An information-based theory of financial intermediation*

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Abstract

We advance a theory of intermediation that builds on private information and heterogeneous screening ability across market participants. We solve for the equilibrium market structure and show that investors with high screening ability are the largest intermediators: they are the most central in trade, they trade frequently, they trade with many different counterparties, and they extract high rents. We derive a set of testable predictions from the model and we test them using transaction-level micro data. Our empirical results provide evidence that our mechanism relying on private information and screening ability is a relevant feature of intermediation in over-the-counter markets.

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1 Introduction

Intermediation is a prevalent feature of how assets are traded in over-the-counter (OTC) financial markets. Assets tend to be reallocated through a sequence of bilateral transactions that involve institutions serving as intermediaries.[1] Understanding how decentralized asset markets function thus requires understanding the determinants of intermediation, and how these shape the OTC market structure. In this paper we build a theory of intermediation based on a key friction inherent in bilateral trade: market participants posses private information about their willingness to pay for assets. Further, we empirically test some key predictions of the theory using transaction-level micro-data for a market that trades over-the-counter.

The theory builds on Duffie, Garleanu, and Pedersen (2005) and Hugonnier, Lester, and Weill (2014) that model trade through random bilateral meetings between investors with heterogeneous valuations of the asset. We augment the theory in two important ways. First, we assume that an investor's valuation of the flow of dividends is private information. While there is common knowledge about the dividend process, each investor is unaware of the private value of their counterparty. For instance, in reality traders can agree about the risk an asset pays off, but still do not know of each others' hedging or liquidity needs. Second, we assume investors are heterogeneous in their ability to learn the private information of their trade counterparty, a technology we refer to as screening ability. Specifically, screening ability is the probability an investor learns the private information of their counterparty in a meeting before trade takes place. This feature is meant to capture that in reality institutions differ according to their level of financial expertise, one aspect of which is having better information about the trading motives of other market participants.

We then show that intermediation is tightly linked to screening ability. We define a concept of an investor's centrality in the market that measures the fraction

[1] A feature of these markets is that a large volume of the reallocation flows through the hands of a small set of institutions that comprise the "core" of the core-periphery market structure widely documented in the literature. For instance, a core-periphery structure exists in the market for municipal bonds (Green, Hollifield, and Schurhoff, 2007), the Fed funds market (Bech and Atalay, 2010), the asset-backed securities market (Hollifield, Neklyudov, and Spatt, 2017), and the corporate bond market (Maggio, Kermani, and Song, 2016), among others.

of trade volume that goes through the hands of a particular investor. We show that the most central investors —those who intermediate assets the most and form the core of the market— possess the highest screening ability. That is, the core of the trade network is populated by screening experts, while the periphery of the trade network is populated by non-screening experts. We also show that, relative to those with low screening ability, screening experts endogenously (i) trade more often, (ii) trade with a larger pool of investors, and (iii) enjoy higher profits from intermediation. Hence, our theory is consistent with other results in the literature about the determinants of core institutions. For instance, Uslu (2016) and Farboodi, Jarosch, and Shimer (2017) build theories where intermediaries are investors that possess a higher arrival rate of meetings, and thus trade more often. Nosal, Wong, and Wright (2014) and Farboodi, Jarosch, and Menzio (2017) build a theory where intermediaries are investors that possess superior bargaining power, providing them with high profits from intermediation. In Chang and Zhang (2015) intermediaries are investors with low volatility in their flow valuation and, as a result, trade with a larger set of counterparties. We also find that intermediaries are investors with intermediate flow valuation, a result consistent with Hugonnier, Lester, and Weill (2014) and Afonso and Lagos (2015) in models similar to ours, as well as Atkeson, Eisfeldt, and Weill (2015) who show that intermediaries tend to have intermediate risk exposure.[2] A notable distinction between our environment and those mentioned, and one that is relevant for our empirical analysis, is that the key friction driving intermediation activity is the information structure.

To understand the intuition for why screening experts are most central in intermediating assets, it is helpful to describe a few features of bilateral trade in partial equilibrium. Consider a meeting between a buyer and seller.We assume that one investor is randomly chosen to make a take-it-or-leave-it (TIOLI) offer in the form of a bid or ask price.[3] If the investor making the offer also observes the type of

[2]We are also related to the literature that model intermediation with explicit links between investors. Examples are Farboodi (2017), Babus and Kondor (2018) and Wang (2018).

[3] We show that TIOLI ask and bid prices are the solution to an optimal mechanism design problem that maximizes the respective profits of sellers and buyers (this is an application of Myerson (1981) to a dynamic general equilibrium setting). Additionally, we study mechanisms that maximize

their counterparty —determined by their screening ability— then they extract all of the surplus in trade. However if the investor is uninformed, as in Myerson (1981), they must set a distortive price that yields informational rents to their counterparty, which destroys some efficient trade. In partial equilibrium, since investors with high screening ability are less likely to resort to setting distortive prices, they endogenously have a higher probability of trade. As a result, they trade more often, with a larger array of counterparties, and gain higher profits than investors with a low screening ability. In other words, in partial equilibrium, higher screening ability implies a better trading technology. In general equilibrium, the intuition is more complicated. For instance, screening experts may find it profitable to wait to buy or sell an asset until they find a highly profitable opportunity. However, we show that the intuition from partial equilibrium survives when we consider general equilibrium effects. Screening experts trade faster as both buyers and sellers, and as a result, are most central in trade and populate the core of the market.

In the second part of the paper, we empirically test the primary result of the theory —that heterogeneity in information leads to differences in intermediation activity through determining who any individual market participant is most likely to directly engage in trade with— using transaction-level data on the OTC market for credit-default-swap (CDS) indexes. To do so, we derive testable implications from the model about the effects of information disclosure requirements. A subgroup of CDS index traders in our sample are required to file a 13-F form to the Securities and Exchange Commission (SEC). The form contains the holdings of all securities regulated by the SEC, which mostly consist of equities that trade on an exchange and equity options. The SEC then makes the 13-F form public immediately after its filed and so other market participants know detailed portfolio information about 13-F filers. We show that (i) CDS asset positions are small relative to the 13-F asset positions of these institutions and (ii) many institutions that file a 13-F do not trade CDS. Hence, we consider a 13-F filing as exogenous variation in the information the market posses about the institution's motives to trade CDS.

total surplus and obtain the same results.

In the context of the model, we assume that filing a 13-F (imperfectly) reveals a filers' private information at a known future date, a shock that is independent of the screening ability of the filer's counterparties. The model predicts that a 13-F filing has heterogeneous effects on trade with core versus periphery investors. Specifically, a 13-F filing discontinuously increases the probability of trade with the periphery, as once a filing occurs the periphery is more likely to know the filer's private valuation and are less likely to distort trade. However, a 13-F filing should have strictly less or no effect on trade with the core, as the model predicts that these investors already possess superior information. In other words, if the core is (at least in part) composed of institutions with better information, then information disclosure should effect these trades less than trades with the periphery.

We then test these predictions in our micro-data. We find that a 13-F filing increases an investor's probability of trade with the periphery in the week following a filing, but find either a zero or smaller increase in the probability of trade with the core. Our results are robust to controlling for different sets of fixed effects, across classes of CDS indexes, and across types of institutions. We also show that a 13-F filing increases trade probabilities only up to two weeks after a filing, but the effect vanishes in week three and beyond. Further, we show the effect is quantitatively smaller in more liquid markets as measured by total trade volume. This result is consistent with our model that posits that private information about own trade motives are less relevant in liquid markets (i.e. markets with high meeting rates). We conclude that these results are evidence that heterogeneity in information is an important determinant of shaping the structure of OTC markets.

The results in our paper follow a long tradition in economics of studying the role of information asymmetries in determining financial market outcomes. A recent literature, including Duffie, Malamud, and Manso (2009), Malamud and Rostek (2017), Babus and Kondor (2018), Golosov, Lorenzoni, and Tsyvinski (2014), Guerrieri and Shimer (2014), Lester, Shourideh, Venkateswaran, and Zetlin-Jones (2015), and Glode and Opp (2016), study information asymmetries in the context of decentralized asset markets. We differ from the majority of the papers in this literature in two ways. First, by considering asymmetric information about private values (information that only affects the individual payoff) as opposed to common values (information that affects the payoff of all agents in the economy).[4] Second, by focusing on how intermediation arises endogenously, while previous work studying the interaction of information and intermediation, typically assume exogenous market makers.[5]

2 Environment

Time is continuous and infinite. There is a measure one of infinitely-lived investors that discount the future at rate $r > 0$. There is transferable utility across investors. There is a supply of assets s. Each unit of the asset pays a unit flow of dividends. The dividend flow is common knowledge and non-transferable—only the investor holding an asset consumes its dividends. Investors can hold either zero or one unit of the asset. We refer to investors holding an asset as owners and those not holding an asset as non-owners.

Trade occurs in a decentralized, over-the-counter market in the style of Duffie et al. (2005). Investors contact each other with Poisson arrival rate $\lambda/2 > 0$. Meetings between two investors that are owners result in no trade: agents can hold at most one asset and since every asset has the same common value, there are no gains from simply exchanging assets. Likewise, meetings between two non-owner investors result in no trade. Only meetings between an owner investor and a non-owner investor involve gains from trade.

Investors are heterogeneous in two dimensions: they differ in their screening ability, α, and in the utility they derive from consuming the dividend flow of an asset, ν. When two investors meet, the screening ability α is public information, while the utility type ν is private information.[6] The screening ability α determines

[4] Exceptions are Duffie (2012) and Chang (2017) that consider both private and common values and Cujean and Praz (2015) and Zhang (2017) that consider private values, but do not study endogenous intermediation.

[5] An early example is Glosten and Milgrom (1985) who show, in the presence of adverse selection, market makers charge a positive bid-ask spread; a more recent example is Lester, Shourideh, Venkateswaran, and Zetlin-Jones (2018) who study the role of market-makers in the presence of adverse selection and search frictions.

