Centralized versus Over The Counter Markets

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Abstract

The opacity of over-the-counter (OTC) markets – in which a large number of financial products including credit derivatives trade – appears to have played a central role in the ongoing financial crisis. We model such OTC markets in a general equilibrium setup with default and study risk sharing when agents’ trades are not mutually observable. In turn, contracts (prices, interest rates, collateral) cannot be conditioned on the risk of counterparty’s default. In this setting, there is excess “leverage” in that parties in OTC contracts take on short positions that lead to levels of default risk that are higher than Pareto-efficient ones. Thus, OTC markets feature a counterparty risk externality that we show can lead to ex ante productive inefficiency. This externality is absent when trading is organized via a centralized counterparty that observes all trades. We extend the model to consider the formation of bubbles and their burst, role of market power in OTC markets, provision of incentives to move from OTC to centralized markets, and policy issues concerning forbearance toward “too-big-to-fail” positions.
1 Introduction

1.1 Motivation and overview of results

Most financial contracts are arrangements between two parties to deliver goods or cash in amounts and at times that depend upon uncertain future events. Designed appropriately, financial contracts facilitate risk-sharing in the economy. There may be many risks in such contracts, but one additional risk to be evaluated at the time of contracting is the risk that the counterparty will not fulfill its future obligations. This counterparty risk is difficult to evaluate because the exposure of the counterparty to various risks is generally not public information. Contractual terms such as prices, interest rates and collateral that affect the terms of trade can be tailored to mitigate counterparty risk, but the extent to which this can be achieved, and how efficiently so, depends in general on how contracts are traded.

One possible trading infrastructure is an over-the-counter (OTC) market in which each party trades with another, subject to a bankruptcy code, that is specified in the contract and/or adheres to a uniformly applicable corporate code, and which determines how counterparty defaults will be resolved. A key feature of OTC markets is their opacity. In particular, even within a set of specific contracts, for example, credit default swaps, no trading party has full knowledge of positions of others. We show theoretically in this paper that such opacity of exposures in OTC markets leads to an important risk spillover – a “counterparty risk externality”1 – that in turn leads to excessive “leverage” (risk-taking through short positions) and inefficient levels of default risk and risk-sharing.

Counterparty risk externality is the effect that the counterparty risk on one contract will be increased if the counterparty agrees to the same contract with another agent because the second contract increases the probability that the counterparty will be unable to perform on the first one. Put simply, the risk on one deal depends on what else is done. The intuition for our result concerning the inefficiency of OTC markets is that in OTC markets it is not at all transparent what else is being done. This makes it likely that excessively large short positions will be built by some institutions without the full knowledge of other market participants and without adequate backing of collateral. If these institutions were to default, their counterparties would

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1 The term “counterparty risk externality” is as employed by Acharya and Engle (2009). A part of the discussion below, especially related to A.I.G. is also based on that article.
also incur significant losses, creating systemic risk in the economy or more formally, inefficient ex-ante risk-sharing.

For example, in September 2008, it became known that A.I.G.’s liquidity position was inadequate given that it had written credit default swaps (bespoke CDS) for many investors guaranteeing protection against default on mortgage-backed products. Each investor realized that the value of A.I.G.’s protection was dramatically reduced on its individual guarantee. Investors demanded increased collateral – essentially posting of extra cash – which A.I.G. was unable to provide and the Treasury had to take over A.I.G. The counterparty risks were so widespread globally that a default would probably have spurred many other defaults generating a downward spiral.

The A.I.G. example illustrates well the cost that large OTC exposures can impose on the system when a large institution operating in OTC markets defaults on its obligations. But, more importantly, it also raises the question of whether A.I.G.’s true risk as a counterparty was reflected by investors in prices and risk controls for protections they purchased from A.I.G. The opacity of the OTC markets in which these credit derivatives trade was primarily responsible for allowing the build-up of such large exposures in the first place.

While a number of financial innovations in fixed income and credit markets have traded until now in OTC markets, many products linked to commodity and equities have traded successfully on centralized exchanges. A distinguishing feature of centralized exchange relative to OTC trading is that even though individual agents still do not see each others’ trades, there is a centralized counterparty – the exchange – that sees all trades (at least on all products traded on that particular exchange). Crucially, this enables the exchange to offer pricing schedules on trades to individual parties (e.g., collateral arrangements) that are contingent not just on observable or public characteristics (e.g., credit ratings) but also on its own knowledge of other trades (e.g., net positions in CDS contracts).

