optimal allocation for a planner that has to respect the distribution of bargaining power, just like we have derived in the special case of $\eta = 1$ in Appendix B. For all other distributions of bargaining power, we get that the contract size does not increase fast enough with the surplus of the transaction expressed through σ. The reason is again the externality where individual bargaining does not take into account the social value of a transaction.