[6] The results in this paper also hold if we assume that both α and ν are private information,

the probability by which an investor learns the utility type of its counterparty. As a result, ν can become public information within a meeting probabilistically. We let $\theta = (\alpha, \nu)$ denote the investor type. When two investors of types $\theta = (\alpha, \nu)$ and $\hat{\theta} = (\hat{\alpha}, \hat{\nu})$ meet, the investor with screening ability α learns $\hat{\nu}$ with probability α, and the investor with screening ability $\hat{\alpha}$ learns ν with probability $\hat{\alpha}$.[7]

Types are fixed over time, are independent across investors, and drawn from the cumulative distribution F. The distribution F has support $\Theta := \{\alpha^i\}_{i=1}^{I} \times \mathbb{R}$, which satisfies $0 \leq \alpha^1 < \alpha^2 < \ldots < \alpha^I = 1$, and density f that is continuous over ν. We assume that the screening ability α has finite support for technical reasons, but note that we can take the number of grid points, I, to be as large as we want. Further, we assume that F implies that α and ν are independent.

Assets mature and investors can produce new assets. An asset matures with Poisson arrival rate $\mu > 0$. When the asset matures, it disintegrates. With Poisson arrival rate $\eta > 0$, an investor faces an opportunity to issue a new asset at no cost. As a result of maturity and issuance, a steady state with positive trade emerges in our economy even without time-varying types, which are required for existence of a steady state with trade in Duffie et al. (2005) and much of the literature that followed. Adding time-varying types in our setup is straightforward but again would not add to our analysis. Thus, we do not incorporate this feature into the model.

To simplify the presentation, we assume that investors cannot freely dispose of assets. This assumption is without loss of generality when considering steady-state equilibria—since types are fixed, those investors that would dispose of an asset would not acquire it in the first place. Therefore, any steady-state allocation associated with equilibria without free disposal of assets can be supported by an

although we believe the current assumption is more realistic.

[7]A natural question is whether one investor knows what the other investor knows in the meeting—that is, what information is common knowledge. Say investors A and B meet, and A happens to learn the utility type of investor B. Does investor B know that A knows his type? And does A know if B knows what he knows? To keep it simple, we assume that the information structure (who knows what) is common knowledge. However, this assumption is without loss of generality. That is because whether an investor knows the utility type of the counterpart or not only informs the counterparty about the screening ability—there is no correlation between what an investor knows and his utility type. Since the screening ability of investors is public information, there is nothing to learn from whether an investor knows the utility type of the counterpart or not.

equilibria with free disposal.

3 Prices, value functions, and equilibrium

In this section, we study the optimal choice of prices, provide expressions for value functions, the distribution of assets among investors, define an equilibrium and prove its existence. We restrict attention to steady-state equilibria and do not include time t in the set of states of the economy. We denote the measures of owners and non-owners of type $\tilde{\theta} \leq \theta$ by $\Phi_o(\theta)$ and $\Phi_n(\theta)$. The measure of assets is given by construction as $s = \int d\Phi_o$. We denote the value function of an owner of type θ by $V_o(\theta)$ and the value function of a non-owner by $V_n(\theta)$. Finally, $\Delta(\theta) = V_o(\theta) - V_n(\theta)$ denotes the reservation value of an investor, which is the price that makes them indifferent between holding and not holding an asset. Whenever it is not ambiguous, we use Δ_o instead of $\Delta(\theta_o)$ and Δ_n instead of $\Delta(\theta_n)$.

3.1 Bilateral trade

As a result of private information, we cannot resort to Nash bargaining or similar protocols to determine the terms of trade. Instead, we assume that when an owner and a non-owner meet, they play a random dictator game. With probability ξ_o the owner makes a take-it-or-leave-it offer, with commitment, to the non-owner that takes the form of an ask price. Likewise, with probability $\xi_n = 1 - \xi_o$ the non-owner makes a take-it-or-leave-it offer, with commitment, to the owner that takes the form of a bid price. We assume that $\xi_o \in (0, 1)$, unless stated otherwise.

The random-dictator game has several nice properties. First, it seems realistic to imagine that in some markets/trades the seller sets the terms, while in other markets/trades the buyer sets the terms. Further, while imposing bid and ask prices may seem restrictive, we show in Appendices B.1 and B.2 that it is equivalent to a generic mechanism design problem where the owner and non-owner maximize their respective expected profits subject to individual rationality and incentive compatibility. That is, even when allowed to design complicated selling and buying mechanisms, take-it-or-leave-it bid and ask prices are indeed optimal. Alternatively, we could impose a mechanism that maximizes the total trade surplus in a meeting, in the spirit of Myerson and Satterthwaite (1983). In Appendix B.3, we study this case and obtain similar results regarding pricing schedules and thus also about the main implications of our theory of financial intermediation.

3.1.1 The optimal ask price

The choice of an ask price depends on whether or not the owner observes the utility type of the non-owner, which occurs with probability α_o, the screening ability of the owner. Since α_n is public information, when an owner observes the utility type of the non-owner, ν_n, they also know their reservation value, Δ_n. As long as there exists a positive trade surplus, i.e. $\Delta_n \geq \Delta_o$, the optimal ask price is the non-owner's reservation value Δ_n. Otherwise, the optimal ask price is the owner's own reservation value, Δ_o. It is straightforward to see how this is optimal. When $\Delta_n \geq \Delta_o$, the reservation value of the non-owner is the highest ask price that generates trade. When $\Delta_n < \Delta_o$, there is no price at which the owner would make positive profit and the non-owner would accept, so the owner is better off asking for her own reservation value and not trading. The non-owner's best response is to accept the offer whenever the ask price is smaller than or equal to her reservation value.

When the owner does not observe the utility type of the non-owner, he sets the ask price under private information. In this case, the optimal ask price solves

$$\max_{ask} \; obj_o(ask; \alpha_n) := [ask - \Delta_o] \left[1 - M_n(ask; \alpha_n)\right], \tag{1}$$

where α_n denotes the screening ability of the non-owner investor and $M_n(\tilde{\Delta}; \alpha_n) = \int \mathbb{1}_{\{\Delta(\theta) \leq \tilde{\Delta},\, \alpha = \alpha_n\}} d\Phi_n(\theta) / \int \mathbb{1}_{\{\alpha = \alpha_n\}} d\Phi_n(\theta)$ denotes the cumulative distribution of reservation values of non-owners with screening ability α_n. For a given ask, the measure $1 - M_n(ask; \alpha_n)$ of counterparties value the asset above the ask price and so accept the offer. If trade occurs, the owner receives the ask price and loses her reservation value Δ_o. It is worth noticing that problem (1) is analogous to a monopolist's profit maximization problem, where Δ_o is the marginal cost of production.

A solution to (1) exists under fairly simple conditions. For instance, the problem has a solution if and only if $M_n(\cdot; \alpha_n)$ has no mass points and finite second moments. We conjecture that a solution to this problem exists and label it $ask_o(\alpha_n)$.

Later, when proving existence of an equilibrium, we verify that the conjecture applies.[8] We omit the argument of the function $ask_o(\alpha_n)$ if it is not ambiguous.

Lemma 1 provides a useful result; the optimal ask price is strictly above the owner's reservation value whenever there are expected gains from trade. The proof of this Lemma and all proofs that will follow are available in Appendix A.

Lemma 1. *Consider the owner's reservation value Δ_o and a non-owner's screening ability α_n. If there is a positive measure of non-owners with screening ability α_n and reservation value above Δ_o, that is, $1 - M_n(\Delta_o; \alpha_n) > 0$, then ask_o is strictly above Δ_o.*

To provide intuition, suppose that $M_n(\cdot; \alpha_n)$ is differentiable, and consider an owner that sets an ask price equal to their reservation value, $ask = \Delta_o$. The derivative of the objective function in (1) evaluated at $ask = \Delta_o$ is given by $\frac{\partial obj_o(\Delta_o, \alpha_n)}{\partial ask} = 1 - M_n(\Delta_o; \alpha_n)$. If $1 - M_n(\Delta_o; \alpha_n) > 0$, the expected gains from trade are positive and the owner strictly prefers to set an ask price at a markup above her own reservation value. At the margin, the owner benefits from asking more for the asset than what it is worth to her. As a result of private information, there exists a measure of non-owners, $M_n(ask_o; \alpha_n) - M_n(\Delta_o; \alpha_n)$, that have reservation value above the owner's but do not buy the asset. The next Corollary formalizes this result.

Corollary 1. *Consider a reservation value of owners Δ_o and a non-owner's screening ability α_n. If there exists $\bar{\epsilon} > 0$ such that $M_n(\Delta_o + \epsilon; \alpha_n) - M_n(\Delta_o; \alpha_n) > 0$ for all $\epsilon \in (0, \bar{\epsilon})$, then with positive probability the non-owner has a higher reservation value than the owner and they still do not trade—that is, $M_n(ask_o - \epsilon; \alpha_n) - M_n(\Delta_o; \alpha_n) > 0$ for some $\epsilon > 0$.*

Corollary 1 implies that trade is inefficient under private information in general equilibrium. The measure of trades that do not occur—those where the non-owner's reservation value Δ_n is above Δ_o and below the ask price—are efficient trades that are destroyed due to private information. This distortion does not arise when the

[8] If it happens that problem (1) has multiple solutions, we let $ask_o(\alpha_n)$ be the lowest ask price that solves (1).

owner observes the type of her counterparty and, as a result, it does not show if we were to assume complete information about θ.

The impossibility of efficient trade under private information (and other technical conditions) is a well-known negative result from Myerson and Satterthwaite (1983), where the distributions, M_n and M_o, are exogenous. Here, these distributions are general equilibrium objects, but the same intuition applies.

3.1.2 The optimal bid price

The optimal bid price follows closely to the optimal ask price. A non-owner observes the utility type of the owner with probability α_n, the screening ability of the non-owner. In this case, the optimal bid price is the owner's reservation value if $\Delta_o \leq \Delta_n$, and the non-owner's reservation value, Δ_n, otherwise. When $\Delta_o \leq \Delta_n$, the non-owner extracts the entire surplus by setting the bid at the lowest possible value such that trade occurs. The owner's best response is to accept the offer whenever the bid price is larger than or equal to her reservation value Δ_o.