We show formally that when trading is organized in the form of a centralized exchange, the conditioning of contract terms for each party depending on its positions is sufficient to get that party to internalize the counterparty risk externality it generates through its trades. In other words, the moral hazard that each party wants to take on excessively short positions – collect cash today and default tomorrow – is counteracted by the fact that they face a steeper price schedule by so doing. Effectively, centralized trading creates one intermediary for which others’ trades are not opaque and this is sufficient
to achieve the efficient risk-sharing outcome.

1.2 Model and results

We derive these results in a competitive general equilibrium (GE) model with two periods but allowing for the possibility of default (Geanakoplos, 1997, Geanakoplos and Zame, 1998, Dubey, Geanakoplos and Shubik, 2005). There is a single financial asset, which can be interpreted as a contingent claim on future states of the world, and agents can take long or short positions in the asset. Trades are collateralized by agents’ endowments. When an agent has short positions that cannot be met by the pledgeable fraction of endowment, there is default. The possibility of default implies that long and short positions do not yield the same payoff and indeed that there is counterparty risk in trading. We assume a natural bankruptcy rule that illustrates why counterparty risk potentially arises in such a setting. In particular, in any given state of the world, the payoff to long positions is determined pro-rata across positions based on delivery from short positions. This rationing of payments implies that each trade imposes a payoff externality on other trades. We call this spillover as “counterparty risk externality.”

In this setup, we consider two trading structures and ask whether counterparty risk externality leads to inefficient risk-sharing. For pedagogical purposes, we start with the centralized exchange in which a competitive central counterparty observes all trades and sets pricing schedules for agents that are conditional on this knowledge. We show that the competitive equilibrium in the economy with a centralized exchange is constrained Pareto efficient.

Next, we consider the OTC setting in which trades are not mutually observed and thus pricing schedules faced by agents are not conditional on their other trades (even though they might be conditioned on public information about their type, e.g., their endowment level or equivalently their credit rating). We study two different cases, one in which a centralized bankruptcy mechanism operates to distribute the cash flow delivered on the short positions of the asset pro-rata with respect to the long positions and one in which the bankruptcy mechanism is bilateral. We show that, in either case, the competitive equilibrium in the OTC economy is generically inefficient compared

\[^2\text{In case of centralized bankruptcy mechanism, delivery from short positions is the sum total of full payments from non-defaulting parties and partial payments from defaulting parties; in case of bilateral bankruptcy mechanism, delivery on short positions is just the partial payment from the defaulting counterparty.}\]
to constrained Pareto efficient outcome. The inefficiency in the OTC setting manifests as excessively large short positions as agents do not internalize the default risk these positions impose on other trades in the economy. We interpret this outcome as characterizing excessive “leverage” from an ex-ante standpoint and excessive systemic risk from an ex-post standpoint.

Put together, these results imply that centralized markets such as an exchange are an efficient regulatory response to the moral hazard that in the absence of perfect observability of trades, agents have incentives to take on short positions that allow them to consume today and default tomorrow. Our analysis also makes it precise that it is the opacity or lack of transparency of the OTC markets that leads to ex-ante inefficiency in terms of excessively large short positions or leverage. On this point, it is worth stressing that in fact, even when a centralized bankruptcy mechanism operates in OTC, equilibria are inefficient and characterized by excessive ”leverage”.

In important extensions,

1. We allow agents to alter their production schedules. In this case, the moral hazard of excessive leverage in the OTC case translates into an additional inefficiency in terms of excessive production. This result clarifies that the inefficiency of OTC markets extends beyond just inefficient risk-sharing and systemic risk. An example of this inefficiency could be the large and inadequately-collateralized short-selling (of protection) on pools of mortgages – contingent claims on state of the real estate in the economy – that apparently fed the excessive creation of the housing stock.

2. We introduce a market for the collateral good, adverse states of the world with low endowment shock for all agents, and a third period. This augmented setting allows us to characterize the possibility of a “bubble” in the market for collateral good (e.g., the housing stock), its subsequent crash upon realization of adverse shocks, and breakdown of credit markets in those states.