When the non-owner does not observe the type of the owner, and therefore only knows the counterparty screening ability, she sets a bid price under private information. In this case, the optimal bid price solves

$$\max_{bid} obj^n(bid;\alpha_o) := [\Delta_n - bid]\, M_o(bid;\alpha_o), \tag{2}$$

where $M_o(\tilde{\Delta};\alpha_o) = \int \mathbb{1}_{\{\Delta(\theta)\leq\tilde{\Delta},\ \alpha=\alpha_o\}} d\Phi_o(\theta) / \int \mathbb{1}_{\{\alpha=\alpha_o\}} d\Phi_o(\theta)$ denotes the cumulative distribution of reservation values of owners with screening ability α_o. For a given bid, the measure $M_o(bid;\alpha_o)$ of owners that are trade counterparties with screening ability α_o accepts the offer and sell the asset to the non-owner. When the non-owner buys the asset, she gains her reservation value Δ_n and pays the bid price. As before, a solution to (2), which we label $bid_n(\alpha_o)$, exists in equilibrium. [9] We omit the argument of the function $bid_n(\alpha_o)$ if it is not ambiguous.

Whereas the optimal ask price under private information is a markup over the reservation value of the owner, the opposite is true for the optimal bid price.

Lemma 2. *Consider a non-owner's reservation value Δ_n and an owner's screening*

[9] If the problem has multiple solutions, we let $bid_n(\alpha_o)$ be the highest bid price that solves 2.

ability α_o. If there is a positive measure of owners with screening ability α_o and reservation value strictly below Δ_n, that is, $lim_{\Delta \nearrow \Delta_n} M_o(\Delta;\alpha_o) > 0$, then bid_n is strictly below Δ_n.

Asset non-owners set a markdown under their reservation value when buying the asset. As a result, owners with reservation value below Δ_n and above the bid, will not sell the asset to the non-owner; private information destroys bilaterally efficient trades. The next corollary formalizes this result.

Corollary 2. *Consider a reservation value of non-owners Δ_n and a owner's screening ability α_o. If there exists $\bar{\epsilon} > 0$ such that $M_o(\Delta_n;\alpha_o) - M_o(\Delta_n - \epsilon;\alpha_o) > 0$ for all $\epsilon \in (0, \bar{\epsilon})$, then with positive probability the non-owner has a higher reservation value than the owner and they still do not trade—that is, $M_o(\Delta_n - \epsilon;\alpha_o) - M_o(bid_n;\alpha_o) > 0$ for some $\epsilon > 0$.*

3.2 Expected gains from trade

The expected gains from trade in a meeting of an owner of type θ_o are given by

$$\pi_o(\theta_o) = \xi_o \int \alpha_o \left(\Delta_n - \Delta_o\right) \mathbb{1}_{\{\Delta_n \geq \Delta_o\}} + (1-\alpha_o)\left(ask_o - \Delta_o\right) \mathbb{1}_{\{\Delta_n \geq ask_o\}} d\frac{\Phi_n(\theta_n)}{1-s} + \xi_n \int (1-\alpha_n)\left(bid_n - \Delta_o\right) \mathbb{1}_{\{bid_n \geq \Delta_o\}} d\frac{\Phi_n(\theta_n)}{1-s}, \tag{3}$$

and the expected gains from trade in a meeting of a non-owner of type θ_n are given by

$$\pi_n(\theta_n) = \xi_n \int \alpha_n \left(\Delta_n - \Delta_o\right) \mathbb{1}_{\{\Delta_n \geq \Delta_o\}} + (1-\alpha_n)\left(\Delta_n - bid_n\right) \mathbb{1}_{\{bid_n \geq \Delta_o\}} d\frac{\Phi_o(\theta_o)}{s} + \xi_o \int (1-\alpha_o)\left(\Delta_n - ask_o\right) \mathbb{1}_{\{\Delta_n \geq ask_o\}} d\frac{\Phi_o(\theta_o)}{s}. \tag{4}$$

Let us providing some intuition on these equations. Consider (3), which accounts for the expected profits of an owner in a meeting. The first term accounts for the expected profits when the owner is selected to make the offer, which occurs with probability ξ_o. In this case, with probability α_o the owner is informed about the utility type of her counterparty and uninformed otherwise. When she is informed, the owner trades with any non-owner with reservation value larger than Δ_o and receives the entire trade surplus, $\Delta_n - \Delta_o$. When she is uninformed, the owner sets an ask price under private information and gets expected profits according to (1). The second term in (3) accounts for the expected profits when the non-owner is selected to make the offer, which occurs with probability ξ_n. In this case, the owner only receives positive profits if (i) her trade counterparty is uninformed about her utility type, which occurs with probability $1 - \alpha_n$, and (ii) her reservation value is is below the optimal bid price of the non-owner. Otherwise, whenever the non-owner is informed about the utility type of the owner, the non-owner extracts the entire gains from trade. Finally, notice that the owner takes expectations over the endogenous distribution of non-owners, $\Phi_n(\theta_n)/(1-s)$. The expected gains from trade in a meeting of a non-owner of type θ_n, presented in (4), follow analogously to (3).

3.3 Value functions and reservation value

The value function of an owner of a type θ is given by

$$rV_o(\theta) = \nu - \mu\big[V_o(\theta) - V_n(\theta)\big] + \lambda(1-s)\pi_o(\theta). \tag{5}$$

This equation states that the value of owning an asset, discounted at rate r, equals the sum of three terms. The first term accounts for the flow utility of holding the asset, ν. The second term accounts for the change in value when the asset matures and the owner becomes a non-owner, which occurs at rate μ. The third term accounts for the expected profits of an owner when meeting a non-owner; the probability that two investors meet is given by $2\lambda/2 = \lambda$ and, conditional on meeting, the owner contacts a non-owner with probability $(1-s)$.

The value function for a non-owner of type θ is,

$$rV_n(\theta) = \eta\big[\max\{V_o(\theta), V_n(\theta)\} - V_n(\theta)\big] + \lambda s \pi_n(\theta). \tag{6}$$

The value of not owning an asset, discounted at rate r, equals the sum of two terms. The first term accounts for the value of receiving an issuance opportunity, which arrives at rate η. Conditional on receiving an issuance opportunity, the non-owner decides whether it is optimal to produce the asset and become an owner, or to not produce and remain a non-owner. The second term accounts for the expected profits of a non-owner in bilateral trade, where a meeting occurs with an owner at rate λs.

Finally, using (5)-(6) we can compute the reservation value for an investor of type θ, $\Delta(\theta) \equiv V_o(\theta) - V_n(\theta)$. The reservation value $\Delta(\theta)$ solves

$$r\Delta(\theta) = \nu - \mu\Delta(\theta) - \eta \max\{\Delta(\theta), 0\} + \lambda(1-s)\pi_o(\theta) - \lambda s \pi_n(\theta). \tag{7}$$

3.4 The distribution of assets

The change over time in the measure of owners of type θ is

$$\dot{\phi}_o(\theta) = \eta\phi_n(\theta)\mathbb{1}_{\{\Delta(\theta)\geq 0\}} - \mu\phi_o(\theta) - \lambda\phi_o(\theta)\bar{q}_o(\theta) + \lambda\phi_n(\theta)\bar{q}_n(\theta), \tag{8}$$

where the probability that an owner of type θ sells an asset in a meeting is

$$\bar{q}_o(\theta) = \int q(\theta, \theta_n)\phi_n(\theta_n)d\theta_n, \tag{9}$$

the probability that a non-owner of type θ buys an asset in a meeting is

$$\bar{q}_n(\theta) = \int q(\theta_o, \theta)\phi_o(\theta_o)d\theta_o \tag{10}$$

and

$$q(\theta_o, \theta_n) = \mathbb{1}_{\{\Delta_n \geq \Delta_o\}} - \xi_o(1-\alpha_o)\mathbb{1}_{\{ask_o > \Delta_n \geq \Delta_o\}} - \xi_n(1-\alpha_n)\mathbb{1}_{\{\Delta_n \geq \Delta_o > bid_n\}} \tag{11}$$

is the probability of trade between a type θ_o owner and a type θ_n non-owner.

The first term on the right-hand side of (8) accounts for the inflow of non-owner investors of type θ that become owners because they receive an issuance opportunity and find it worthwhile to produce the asset. The second term accounts for the outflow of owners of type θ because of asset maturity. The third term accounts for the outflow of owners of type θ that sell their asset. The fourth term accounts for the inflow of non-owners of type θ that buy an asset. A steady-state equilibrium satisfies $\dot{\phi}_o(\theta) = 0$ for all θ.

Since the measure of types, $f(\theta)$, is exogenous, we can obtain an expression for the measure of non-owners from the following equilibrium condition,

$$\phi_o(\theta) + \phi_n(\theta) = f(\theta). \tag{12}$$

Finally, since all assets in the economy are held by owners, total asset supply is given by

$$s = \int \phi_o(\theta) d\theta. \tag{13}$$

3.5 Equilibrium

We focus on symmetric steady-state equilibria.

Definition 1. *A family of bid and ask price functions, reservation values and distributions,* $\{bid_n, ask_o, \Delta, \phi_o, \phi_n, s\}$*, constitutes a symmetric steady-state equilibrium if it satisfies: (i) the ask price function,* ask_o*, solves the owner's problem* (1)*, and the bid price function,* bid_n*, solves the non-owner's problem* (2)*; (ii) investors' reservation value,* Δ*, is continuous on* ν *and satisfies* (7)*, where* π_o *and* π_n *are given by* (3) *and* (4)*; and (iii) the density of owners,* ϕ_o *satisfies* (8) *with* $\dot{\phi}_o = 0$*, the density of non-owners,* ϕ_n*, satisfies* (12)*, and the stock of assets,* s*, satisfies* (13)*.*

Notice that the equilibrium definition does not include the value functions V_o and V_n because we can recover them from (5) and (6). The next Proposition guarantees that an equilibrium exists in the economy, and further, that imposing trade using bid and ask prices is not restrictive.

Proposition 1. *There exists a symmetric steady-state equilibrium, with bid and ask prices associated with optimal buying and selling mechanisms.*

Proving existence of an equilibrium in this economy is not straightforward. In partial equilibrium, existence of optimal bid and ask prices in (1) and (2) require conditions on the equilibrium objects ϕ_o, ϕ_n and Δ. However, these objects are themselves determined by optimal bid and ask prices. Hence, there is no guarantee that there exists operator that maps the space of well-behaved equilibrium objects into itself and, as a result, we cannot invoke standard fixed-point arguments. Instead, we show existence by constructing a well-behaved polynomial approximation to the operator and show there exists a fixed point for any finite degree of polynomials. Then, we invoke the Arzelà-Ascoli theorem to show there exists a convergent sub-sequence of the fixed points as the degree of polynomials goes to infinity.

4 Intermediation

In this section we study intermediation, or the process by which assets flow from low-value owners to high-value non-owners. We begin in subsection 4.1 by showing that the speed at which an investor trades is related to her screening ability. In subsection 4.2 we study how the value of intermediation relates to screening ability and we study how screening ability shapes the average return from buying and selling assets, i.e. the bid-ask spread. In subsection 4.3, we use insights from the previous subsections to argue that screening experts— those with the highest α—are the most central in trade and therefore serve as intermediaries. Finally, in subsection 4.4 we study the relationship between screening ability and the number of distinct trade counterparties.

4.1 Trade speed

Intermediation has been linked to higher trade speed at least since Rubinstein and Wolinsky (1987), that modeled heterogeneity in trade speed through heterogeneity in the exogenous arrival rate of trading opportunities. Recent empirical findings on the importance of intermediation in OTC financial markets motivated a series of papers building on their insights. Some examples are Nosal, Wong, and Wright (2014), Uslu (2016) and Farboodi, Jarosch, and Shimer (2017).

In our model, investors do not differ in trading speed as a result of heterogeneity in their meeting rate, λ. Rather, differences in trading speed are a result of endogenous heterogeneity in the probability of trade, conditional on a meeting. These differences follow from the fact that investors differ in their screening ability. In this section we show that, conditional on a reservation value Δ, investors with higher screening ability α have a higher trade probability within a meeting and, as a result, a higher trading speed. This result provides us with the first step towards understanding why screening experts –those with high α– are most central in trade. The next proposition provides the result that relates trade probabilities and screening ability of investors.

Proposition 2. *Consider a symmetric steady-state equilibrium* $\{bid_n, ask_o, \Delta, \phi_o, \phi_n, s\}$, *and let types $\theta = (\alpha, \nu)$ and $\hat{\theta} = (\hat{\alpha}, \hat{\nu})$ satisfy $\Delta(\theta) = \Delta(\hat{\theta})$ and $\alpha > \hat{\alpha}$. Then the probability of trade of an owner and non-owner satisfy, (i) $\bar{q}_o(\theta) > \bar{q}_o(\hat{\theta})$, and (ii) $\bar{q}_n(\theta) \geq \bar{q}_n(\hat{\theta})$, with strict inequality if $\Delta(\theta) = \Delta(\hat{\theta}) > 0$.*

Part (i) of proposition 2 states that for a given meeting, and conditional on the reservation value Δ, the probability that an owner sells an asset is increasing in her screening ability. Likewise, part (ii) of the proposition states that for a given meeting, and conditional on the reservation value Δ, the probability that a non-owner buys an asset is increasing in her screening ability. We emphasize that Proposition 2 does not rely on any condition on the distribution of reservation values—such as those used in Lemmas 1 and 2. Those conditions are satisfied in equilibrium.

The speed at which investors trade follows from Proposition 2. Define an owner's trading speed as $speed_o(\theta) = \lambda\bar{q}_o(\theta)$, and a non-owner trading speed as $speed_n(\theta) = \lambda\bar{q}_n(\theta)$, the contact rate times the probability of trade in a meeting.

Corollary 3. *Consider a symmetric steady-state equilibrium $\{bid_n, ask_o, \Delta, \phi_o, \phi_n, s\}$, and let the types $\theta = (\alpha, \nu)$ and $\hat{\theta} = (\hat{\alpha}, \hat{\nu})$ satisfy $\Delta(\theta) = \Delta(\hat{\theta})$ and $\alpha > \hat{\alpha}$. Then, (i) $speed_o(\theta) > speed_o(\hat{\theta})$, and (ii) $speed_n(\theta) \geq speed_n(\hat{\theta})$, with strict inequality if $\Delta(\theta) = \Delta(\hat{\theta}) > 0$.*

That is, in our model there is heterogeneity in trading speed, even though investors share the same Poison meeting rate λ. Furthermore, heterogeneity in trading speed is linked to heterogeneity in screening ability: higher screening ability implies higher trading speed.

4.2 Intermediation rents and reservation values

An object of interest when studying intermediation is the relationship between intermediation and the rents extracted by those intermediating. For example, Farboodi et al. (2017) advance a theory of intermediation centered on the ability to extract rents. In their model, investors with high bargaining power buy assets from investors with low bargaining power since they can extract more rents when selling the asset. As a result, investors with high bargaining power act as intermediaries, extract more rents, and gain higher profits from trade.

In our theory, as we shall see later on, investors with high screening ability act as intermediaries. Relative to investors with low screening ability, investors with high screening ability are more likely to observe the valuation of their trade counterparty and thus less likely to concede informational rents when trading. As a result, investors with high screening ability endogenously extract more rents than investors with low screening ability. The following proposition formalizes this result.

Proposition 3. *Consider a symmetric steady-state equilibrium* $\{bid_n, ask_o, \Delta, \phi_o, \phi_n, s\}$, *and let types* $\theta = (\alpha, \nu)$ *and* $\hat{\theta} = (\hat{\alpha}, \hat{\nu})$ *satisfy* $\Delta(\theta) = \Delta(\hat{\theta})$ *and* $\alpha > \hat{\alpha}$. *Then, (i)* $\pi_o(\theta) > \pi_o(\hat{\theta})$, *and (ii)* $\pi_n(\theta) \geq \pi_n(\hat{\theta})$, *with strict inequality if* $\Delta(\theta) = \Delta(\hat{\theta}) > 0$.

That is, if two investors have the same reservation value for an asset but differ in their screening ability, the one with higher screening ability extracts more rents when trading, either as a buyer or a seller. In general equilibrium, screening ability affects expected profits, which determine investors' valuation for assets. To see this in greater detail, rewrite (7) as

$$\Delta(\theta) = \underbrace{\frac{\nu}{r + \mu + \eta \mathbb{1}_{\{\Delta(\theta) \geq 0\}}}}_{\substack{\text{fundamental} \\ \text{value}}} + \underbrace{\frac{\lambda(1-s)\pi_o(\theta)}{r + \mu + \eta \mathbb{1}_{\{\Delta(\theta) \geq 0\}}}}_{\substack{\text{option value} \\ \text{to sell}}} - \underbrace{\frac{\lambda s \pi_n(\theta)}{r + \mu + \eta \mathbb{1}_{\{\Delta(\theta) \geq 0\}}}}_{\substack{\text{option value} \\ \text{to buy}}}.$$

This equation decomposes the reservation value into three components. The first component represents the fundamental value of holding an asset, the discounted utility of the dividend payoff, ν. The second component represents the gain in value that follow from becoming an owner and gaining the option value to sell the asset. The third component represents the loss in value that follow from becoming an owner and losing the option value to buy the asset. Investors discount the three components by the discount rate, r, the depreciation rate, μ, and the opportunity rate of new issuance $\eta \mathbb{1}_{\{\Delta(\theta) \geq 0\}}$. We call the term $r + \mu + \eta \mathbb{1}_{\{\Delta(\theta) \geq 0\}}$ the effective discount rate of a type θ investor.

From Proposition 3, the expected profits from trade when selling and buying an asset, $\pi_o(\theta)$ and $\pi_n(\theta)$, are increasing in the investors screening ability. However, they enter the reservation value with opposite sign; larger expected profits when selling increases the reservation value of owning an asset while larger expected profits when buying decreases the reservation value of owning an asset. As a result, the reservation value can be increasing or decreasing in screening ability depending which term is larger. The next proposition provides some useful insights on how screening ability affects the reservation value.

Proposition 4. *Consider a symmetric steady-state equilibrium* $\{bid_n, ask_o, \Delta, \phi_o, \phi_n, s\}$. *The following holds: (i) If* $\xi_o = 1$*, then* $\Delta(\theta)$ *is strictly increasing in* α*, and (ii) if* $\xi_n = 1$*, then* $\Delta(\theta)$ *is decreasing in* α*, and strictly decreasing if* $\Delta(\theta) > 0$.

Case (i) considers the scenario where the owner of the asset sets the terms of trade. In this case, the screening ability of an investor only affects expected profits when selling. When this investor is a non-owner, she only receives profits through informational rents, which do not depend on the non-owner's screening ability. As a result, the reservation value is increasing in screening ability α. Case (ii) considers what happens when, in every trade meeting, it is only the non-owner who is selected to make the offer. In this case, an investor's screening ability only affects the expected profits when buying an asset, and thus reservation values are decreasing in screening ability α. A natural implication of this proposition is that for intermediate values of ξ_o and ξ_n, reservation values can be increasing or decreasing in α.

In our environment, reservation values shape up bid-ask spreads. Bid-ask spreads are a common measure of investors' market power in OTC markets. One may expect the more important, or central, an investor is in intermediation, the larger spread they should obtain. However, empirical evidence suggests that the relationship between spreads and centrality in OTC markets is ambiguous. For instance, in the municipal bond market, Li and Schürhoff (2014) find that central investors charge higher bid-ask spreads than those not central, but in the corporate bond market or in the market for asset-backed securities, Maggio et al. (2016) and Hollifield et al. (2017), respectively, find no relationship.