3. We consider bilateral OTC markets in the presence of a “large” individual agent that effectively observes the trades of all others but whose trades are not seen by others. Since such an agent would be strategic, rather than competitive, the equilibrium outcome is worse in terms of efficiency. Further, the benefits enjoyed by such large traders in the
OTC setting reduce private incentives in the economy to coordinate on a centralized trading platform and achieve Pareto improvement.

4. We consider the possibility of regulatory forbearance of “too big to fail” (or liquidate) trades and the role played by centralized exchanges in affecting time-inconsistency of regulation.

1.3 Implications

Analysis of the role played by OTC markets in the ongoing financial crisis has led to several reform proposals. Our theoretical analysis helps provide a normative comparison of these proposals.

For example, Acharya, Engle, Figlewski, Lynch and Subrahmanyam (2009) divide the proposals into requiring a (i) centralized registry with no disclosure to market participants; (ii) centralized counterparty with no disclosure (except aggregates) to market participants; and (iii) exchange with public disclosure of prices and volumes. Our theoretical analysis makes it clear that a centralized registry by itself is not sufficient as it only gives regulators ex-post access to trade-level information but does not counteract the ex-ante moral hazard of institutions wanting to take on excessive leverage. Both centralized counterparty and exchange suffice on this ground but it is the centralized counterparty that is crucial rather than an exchange; in other words, it is sufficient that one party sees all trades and sets price schedules and risk controls conditional on that information, and it is not necessary to disclose information on all trades to individual agents.

Regulatory reforms announced in March 2009 by Treasury Secretary Geithner involve significant changes to the trading infrastructure of OTC markets, with the objective of reducing systemic risk in the financial sector. Under the proposed reforms, mature and standardized credit derivatives such as the credit default swaps (CDS) and indices linked to the CDS will be traded through a centralized counterparty; there is no proposal yet to mandate that these be traded on an exchange. Regulators will gain unfettered access to information on prices, volumes and exposures from the centralized counterparties, but the proposals do not require that such information be made public. While some aggregate information will be disseminated to all market participants, such as the recent data published by the Depository Trust and Clearing Corporation (DTCC) on all live positions in credit derivatives, full transparency is being required only for regulatory usage.
Our results suggest that these proposed changes are likely to be adequate except that many financial products such as the customized or “bespoke” collateralized debt and loan obligations (CDOs and CLOs) are deemed not to be amenable to centralized clearing. The OTC markets will surely exist if only to trade these remaining contracts. It might seem that these bespoke products can be ignored from a risk point of view, however nearly all the problem legacy assets are of this type and these we now know are extremely risky systemically. On these assets, our results suggest that further trade-level transparency among market participants will likely be required in at least some form.

We also note that by assuming a specific bankruptcy mechanism, our theoretical analysis does not consider practical issues relating to the extent of netting of positions that is possible when a centralized exchange is restricted to a part of the financial products space. Duffie and Zhu (2009), for example, explain with calibrations that for a centralized exchange for CDS to reduce counterparty risk more than the OTC setting, it would require netting not just across CDS but also across other OTC products such as interest-rate swaps. It is our conjecture that if there were a centralized registry of positions observed by different exchanges, and the registry in turn was observed by all exchanges, then we would obtain efficient ex-ante pricing/collateral arrangements, and thereby, efficient levels of ex-post default risk.

The remainder of the paper is structured as follows. Section 2 presents the basic GE model, the centralized exchange case, the OTC case, the Pareto efficient case, and the welfare analysis. Section 3 discusses several possible extensions of the model. Section 4 concludes.

2 The model

Let us start with a general equilibrium (GE) model without production or intermediation. Effectively, a two-period GE model with default (Geanakoplos, 1997, Geanakoplos and Zame, 1998, Dubey, Geanakoplos and Shubik, 2005), extended to allow for the different information structures of centralized versus OTC markets, is enough to illustrate the main issues.

Agents and endowments The economy is populated by $i = 1, \ldots, I$ types of agents. Let $x_{i}^{0}$ be consumption of agent $i$ at time 0. Let $s = 1, \ldots, S$ denote
the states of uncertainty in the economy, which are realized at time 1. Let $x^i_1$ be agent $i$’s consumption at time 1, a random variable over the state space $S$: $x^i_1(s)$, for $s \in S$. Let $w^i_0$ be the endowment of agent $i$ at time 0; and $w^i_1(s)$ her endowment at time 1 in state $s$.