Our theory suggests that examining bid-ask spreads may be a misleading measure of an investor's market power. Screening experts in our model extract more rents when trading, however they do not necessarily have higher bid-ask spreads.

For example, consider the choice of an ask price. If an owner knows the utility type of the non-owner, her expected ask price is the expected non-owner's reservation value, conditional on positive gains from trade, $\Delta_n \geq \Delta_o$. If the owner does not know the utility type of the non-owner, then the expected ask price is ask_o, conditional on $\Delta_n \geq ask_o$. Since $ask_o > \Delta_o$, there are some trades that occur under complete information at a lower price than under incomplete information. Hence, depending on the shape of the distribution of non-owners', an informed owner can expect to sell at a lower price than an uninformed owner.

The same result applies for the bid price, but in the opposite direction; an informed non-owner could buy at a larger bid relative to an uninformed non-owner. Hence, even if informed investors obtain a larger share of the surplus than uninformed ones, bid-ask spreads may not reflect this.

4.3 Centrality

In this section, we study how screening ability endogenously shapes the market structure of the economy. Specifically, we characterize an investor's trade centrality (or just centrality to keep it short), which measures how much the investor engages in buying and selling assets. Given the expected probability of trade as an owner and non-owner presented in (9)-(10), i.e. $\bar{q}_o(\theta)$ and $\bar{q}_n(\theta)$, we define centrality as

$$c(\theta) = \frac{\lambda}{2Vol} \times \frac{\phi_o(\theta)\bar{q}_o(\theta) + \phi_n(\theta)\bar{q}_n(\theta)}{f(\theta)}, \tag{14}$$

where $Vol = \lambda \int \int q(\theta_o, \theta_n) d\Phi_o(\theta_o) d\Phi_n(\theta_n)$ is total trade volume. Centrality measures the extent an investor of type θ accounts for total trade volume, either when buying or selling assets. Notice that $\int c(\theta) f(\theta) d\theta = 1$.

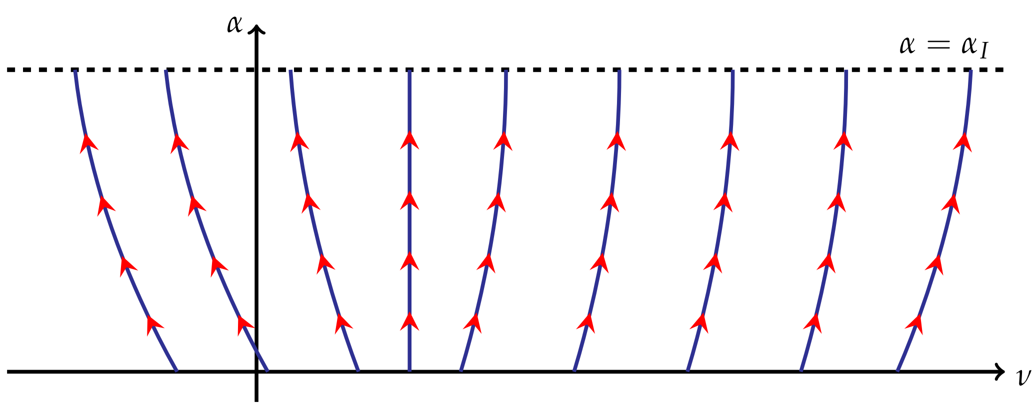
The following proposition establishes that, if two investors have the same reservation value for an asset, the investor with superior screening ability is more central.

Proposition 5. *Consider a symmetric steady-state equilibrium* $\{bid_n, ask_o, \Delta, \phi_o, \phi_n, s\}$, *and let the types* $\theta = (\alpha, \nu)$ *and* $\hat{\theta} = (\hat{\alpha}, \hat{\nu})$ *satisfy* $\Delta(\theta) = \Delta(\hat{\theta})$ *and* $\alpha > \hat{\alpha}$. *Then, (i) if* $\Delta(\theta) = \Delta(\hat{\theta}) < 0$, *we have that* $c(\theta) = c(\hat{\theta}) = 0$, *and (ii) if* $\Delta(\theta) = \Delta(\hat{\theta}) \geq 0$, *we have that* $c(\theta) > c(\hat{\theta}) > 0$.

Figure 1 illustrates the results in Proposition 5. The figure shows the level curves of the reservation value in a two-dimensional graph with the utility type ν on the horizontal axis and screening ability α on the vertical axis. For a given level curve, the red arrows indicate the direction in which centrality increases: for a given reservation value, the higher the screening ability α, the higher the centrality.

Notice that the level curves of the reservation value can be upward or downward sloping. Reservation values are always increasing in utility type ν because it represents the flow value of holding an asset. However, the effect of increasing screening ability α depends on the level of ν. When ν is high, investors are typically buyers as it is very costly for them to give up the utility stream ν that follows from holding an asset. For those investors, the change in α needed to keep their reservation value constant must decrease the difference between the option value of selling an asset relative to buying an asset, as can be seen in (**??**). The option value of selling an asset barely moves with α when ν is high (as the measure of potential buyers is very small), while the option value of buying can be increased by providing higher rents to the investor when buying, which requires increasing α (as the value of potential sellers is very high). This explains why the level curves are upward sloping for high values of ν. When ν is low, a similar argument explains why the level curves are downward sloping.

Figure 1: Reservation value level curves



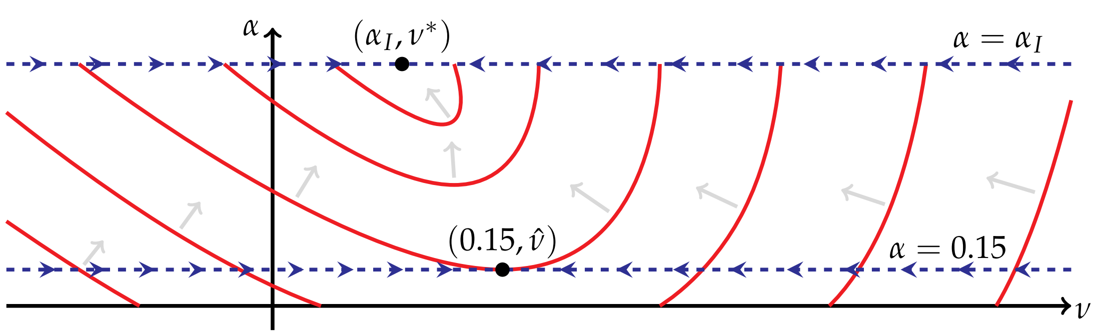
Notes: The figure presents reservation value level curves –i.e. $\Delta(\theta) = \tilde{\Delta}$– as a function of asset valuation ν and screening ability α. Each blue line represents a different level curve. The red arrows represent the direction by which centrality increases, for a given reservation value level curve.

Definition 1. *An investor type θ^* is the most central if $c(\theta^*) \geq c(\theta)$ for all $\theta \in \Theta$.*

Investors with the highest screening ability, $\alpha = \alpha_I$, maximize trade centrality keeping the reservation value constant. It does not mean, however, that all investor types with $\alpha = \alpha_I$ are the most central. The utility type of the investor also determines centrality. Investors with low ν have a high opportunity cost of buying an asset and hold it until the chance of selling it, which implies a low reservation value. Investors with high ν have a high cost of selling an asset and wait until the chance of buying another asset, which implies a high reservation value. Investors with too-low or too-high a reservation value are not central—it is either unlikely for them to find an owner with a lower reservation value to buy from or it is unlikely to find a non-owner with a higher reservation value to sell to. This point has been made by Hugonnier et al. (2014) in a model similar to ours but with complete information; the investor who is more central to trade has an intermediate value of ν. If screening ability, α, is fixed in our environment, the result is similar, but we also show that the most central investor must have screening ability $\alpha = \alpha_I$.

Proposition 6. *Consider a symmetric steady-state equilibrium* $\{bid_n, ask_o, \Delta, \phi_o, \phi_n, s\}$. *If an investor type* $\theta^* = (\alpha^*, \nu^*)$ *is the most central, then* $\alpha^* = a_I$ *and* $c(\theta^*) > c(\theta)$ *for all* $\theta \in \Theta$ *satisfying* $\alpha < a_I$.

Figure 2: Trade centrality level curves



Notes: The figure presents trade centrality level curves –i.e. $c(\theta) = \tilde{c}$– as a function of asset valuation ν and screening ability α. The gray arrows show the direction by which the level curves increase. The arrows over the blue dotted lines show, for a given value of α, how centrality increases with ν. Finally, centrality is maximized at (α_I, ν^*).

Figure 2 illustrates the results in Proposition 6. It shows the level curves of centrality in a two-dimensional graph, with screening ability α and utility type ν. For a given value of the screening ability, α, centrality behaves similar to Hugonnier et al. (2014). For example, consider the level of $\alpha = 0.15$ as displayed in the figure. For this value of α, centrality is maximized at certain intermediate value, $\hat{\nu}$. However, using the result in Proposition 5, if we consider investors with $\alpha' > \alpha$ and reservation value $\Delta(0.15, \hat{\nu})$, we can get investors with higher centrality. We can iterate this result until we get to the maximum level of screening ability $\alpha = \alpha_I$. Hence, the most central investor must have the highest screening ability and also have centrality strictly higher than any other investor with ability $\alpha < 1$.

Not only does the most central investor have screening ability $\alpha = \alpha_I$, but all investors above a certain centrality threshold do as well.

Proposition 7. *Consider a symmetric steady-state equilibrium* $\{bid_n, ask_o, \Delta, \phi_o, \phi_n, s\}$ *and define* $\underline{c} := \frac{1}{2}\sup_{\theta \in \Theta}\{c(\theta)\} + \frac{1}{2}\sup_{\theta \in \Theta}\{c(\theta);\ s.t.\ \alpha \leq \alpha_{I-1}\}$. *Then,* $\alpha = \alpha_I$ *for all investors type* $\theta = (\alpha, \nu) \in \Theta$ *such that* $c(\theta) \geq \underline{c}$.