Financial asset and trading We assume, for simplicity, that only one financial asset is traded in this economy, an asset whose payoff is $R$, a non-negative vector in $S$. The payoff $R$ is exogenous. We can imagine it representing a derivative contract, e.g., a credit default swap. We make a purely technical assumption that trading the asset is costly, in the amount of $\varepsilon$ units of consumption good at time 0 per transacted unit of the asset. This assumption is required to bound equilibrium positions of agents, as we will explain shortly.

Default risk Let $z^i_+$ and $z^i_-$ be the portfolio vectors of long and short positions, respectively, of agent $i$ in financial markets. Agents selling the asset might default on their required payments. In particular, agent $i$’s short positions are collateralized by the pledgeable fraction $\alpha$ of her endowment at time 1. In other words, in the event of default, creditors (counterparties holding long positions on the asset with the defaulting party) have recourse only to a fraction $\alpha$ of the debtor’s endowment $w^i_1(s)$. Only a fraction of the debtor’s endowment can be pledged as collateral, for instance because a part of the endowment is agent-specific. No creditor has direct privileged recourse to a debtor’s collateral, in case of default. That is, all creditors share pro-rata the debtor’s collateral, given their respective long positions. Other than the defaulting agent simply losing her collateral to counterparties, default is assumed to have no direct deadweight costs.

The default condition An agent of type $i$ with (long, short) portfolio position $(z^i_+, z^i_-)$ will default in period 1 in state $s$ iff her income after assets pay off is smaller than the non-pledgeable fraction of her endowment. Let $R_+(s)$ denote the payoff in state $s$ of long positions in the asset. It is endogenous as it depends on the default rate in the economy at equilibrium. Then, the default condition can be expressed as:

\[ R_+(s) \geq 0 \] and hence any agent $i$ defaulting for some $s$ must have $z^i_- > 0$, or in other words, have some short position in the asset.
\[ w_1^i(s) + R_+(s)z^+_i - R(s)z^-_i < (1 - \alpha) w_1^i(s) . \] 

This can be rearranged in the more intuitive form:

\[ \alpha w_1^i(s) + R_+(s)z^+_i < R(s)z^-_i , \]

that is, the pledgeable endowment (collateral) of the agent plus payoffs on the long position fall short of what is owed on her short position.

Finally, let \( I^d(z_+, z_-; s) \) the subset of agents with portfolio \( (z_+, z_-) \) defaulting at equilibrium in state \( s \):

\[ i \in I^d(z_+, z_-; s) \text{ iff } w_1^i(s) + R_+(s)z^+_i - R(s)z^-_i < (1 - \alpha) w_1^i(s) . \]

Given this setup, we can analyze equilibrium and its efficiency when trading in the economy is through a centralized exchange or over-the-counter.

## 2.1 Centralized exchange economy

We first study an economy in which all asset trades are operated by a competitive centralized "exchange." In essence, the exchange is a centralized counterparty that observes all trades and conditions contract terms for individual agents on these trades. First, we explain how the exchange resolves default, and next, we explain how it conditions contract terms.

**Bankruptcy resolution**  As stated before, no creditor has direct privileged recourse to a debtor’s collateral, in case of default. The centralized exchange, on the other hand, has full recourse to the debtors’ pledgeable collateral. Furthermore, the exchange operates as a bankruptcy mechanism, by distributing the cash flow of the short positions of the asset, pro-rata with respect to the long positions. To be precise, there are short positions that deliver on the contracts in a given state of the world, and there are others that default. The sum total of these cash flows is distributed pro-rata among the holders of long positions. Thus, the payoff of long positions in state \( s \), \( R_+(s) \), is

\[ R_+(s) = \frac{\sum_{i \in I^d(z_+, z_-; s)} \alpha w_1^i(s) + \sum_{i \in I \setminus I^d(z_+, z_-; s)} R(s)z^-_i}{\sum z^+_i} , \]

where \((z^+_i, z^-_i)\) are the equilibrium portfolios of agents of type \( i \).
Prices

Prices are competitive. Agents are price-takers and so is the exchange (for instance because many could operate the same exchange). We turn therefore to qualify the price taking assumption. This is necessary because agents holding short positions on the asset might default on their required payments, and their default position depends on their type and on their total trading position. Since the exchange observes the agents’ types and total trading positions, it will offer a different ask price to different agents, reflecting the probability of default implied by their characteristics (type as well as trading positions). More specifically, the exchange can compute the cash flow of any short position by agent \( i \) with trading position \((z^i_+, z^i_-)\):

\[
R^i(z^i_+, z^i_-; s) = \begin{cases} 
\alpha w^i(s) & \text{if } i \in I^d(z^i_+, z^i_-; s) \\
R(s) & \text{else}
\end{cases} \forall s. 
\]  

(5)

Consequently, the exchange will offer (and the agents will face) the price map \( q^i_-(z^i_+, z^i_-) = E(mR^i(z^i_+, z^i_-)) \); taking as given the stochastic discount factor \( m \), a vector in \( S \), which prices the asset at equilibrium.\(^4\)

As explained above, on the other hand, all agents long in the asset receive the same cash flow \( R_+ \), a vector in \( S \), at time 1 per unit held. Then, perfect competition on the part of the exchange implies that the exchange as well as any agent faces the same bid price of the asset; let it be denoted \( q_+ \).

Budget constraints

The budget constraints of agent \( i \) are then given by the following equations for consumption at date 0 and in states at date 1:\(^5\)

\[
x^i_0 + q_+ z^i_+ - q^i_- (z^i_+, z^i_-) z^i_- = w^i_0 - \varepsilon (z^i_+ + z^i_-) \\
x^i_1 (s) = \max \{ w^i_1 (s) + R_+ (s) z^i_+ - R(s) z^i_- , (1 - \alpha) w^i_1 (s) \} \\
\]  

(7)

where \( z^i_+, z^i_- \geq 0. \)

\(^4\)Formally, the stochastic discount factor \( m(s) \) in equilibrium will be the marginal rate of substitution between date 0 and state \( s \) at date 1 for agents that hold long positions in the asset.

\(^5\)To avoid clogging the notation, we assume here and in the rest of the paper that each agent of type \( i \) will, in equilibrium choose the same portfolio positions \((z^i_+, z^i_-)\). In fact, existence of an equilibrium might require allowing identical agents to choose different portfolios to guarantee enough continuity to aggregate demand.
The agents’ demand functions for going long and short on the asset, \((z^+_i, z^-_i)\), are obtained from their optimization, taking the price \(q_+\) and the price map \(q_i^- (z^+_i, z^-_i)\) as given. Note that, typically, agents will have both long and short positions in their portfolios, as the payoffs of long and short positions are not perfectly colinear, because of the default option embedded in short positions.

**The exchange’s problem**  We turn next to the decision problem of the competitive centralized exchange, which controls the supply of the asset to agents. Let such supply be denoted \((\theta^+_i, \theta^-_i)\), for any \(i\).

Recall that the exchange will face a bid price \(q_+\) and a whole ask price map \(q_i^- (\theta^+_i, \theta^-_i)\). To summarize, a competitive exchange will take as given the stochastic discount factor \(m\) which prices the asset at equilibrium, while anticipating the compositional effects on default risk of portfolios of different agent type, and solve the following problem:\(^6\)

\[
\max_{\{\theta^+_i, \theta^-_i : \sum_i \theta^+_i - \sum_i \theta^-_i = 0\}} \sum_i q_+ \theta^+_i - q_i^- (\theta^+_i, \theta^-_i) \theta^-_i
\]

subject to

\[
q_i^- (\theta^+_i, \theta^-_i) = E \left( mR_i (\theta^+_i, \theta^-_i) \right)
\]

where \(R_i (\theta^+_i, \theta^-_i; s) = \{ \frac{\alpha_{\omega i}(s)}{z^-_i} \text{ if } i \in I^d(\theta^+_i, \theta^-_i; s) \} R(s) \text{ else} \forall s \).

**Competitive equilibrium**  At competitive equilibrium, the portfolios demanded by the agents are offered by the competitive exchange and markets clear:

\[
\theta^+_i = z^+_i, \quad \theta^-_i = z^-_i, \quad \forall i.
\]

It naturally follows that a competitive equilibrium, prices satisfy:

\[
q_+ = E (mR_+),
\]

\[
q_i^- (z^+_i, z^-_i) = E \left( mR_i (z^+_i, z^-_i) \right).
\]

\(^6\)See Acharya and Bisin (2008) and Bisin, Gottardi and Ruta (2009) for a related notion of price-taking and competitive equilibria.
2.2 OTC markets

Let us now assume that trading does not occur on a centralized exchange (or any exchange for that matter), but is instead intermediated in Over The Counter (OTC) markets. We model OTC markets as standard competitive markets with no centralized exchange.