Proposition 7 implies that the core group of investors in an OTC are all experts with the highest screening ability. We call the investors satisfying the condition $c(\theta) \geq \underline{c}$ in Proposition 7 as the core. They are the top-p investors in terms of centrality, where $p := \int \mathbb{1}_{\{c(\theta) \geq \underline{c}\}} dF$.

4.4 Trade network

Several papers studying financial trade networks, such as Green, Hollifield, and Schurhoff (2007), Bech and Atalay (2010) and Hollifield, Neklyudov, and Spatt (2017), document that central traders not only have a large share of trade volume but also trade with a larger set of investors. A natural question then, in the context of our theory, is if investors with high screening ability also trade with a larger number of counterparties. The number of counterparties of an investor of type θ is

$$np(\theta) = \int \left[\mathbb{1}_{\{q(\theta,\hat{\theta})>0\}} + \mathbb{1}_{\{q(\hat{\theta},\theta)>0\}}\right] dF(\hat{\theta}). \tag{15}$$

The function $np(\theta)$ captures the number (or more precisely, the measure) of counterparties that an investor of type θ trades with—either as a seller, $q(\theta, \hat{\theta}) > 0$, or as a buyer, $q(\hat{\theta}, \theta) > 0$. It is easy to show that, if an investor type θ has positive probability to trade with every other investor type, then $np(\theta) = 1$.

To simplify the analysis, for the remaining of this section we focus on one parametric case of our environment.

Assumption 1. *There are only two screening abilities,* $\alpha_h = 1$ *and* $\alpha_l < 1$.

We call investors with screening ability α_h experts and investors with screening ability α_l non-experts. The following proposition shows that experts trade with a larger set of counterparties, or in other words, have a larger trade network.

Proposition 8. *Consider a symmetric steady-state equilibrium* $\{bid_n, ask_o, \Delta, \phi_o, \phi_n, s\}$ *and some investor type* $\theta \in \Theta$ *such that* $\Delta(\theta) > 0$. *Under assumption 1, we have that* $np(\theta) = 1$ *if, and only if,* $\alpha = \alpha_h = 1$.

In Proposition 8, we only consider types with positive reservation value because they are the ones that are active in the economy—investors with negative reservation value do not hold or trade assets in equilibrium. Among the investors with positive reservation value, an investor trades with every other investor type if, and only if, he is a screening expert (has screening ability $\alpha = \alpha_h = 1$). Non-experts distort trade due to the private information they face when trading. Therefore, they do not trade with some other investors, resulting in a $np(\theta) < 1$. As a result, our theory is able to accommodate the result that those investors that populate the core of the trade network have a larger network of trade counterparties.

5 Empirical validation

The central feature of our theory is that heterogeneity in private information shapes the market's structure by influencing the probability of trade. All else equal, experts—investors who are more likely to know the trading needs of their counterparties — trade faster. As a result, experts form the core of the market and serve as natural intermediaries in trade. In this section, we test these predictions using trade data on credit default swaps (CDS) and regulatory reports of financial holdings.

Our strategy to test the model is the following. A subgroup of investors, which includes managers from banks, insurance companies, broker-dealers, pension funds, and corporations, are required to file a 13-F form to the Securities and Exchange

Commission (SEC). The form contains the holdings of all securities regulated by the SEC, which mostly consist of equities that trade on an exchange and equity options, but also shares of closed-end investment companies and certain debts. The SEC makes the 13-F form public immediately after its filed, and hence market participants know detailed portfolio information about 13-F filers.

We then study how a 13-F filing impacts an investor's probability of trade with core versus periphery counterparties in the OTC market for CDS. Since CDS are a primary way for institutions to hedge against risk in their portfolio, we interpret a 13-F filing as (imperfectly) revealing information about an investor's trading needs in the CDS market. This interpretation is supported both theoretically and empirically. For instance, the seminal model of Merton (1974) illustrates that a firm's credit spreads and equity prices are fundamentally linked through the firm's optimal choice of capital structure. Hence, if credit and equity assets have correlated returns, then the demand for an asset written on a firm's credit (e.g. CDS) is correlated with the holdings of their equity (which 13-F reports reveal). Empirically, a series of papers have found evidence of correlated debt and equity returns.[10]

5.1 Model predictions about the effects of a 13-F filing

Before moving to the empirical tests, we first develop a set of theoretical predictions about the effects of a 13-F filing on an individual investor's probability of trade with core versus periphery investors, summarized in Proposition 9. To this end, consider the baseline model above, but suppose a randomly-selected investor, which we label a 13-F investor, has to publicly reveal information about their type at a particular known, future filing date, $T > 0$. All investors know the identity of the 13-F investor, but not their type.

We assume the filing date is known beforehand by all investors since, in the data, institutions who file tend to file every quarter and the filing rules governed by the SEC are common knowledge among market participants. Since we are interested in the effects of filing for an individual investor, the equilibrium conditions from

[10] A few examples are Campbell and Taksler (2003), Blanco, Brennan, and Marsh (2005), Longstaff, Mithal, and Neis (2005), Zhang, Zhou, and Zhu (2009) and Forte and Pena (2009).

Definition 1 remain unchanged except for the reservation value of the 13-F investor, which accounts for them revealing information about their type at date T.

We assume the information revealed by filing a 13-F is imperfect, in the following way. Let $\rho \in (0,1]$ be the probability that in any meeting after date T the 13-F report perfectly reveals the type of the 13-F investor to the counterparty. With probability $1-\rho$, the 13-F report is uninformative. We assume this shock is independent and identically distributed across 13-F investors and meetings and is independent from other shocks.[11]

Our key statistic of interest is how a filing affects the 13-F investor's conditional probability of trade with a given set of counterparties, $\hat{\Theta} \subseteq \Theta$. The conditional probability the 13-F investor trades with counterparties in $\hat{\Theta}$ at time t is given by

$$\bar{q}_t^{13F}(\theta;\hat{\Theta}) = \omega_o\, \bar{q}_{ot}^{13F}(\theta;\hat{\Theta}) + \omega_n\, \bar{q}_{nt}^{13F}(\theta;\hat{\Theta}), \tag{16}$$

where $\bar{q}_{ot}^{13F}(\theta;\hat{\Theta})$ and $\bar{q}_{nt}^{13F}(\theta;\hat{\Theta})$ are the conditional probabilities the 13-F investor sells an asset to and buys an asset from a counterparty in $\hat{\Theta}$, respectively, and $\omega_{o,t} = \phi_{o,t}(\theta)/f(\theta)$ and $\omega_{n,t} = 1-\omega_{o,t}$ are weights that give the probability of being an owner or non-owner, respectively.[12]

It is useful to define the discontinuity in trade probability for an investor of type θ trading with a group of investors $\hat{\Theta}$ as $D_t^{13F}(\theta;\hat{\Theta}) = \lim_{\epsilon \searrow 0} \bar{q}_{t+\epsilon}^{13F}(\theta,\hat{\Theta}) - \bar{q}_{t-\epsilon}^{13F}(\theta;\hat{\Theta})$. We are interested in the effect of a 13-F filing on this discontinuity at time $t=T$, $D_T^{13F}(\theta;\hat{\Theta})$. In our case of interest, we can write the discontinuity in trade probability in closed form as,

$$\begin{aligned} D_T^{13F}(\theta;\hat{\Theta}) = \; & \omega_o \xi_n \mathbb{E}_{\hat{\Theta}}\Big\{\rho(1-\alpha_n)\mathbb{1}_{\{\Delta_n \geq bid_T^{13F}(\Delta_n)\}}\Big\} \\ & + \omega_n \xi_o \mathbb{E}_{\hat{\Theta}}\Big\{\rho(1-\alpha_o)\mathbb{1}_{\{ask_T^{13F}(\Delta_o)\geq \Delta_o\}}\Big\}. \end{aligned} \tag{17}$$

The expectation operator in the first and second term of (17) are conditional expectations over $\theta_n \in \hat{\Theta}$ and $\theta_o \in \hat{\Theta}$, respectively. The effect of a 13-F filing depends

[11] Alternatively, we could model a 13-F filing as providing a noisy signal about the flow value of filers. The main predictions of the extension would remain unchanged at the cost of additional complexity. We choose instead to keep the thought experiment as simple as possible.

[12] We omit the expressions for $\bar{q}_{ot}^{13F}(\theta;\hat{\Theta})$ and $\bar{q}_{nt}^{13F}(\theta;\hat{\Theta})$, but they follow from (9)-(11) replacing the distributions ϕ_n and ϕ_o with conditional distributions with support over $\hat{\Theta}$.

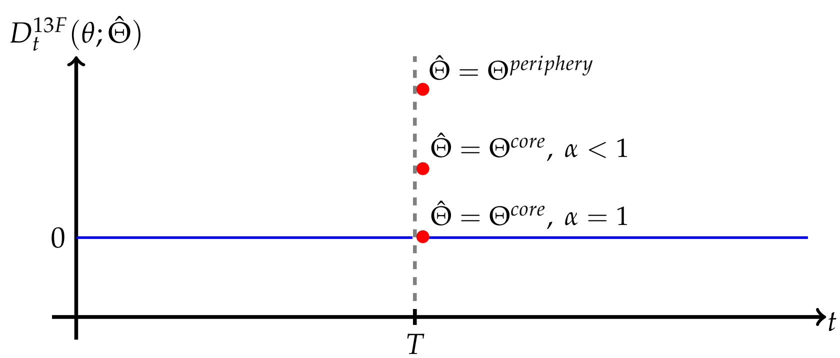
positively on how informative a filing is, ρ, and negatively on the screening expertise of the set of counterparties, α_n and α_o. Intuitively, if the set of counterparties includes investors with higher screening ability, the discontinuity is lower.

The following proposition establishes our main set of testable predictions: at time T, (i) a 13-F filing causes a strictly-positive jump in the probability of trade with periphery investors, (ii) a 13-F filing causes a weakly positive jump in the probability of trade with core investors, and (iii) a 13-F filing shifts the probability of trade towards periphery investors relative to core investors.