We consider in turn two different bankruptcy resolution mechanisms, a centralized one and a bilateral one.

2.2.1 OTC markets with centralized bankruptcy

We assume that no creditor has privileged recourse to a debtor’s collateral in case of default. Nonetheless, a bankruptcy mechanism operates to distribute the cash flow delivered on the short positions of the asset (full cash flow or collateral-based recovery in case of default) pro-rata with respect to the long positions. Thus, as far as bankruptcy resolution is concerned, OTC markets with centralized bankruptcy are comparable to a centralized exchange.

Prices

As before, let \( z^+_i \) and \( z^-_i \) be the long and short positions, respectively, of agent \( i \) in the asset. The important point is that OTC markets have no centralized clearing mechanism (nor a centralized registry) and hence the trades of each agent \( i \), \((z^+_i, z^-_i)\), are not observed in OTC markets by other agents. No traders in OTC markets can therefore “net” agents’ positions or offer to agent \( i \) a price which reflects her default probability. Note that the bankruptcy mechanism allows for such netting in case of default when all trades are revealed, but absent observation of trades ex ante, such netting cannot be conditioned on trades while setting prices.

However, long and short positions will in general still be associated with distinct prices, \( q^+_i \) and \( q^-_i \) respectively. The ask price depends on the agent’s type \( i \), as the type affects the probability of default and it is observed by all traders. Importantly though, the ask price for agent \( i \) is not conditioned on her trades. This is the primary distinction between OTC and centralized markets, that contract terms (prices, interest rates, collateral requirements, etc.) are not conditioned on agents’ trades in the case of OTC markets whereas they are in case of centralized exchange.

Budget constraints

The budget constraints of agent \( i \) are thus given by:
\[ x_0^i + q_+ z_+^i - q_- z_-^i = w_0^i - \varepsilon(z_+^i + z_-^i) \]
\[ x_1^i(s) = \max \{ w_1^i(s) + R_+(s)z_+^i - R(s)z_-^i, (1 - \alpha) w_1^i(s) \} \tag{14} \]

where \( z_+^i, z_-^i \geq 0 \).

**Competitive equilibrium**  Agents determine their demands for long and short positions by maximizing their objectives, taking as given the payoff of long positions on the asset, \( R_+(s) \). At equilibrium, however, the payoff \( R_+(s) \) must satisfy the consistency condition:

\[ R_+(s) = \frac{\sum_{i \in \mathcal{I}(z_+^i, z_-^i)} \alpha w_1^i(s) + \sum_{i \in \mathcal{I}(z_+^i, z_-^i)} R(s)z_-^i}{\sum_i z_+^i}, \forall s. \tag{15} \]

At the competitive equilibrium, furthermore, financial markets clear:

\[ \sum_i z_+^i - z_-^i = 0. \tag{16} \]

It naturally follows that at a competitive equilibrium asset prices satisfy:

\[ q_+ = E(mR_+), \tag{17} \]
\[ q_- = E(mR_-). \tag{18} \]

### 2.2.2 OTC markets with bilateral bankruptcy

In this section we continue assuming that trading does not occur on a centralized exchange (or any exchange for that matter), but is instead intermediated in Over The Counter (OTC) markets. We continue modeling OTC markets as standard competitive markets with no centralized exchange. No creditor has privileged recourse to a debtor’s collateral in case of default, but a bilateral bankruptcy mechanism operates to distribute the collateral-based recovery on each agent in default, pro-rata with respect to the agent’s creditors.

**Prices**  Agents enter into bilateral contracts. Let \( z_{ij}^+ \) be long positions of agents of type \( i \) sold to agents of type \( j \) (all agents of the same type are symmetric). Let \( z_{ij}^- \) be short positions of agents of type \( i \) (all short positions are symmetric for the agents shorting the asset, independently of the
counterparty). OTC markets have no centralized clearing mechanism (nor a centralized registry) and hence the trades of each agent \( i \), \((z^i_{+}, z^i_{-})\), are not observed in OTC markets by other agents.