Proposition 9. *Let $\epsilon > 0$ be an arbitrarily small number. Then, if $\alpha_I \in [1-\epsilon, 1]$, then: (i) $D_T^{13F}(\theta; \Theta^{periphery}) > 0$, (ii) $D_T^{13F}(\theta; \Theta^{core}) \geq 0$, and (iii) $D_T^{13F}(\theta; \Theta^{periphery}) - D_T^{13F}(\theta; \Theta^{core}) > 0$, where $\Theta^{core} = \{\theta \in \Theta : c(\theta) \geq \underline{c}\}$, $\Theta^{periphery}$ is its complement, and $\underline{c}$ is defined in Proposition 7.*

Proposition 9 considers the set of core investors as those with a centrality measure in the top-p percentile, which Proposition 7 established as investors with $\alpha = \alpha_I$. Information revelation can potentially increase the probability of trade with both core and periphery investors, however it must have a greater impact on the probability trade with periphery investors relative to core investors precisely because core investors already have an informational advantage.

Figure 3: Filing form 13-F and the discontinuity in the probability of trade



Notes: The figure presents the discontinuity in trade probability $D_t^{13F}(\theta; \hat{\Theta})$ around the filing date for Form 13-F, $t = T$. Away from $t = T$, there is no discontinuity. At $t = T$: (i) in the economy where maximum screening ability is $\alpha_I = 1$, there is no discontinuity when trading with core investors, (ii) in the economy where maximum screening ability is strictly less than one –i.e. $\alpha_I < 1$, there is a discontinuity when trading with core investors, (iii) for either economy there is a discontinuity when trading with periphery investors, and this discontinuity is always larger than when trading with core investors.

This result, illustrated in Figure 3, is the key prediction of our model. If central traders do indeed posses a better screening technology then we would expect to find that public information revelation impacts them less. We test this prediction in the remainder of the section.

In our model, because investors share the same arrival rate of trade opportunities λ, differences in trade probability –or differences in the frequency of trade– with core and periphery investors are only due to variation in ν and α. However, if for example investors were to be also heterogeneous in the arrival rate of trade opportunities, as it is the case in Uslu (2016) and Farboodi et al. (2017), the probability of trade with core investors would be higher that the probability of trade with periphery investors, but for motives not related to screening ability. Although our theoretical results regarding screening ability and centrality still hold, the results in Proposition 9 need to be re-stated in order to adjust for this extra source of variation. In particular, the discontinuity $D_T^{13F}(\theta;\hat{\Theta})$ in Proposition 9 can be standardized by the unconditional trade probability with the particular group $\hat{\Theta}$.

5.2 Data description and summary statistics

We combine two regulatory datasets: 13-F filings from the Securities and Exchange Commission (SEC) and CDS trade-level data from the Trade Information Warehouse (TIW) of the Depository Trust and Clearing House Corporation (DTCC). Our sample includes trades from the 1st quarter of 2013 to the 4th quarter of 2017—a total of 19 quarters or 246 weeks.

13-F filings. Congress passed Section 13(f) of the Securities Exchange Act in 1975 in order to increase the public availability of information regarding the security holdings of institutional investors. Under Section 13(f), any registered investment manager with discretion over its own or a client account with an aggregate fair market value of more than $100 million in Section 13(f) securities must file a 13-F form. The 13-F form lists the holdings of Section 13(f) securities, which primarily includes U.S. exchange-traded stocks (e.g., those traded on NYSE, AMEX, NASDAQ), stock options, shares of closed-end investment companies, and shares of exchange-traded funds (ETFs).[13] Importantly, CDS are not included in the list of 13(f) securities.

The SEC makes 13-F filings publicly available through its Electronic Data Gathering, Analysis, and Retrieval (EDGAR) program. The identity of the institutions that must file a 13-F form is known by market participants. This implies that when a report is filed, counterparties of 13-F filers posses detailed portfolio information when trading. Since CDS indexes are a way for institutions to hedge against risk in their portfolio, we interpret the information provided to the market in the 13-F form as information related to the trading needs of investors on CDS

When filing a 13-F form, institutions are required to list their portfolio ownership of all Section 13(f) securities as of the last trading day of each quarter, which we label the *report date*. However, institutions have the discretion to delay reporting and file a 13-F form up to 45 days past the report date.[14] We label the day in which institutions actually file the *filing date*. The 45-day delay rule is designed to protect investors from *copycatting* and *front-running* and many in fact choose to delay reporting.[15] From EDGAR we observe the filing date and the unique Central Index Key (CIK) of the filing manager, which gives us the institution name and is used to link filing institutions to those trading CDS.

CDS data. The Dodd-Frank Wall Street Reform and Consumer Protection Act requires real-time reporting of all swap contracts to a registered swap data repository (SDR). The DTCC operates a registered SDR on CDS. The Dodd-Frank Act also requires SDRs to make all reported data available to appropriate prudential regulators.[16] As a prudential regulator, members of The Federal Reserve System have access to the transactions and positions involving individual parties, counterparties, or reference entities that are regulated by the Federal Reserve. For each transaction, we observe the day of the trade, the company name of the buyer and seller, the ref-

[13]See https://www.sec.gov/fast-answers/answers-form13fhtm.html for a complete list of 13(f) securities and other institutional details.

[14]If day-45 lies on a weekend or holiday, the window is extended to the first business day past 45 days.

[15] In the next subsection we discuss at length the potential endogeneity concern delay poses.

[16]See Sections 727 and 728 of The Dodd-Frank Wall Street Reform and Consumer Protection Act.

erence entity (or series of the index), and other details of the contract (e.g. notional amount, initial payment, etc.). We access the raw CDS trade data from the Federal Reserve Board (FRB) servers via the DTCC regulatory portal.

The market for CDS is large and active, with a daily notional volume around $2 trillion. Generally a CDS contract, called a single-name CDS, involves an agreement in which the buyer of protection makes regular payments to the seller of protection in exchange for a contingent payment from the seller upon a credit event (e.g. nonpayment of debt) on a specified reference entity (e.g. a single corporate bond issue). In our analysis, we focus on trades of US CDS indexes, which are bundles of single-name CDS.

We choose to focus on CDS indexes for several reasons. First, unlike single-name CDS, the contract terms in CDS indexes are standardized and more easily comparable across investors. Second, CDS indexes are centrally cleared in the time period we consider, which helps us avoid having counterparty risk determine counterparty choice, as discussed in Du et al. (2017). Third, while CDS indexes are still traded OTC, they are more liquid than single-name CDS and have a higher frequency of trade. Frequent trade for a given CDS index allows us to control for unobservable index, institution, and time period characteristics using fixed effects. Finally, our main results focus on U.S. CDS indexes because the data only covers trades that either have a party or reference entity regulated domestically. Since US indexes are mostly traded by U.S. firms or subsidiaries of foreign firms, they are more likely to be regulated by the Federal Reserve and be included in our data.

Combining the 13-F fillings with the CDS trade data. We merge CDS trade data with 13-F filings using the names of the institution of each trader. Since the institutions' names do not match perfectly we approximate them using Levenshtein-edit distance. The Levenshtein edit distance is a measure of approximateness between strings: it is the total number of insertions, deletions and substitutions required to transform one string into another. We match the names with Levenshtein-edit distance less than 0.5. We only use the first three words of the identifiers when computing the Levenshtein edit distance because this is where the identifying parts of the institution's name tend to be.[17] We manually check the matched names to make sure there are no bad matches, which is feasible given there are not many institutions filing that also trade CDS, see Table 1.

In some cases, we find multiple DTCC account IDs, but only one CIK ID from EDGAR. That is, not everything is one-to-one between the data sets.[18] These cases happen because the DTCC IDs can be granular, while the 13-F filings tend to be more at the institution level. We keep the institution ID from the DTCC data, so one filling that is associated with a CIK in the EDGAR data, will be associated with multiple DTCC IDs in our data.

Descriptive Statistics. Table 1 provides summary statistics of the data after merging. We consider three different samples. Our preferred sample includes only institutions that filed at least once in the sample period, which we label as *filers*, and trades of U.S. CDS indexes. Since in our regressions we control for fixed effects at the institution level, narrowing the sample to include only filers is enough to identify the effect of a 13-F report in the time period around a filing. We provide more details on identification in the next section. However, since we also control for trade activity at the index-class level we report results for the sample that includes all traders, regardless of filing status.

We observe a total of 4,124 institutions trading U.S. CDS indexes in our sample period, of which 52 of filed a 13-F in at least one quarter. Most CDS-index traders are not filing 13-F reports. Additionally, not all filing institutions filed in every quarter in our sample; out of the 52 institutions that filed in at least one quarter, a little over half filed in every quarter. To capture any endogeneity that concerns selection into filing a 13-F, we will show results that control for fixed effects at the institution-quarter level. That is, we will only exploit variation within a quarter around filing dates.

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[17] After the first three words, there tend to be "filler" words such as "LTD" - "LIMITED", "CORP" or "CORPORATION".

[18] For example, the Edmond De Rothschild Holdings has an unique CIK in the EDGAR data, and it is associated with four DTCC IDs: EDMOND DE ROTHSCHILD EMERGING BONDS, EDMOND DE ROTHSCHILD Bond Allocation, EDMOND DE ROTHSCHILD QUADRIM 8 and EDMOND DE ROTHSCHILD QUADRIM 4.

Table 1: CDS trades and 13-F filings, summary statistics

	Sample	
	US indexes, filers	US indexes, all institutions
Number of institutions	52	4,124
% that file in every quarter	51.9	0.7
Number of trades	113,900	369,527
% involving two *filers*	4.6	1.7
% in which at least one institution filed in prev. week	2.2	0.8
% in which at least one institution filed in previous 2 weeks	4.3	1.6
average trades per week	463.0	1,502.1
average trades per week, per institution	8.9	0.4
Number of index-classes traded	36	36

While filers make up a small fraction of institutions trading CDS indexes, they are included in a large number of trades. Of the total 369,527 CDS-index transactions we observe, 36.24% involve at least one *filer*. This is in line with the idea that 13-F filers tend to be larger institutions, and the amount of trade activity provides us with enough observations for identification. However as we will discuss later, while 13-F filers trade more than the average non-13-F filer, they do not comprise the core of the CDS-index market. In other words, there are other non-13-F institutions that trade even more disproportionately than 13-F filers.