Long and short bilateral position will in general be traded at a price \( q^j \), where the apex \( j \) denotes the type of the agent in the short position. Importantly though, while the price depends on the type of the debtor, it is not conditioned on the agents’ other trades, which are not observed.

**Budget constraints**  The budget constraints of agent \( i \) are thus given by:

\[
x^i_0 + q^j \sum_{j \in I \setminus \{i\}} z^i_{j} - q^i z^i_{-} = w^i_0 - \varepsilon (\sum_{j \in I \setminus \{i\}} z^i_{j} + z^i_{-})
\]

\[
x^i_1(s) = \max \left \{ w^i_1(s) + \sum_{j \in I \setminus \{i\}} R^j(s) z^i_{j} - R(s) z^i_{-}, (1 - \alpha) w^i_1(s) \right \}
\]

where \( z^i_{+}, z^i_{-} \geq 0, \forall j \in I \setminus \{i\} \).

**Competitive equilibrium**  Agents determine their demands for long and short positions by maximizing their objectives, taking as given the payoff of long positions on the asset, \( R^j(s) \), for any possible counterparty \( j \in I \setminus \{i\} \). At equilibrium, however, the payoff \( R^j(s) \), for any \( j \in I \), must satisfy the consistency condition:

\[
R^j(s) = \left \{ \frac{\alpha w^i_1(s)}{\sum_{j' \in I \setminus \{j\}} R(s)} \right \} \forall s, j' \in I \setminus \{j\}.
\]

where

\[
i \in I^d \text{ iff } w^i_1(s) + \sum_{j \in I \setminus \{i\}} R^j(s) z^i_{j} - R(s) z^i_{-} < (1 - \alpha) w^i_1(s)
\]

and where \((z^i_{+}, z^i_{-})_{j \in I \setminus \{i\}}\) are evaluated at equilibrium, for any agent \( i \).

At the competitive equilibrium, furthermore, financial markets clear:

\[
\sum_{j \in I \setminus \{i\}} z^i_{j} - z^i_{-} = 0.
\]
2.3 Welfare

How does the competitive equilibrium under OTC markets compare in terms of efficiency properties to the competitive equilibrium under centralized exchange? To answer this question, we write down the constrained Pareto efficient outcome as the solution to the following problem:

\[
\max_{(x^0_i, x^1_i, z^+_i, z^-_i)} \sum_i \lambda^i E\left(u^i(x^0_i, x^1_i)\right)
\]

\[s.t.
\sum_i x^0_i - w^0_i = -\sum_i \varepsilon(z^+_i + z^-_i),
\]

\[\sum_i x^1_i - w^1_i = 0,
\]

\[x^1_i(s) = \max \left\{ w^1_i(s) + R_+(s)z^+_i - R(s)z^-_i, (1 - \alpha) w^1_i(s) \right\}, \forall i, s
\]

\[R_+(s) = \frac{\sum_{i \in I^d(s)} \alpha w^1_i(s) + \sum_{i \in I \setminus I^d(s)} R(s)z^-_i}{\sum_i z^+_i}.
\]

where \(\lambda^i\) is the Pareto weight associated to agents of type \(i\).

This is the standard constrained efficiency problem for a GE economy once it is assumed that default is not controlled by the planner. The constraint

\[x^1_i(s) = \max \left\{ w^1_i(s) + R_+(s)z^+_i - R(s)z^-_i, (1 - \alpha) w^1_i(s) \right\}, \forall i, s
\]

serves two purposes:

(i) it restricts the planner’s allocations to those that can be achieved with the limited financial instruments available in the economy; and

(ii) it accounts for the fact that each agent can choose to default, in each state \(s\): consumption in a default state \(s\) is \((1 - \alpha) w^1_i(s)\), the non-pleadgable fraction of endowment.

\(\text{Formally, the constraint includes the incentive compatibility constraint for each agent’s choice of default:}
\]

\[u^i(x^0_i, x^1_i(s)) \geq u^i(x^0_i, (1 - \alpha) w^1_i(s)).
\]

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2.4 Results

We can derive the following results on the constrained efficiency of the centralized exchange economy and the (generic) constrained inefficiency of the economy with OTC markets:

**Proposition 1.** *Any competitive equilibrium of the centralized exchange economy is constrained Pareto optimal.*

The intuition for efficiency of the centralized exchange economy is that each agent $i$ that is short on the asset faces a price $q_i^t(z_i^+, z_i^-)$ that is conditioned on her positions. Consequently, she internalizes the effect of her default on the payoff of long positions on the asset $R_+(s)$. The observability of all trades by the exchange and its conditioning of prices based on this information enables the economy with default risk to get agents to internalize the costs they impose (in terms of inefficient risk-sharing) on other agents due to positions that lead to “excessive” defaults ex post.

In striking contrast,

**Proposition 2.** *Any competitive equilibrium of the OTC markets economy with centralized bankruptcy is generically not constrained Pareto efficient.*

We can in fact show that any competitive equilibrium of the OTC markets economy with centralized bankruptcy is characterized by excessive leverage. In OTC markets, agents wanting to short the financial asset do not face ask prices that penalize them for their own incentives to default. As a consequence, other things equal, with OTC markets agents will have incentives to exceed the Pareto efficient short positions, thereby increasing the equilibrium default rate.

Not surprisingly, the same result holds for OTC markets economies with bilateral bankruptcy.

**Proposition 3.** *Any competitive equilibrium of the OTC markets economy with bilateral bankruptcy is generically not constrained Pareto efficient.*

**Opacity and counterparty risk externality** When combined together, Propositions 1, 2, and 3 imply that centralized markets such as an exchange are an efficient response to the moral hazard that in the absence of perfect observability of trades, agents have incentives to take on short positions that allow them to consume today and default tomorrow. Our analysis, especially in Propositions 2 and 3, makes it precise that it is the *opacity* or lack of
transparency of the OTC markets that leads to ex ante inefficiency in terms of excessively large short positions or leverage. We call this inefficiency as “counterparty risk externality” since it stems from counterparty risk, the risk of default of the short party on long positions, and excessive level of such counterparty risk lowers the payoff to all long positions in the economy, constituting an important negative externality on economy-wide risk sharing.

2.5 Comment on the Bankruptcy Mechanism

The economy with a competitive centralized exchange is equivalent to one in which many exchanges might trade the same asset and agents’ positions in one exchange are not observable to the other exchanges, provided a bankruptcy mechanism exists which implements a particular “seniority rule.” In this case, agents can trade assets at prices conditional on having exclusive recourse to the pledgeable fraction of the agent endowment. It is straightforward to show that in this case the bankruptcy mechanism effectively mimics the centralized exchange and the economy will effectively operate efficiently, letting creditors exercise exclusive recourse to the pledgeable fraction of all traders’ endowments.

3 Extensions (to be completed)

1. Add production so as to show that OTC markets induce too much aggregate risk.

2. Present a model with “bubble” in collateral good (value of Lagrange multiplier). The coherent modeling of a drop in value of collateral (the bursting of the real estate bubble) can be modeled properly as a state of the world at time 1 in which $w_1^i$ is low for all $i$.

3. Because of the endogeneity of interest rates, if we had a third period in the model we could easily have the breakdown of credit markets: investors rationally expect borrowing at time 1 to be used to repay debtors at time 1 to then default at time 2.

4. Model market power in OTC markets - where large players also naturally observe part of the order flow.
5. When studying policy consider that the existence of centralized exchanges makes it less costly for government to time-inconsistently regulate market.

6. Model government bailout of *too-big-to-fail* positions in the context of an economy with a centralized exchange, to show that efficiency is compromised with such forbearance.

4 Conclusion

While we have focused on symmetric information about states of the world in our analysis of centralized versus over the counter markets, the model can be extended to relax this assumption. In particular, it is possible to add adverse selection to the model, e.g., in the form of unobservable probability distributions over $S$, the uncertainty states at time 1. The model would combine features of Rothschild and Stiglitz (1976) and Akerlof (1970), with separating equilibria in the economy in the economy with centralized exchanges and excessive *lemons* trading, in the form of risky short positions, in the case of OTC markets. It remains an important exercise for future to confirm that the relative inefficiency of OTC markets relative to centralized markets persists in this setting. Indeed, we conjecture that it will be exacerbated in a setting with adverse selection.

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*Santos and Scheinkman (2001) have adverse selection as well in their model of competition of exchanges.*
References