Typically, only one of the two participants in a transaction are a filer; only 4.6% involve a trade between two filers in the main sample.[19] Table 1 also shows the extent of trades we observe in the time period recently following a 13-F report. Since our theoretical predictions are all local in nature, our tests focus on trading activity during this time period. Of the total trades we observe, 0.81% involve an institution that filed a recent 13-F report, that is within the previous week, and 1.56% involve an institution that filed within the previous two weeks.

We observe trades of 36 U.S. CDS-index classes. Most of the trade activity is

[19] Among the trades involving at least one filer, the share in which buyer or seller filed is split roughly even.

concentrated in two groups: North American CDS indexes (CDX.NA) and Commercial Mortgage Backed Security Indexes (CMBX). These two groups account for 89% of all U.S. trades in our data. The average number of trades in a given week for any of the indexes across all institutions is 1,502, and the number falls to 463 when we restrict to trades involving at least one filer. Hence, even though CDS indexes are more liquid than single-name CDS, they are still traded relatively infrequently. As a result, our regressions will use observations of trade at a weekly frequency.

As mentioned above, institutions have the option to delay filing a 13-F form up to 45 days past the end of the quarter, the report date. We define delay as the difference in days between the report date and filing date. All institutions delay, with a minimum delay of 6 days and some institutions delay over the standard limit of 45 days.[20] Since delay is a choice, a potential concern is the endogeneity of delay and CDS trading activity around the filing date. The literature on 13-F filing studies why institutions delay filing. Christoffersen et al. (2015) argues that institutions primarily delay filing to prevent front-running—a situation in which other investors, upon observing the portfolio shares of the reporting institution, infer their future trades and attempt to execute a trade in the same direction before, obtaining a better price.[21] Institutions tend to delay filing a 13-F so they can execute their trading without competition from front-runners. The test of our model will be if the probability of trade *increases* in the time period following a 13-F report. However, if front-running is the primary reason for delay, the probability of trade would *decrease* in the time period following a report. Hence, it would lead to bias in the opposite direction of our tests.

Finally, as is true with many OTC markets, the market for CDS indexes is concentrated, where a set of institutions comprise a large share of trade volume. To see this, for each institution we calculate the percentage of all trades in which they participate, either as a buyer or seller, then rank them from largest to smallest. This

[20] This can occur for two reasons. If day 45 falls on a weekend or holiday the deadline is extended until the following business day. Also, institutions can apply to extend the standard delay period.

[21] Christoffersen et al. (2015) also find evidence of institutions delaying in order to hide corporate voting power as a result of shares of corporate securities.

measure aligns with our measure of centrality in Section 4.3. We find that the top five institutions account for the majority of trade we observe; 92% of all observed trades involve a top five institution. We associate the top five institutions in the data with the set of core institutions in our theory. We chose the top five because there is a noticeable discontinuity in centrality from the top-5th to the top-6th institution. The institution ranked 5th has a centrality measure 102% higher than the institution ranked 6th, while the institution ranked 4th has a centrality measure only 19% higher than the institution ranked 5th.

5.3 Empirical results

In this section we test the predictions of our model, as described in Proposition 9, that a 13-F filing (i) strictly increases the probability of trading with periphery institutions, (ii) weakly increases the probability of trade with core institutions, and (iii) shifts trade towards periphery institutions. To do so, we estimate the following linear model:

$$Y_{ijt} = \beta F_{j,t-1} + \text{Fixed Effects}_{jit} + \epsilon_{jit} \tag{18}$$

where i denotes a CDS-index class (e.g. CDX.NA.IG), j denotes an institution, and t denotes a time period, which we set to be equal to a week. The variable Y_{ijt} represents the outcome of interest which is one of two possible dummy variables, $D_{ijt}^{periphery}$, D_{ijt}^{core}. The variable $D_{ijt}^{periphery}$ is a dummy for a trade by institution j involving CDS index i in week t trading with a periphery institution. Similarly D_{ijt}^{core} is a dummy for trade by institution j involving CDS index i in week t trading with a core institution.

The coefficient of interest is β—the coefficient on the dummy variable $F_{j,t-1}$, which equal to one if institution j filed a 13-F report in the week previous to t. As we discuss in subsection 5.1, we normalize the coefficient β in each regression by the frequency of trade in the sample. This normalization allows us to control for other determinants of trade centrality, such as trade speed as discussed in Uslu (2016) and Farboodi et al. (2017), that would affect differentially the level of trade when trading with core relative to periphery investors.

Before discussing our empirical results it is useful to discuss identification. Identification primarily comes from two sources: (i) comparing trade activity by the same institution in weeks following a report versus not, and (ii) comparing trades within a week across institutions that filed in the week before versus those that did not. For (i) we have variation in the weeks and indexes that institutions trade relative to the weeks where they file a 13-F. For (ii) we have variation in the weeks where different institutions file. Since transactional data gives us a large sample size, we are able to control for many unobservable correlations using a combination of fixed effects on institutions, weeks and indexes. One potential concern is endogeneity bias that stems from the filing requirements of Form 13-F causing selection on unobservables that are correlated with trading activity in CDS markets. This type of bias is unlikely to effect our results since the number of institutions required to file Form 13-F is considerably larger than those that file *and* trade CDS indices.[22] However, we address this concern by narrowing our baseline sample to only filers.

Table 2 reports our baseline results. Column (1) includes fixed effects for week-index pairs and institutions, and restricts the sample to filers and US indexes. We find that the probability of trade with periphery institutions increases by 22.5% in the week after a 13-F filing. We also find that the probability of trade with core institutions increases, by 9.6%. Both effects are statistically significant and positive, consistent with parts (i) and (ii) in Proposition 9; a 13-F report leads to increased trading activity in the week following the report. However, part (iii) of 9 suggests that the information revelation should shift the probability of trade towards periphery institutions. The third panel of Table 2 shows the results of testing the difference in the first two coefficients. We find that the difference is positive and significant; a 13-F report increases trade with periphery institutions by 12.9% relative to core institutions.

Columns (2) and (3) in Table 2 test for the robustness of our results to the sample

[22]For instance, there are 5,560 financial institutions that filed at least one Form 13-F between 2013 and 2017, while only 52 institutions in our dataset trade CDS indices and filed form 13-F at least once in the same sample period.

Table 2: Impact of a 13-F filing on trade

	US index, filers	All index, filers	US index, all inst.	US index, filers
	(1)	(2)	(3)	(4)
Trade with Periphery, $\frac{\beta^{periphery}}{Freq^{periphery}}$	0.225***	0.125***	0.501**	0.137*
	(0.075)	(0.046)	(0.198)	(0.074)
R-squared	0.176	0.167	0.107	0.198
Trade with Core, $\frac{\beta^{core}}{Freq^{core}}$	0.096*	0.095**	-0.002	-0.010
	(0.054)	(0.038)	(0.128)	(0.053)
R-squared	0.182	0.177	0.069	0.204
Test on difference, $\frac{\beta^{periphery}}{Freq^{periphery}} - \frac{\beta^{core}}{Freq^{core}}$	0.129*	0.030	0.498**	0.147**
	(0.073)	(0.042)	(0.209)	(0.072)
Fixed Effects				
Week − index	yes	yes	yes	yes
Institution	yes	yes	yes	no
Institution − quarter	no	no	no	yes
Observations	460,512	1,100,358	36,522,144	460,512

Notes: Sample includes trades of US credit default swap indexes by regulated institutions or those trading CDS indexes on regulated institutions, that filed a 13-F report at least once in the sample period, 2013Q1-2017Q4. The independent variable is a dummy equal to one if institution j filed a 13-F in the previous week. The two dependent variables are dummies if institution j traded CDS index i in week t with a periphery and core institution, respectively. We normalize the coefficients of each regression by the frequency of trading with each group so that coefficients are comparable. Test on difference: tests whether the difference in the normalized coefficients are equal to zero. Standard errors are in parentheses. *** p$<$0.01, ** p$<$0.05, * p$<$0.1.

selection. In column (2) we extend our baseline sample to include non-US indexes, and in column (3) we extend our sample to also include all institutions, regardless of filing status. The results remain consistent with those presented in column (1). Specifically, extending the sample to include all institutions implies the effects of a 13-F on trade with core institutions disappears and leads to a nearly 50% increase in the probability of trade with periphery institutions.

In column (4), we report results that control for fixed effects at the institution-quarter level. In our sample of filers not all institutions filed in every quarter. This may be resulting from either an error in our process of matching 13-F reports to CDS trades or in variation in the size the institution's 13(f) portfolio from quarter to quarter that could, in principle, bias in our results.[23] Adding institution-quarter fixed effects address both of these concerns by limiting our identifying variation

[23]For instance, we may be unable to recover the filing date if the institution manager changes since the last filing – as filing is manager specific– or if she files the report jointly with another manager, which can occur if both managers belong to a bigger corporation.

to weeks within an institution's filing quarter. Doing so leads to results that are in line with columns (1)-(3). A 13-F report increases the probability of trade with periphery institutions relative to core institutions by 14.8%.

Table 3: Impact of 13-F filing on trade, varying lag lengths

	1 week $F_{j,t-1}$ (1)	2 weeks $F_{j,t-2}$ (2)	3 weeks $F_{j,t-3}$ (3)	4 weeks $F_{j,t-4}$ (4)
Trade with Periphery, $\frac{\beta^{periphery}}{Freq^{periphery}}$	0.137*	0.146**	0.029	-0.058
	(0.074)	(0.058)	(0.052)	(0.049)
Trade with Core, $\frac{\beta^{core}}{Freq^{core}}$	-0.009	-0.014	-0.006	-0.037
	(0.053)	(0.042)	(0.038)	(0.035)
Test on difference, $\frac{\beta^{periphery}}{Freq^{periphery}} - \frac{\beta^{core}}{Freq^{core}}$	0.147**	0.160***	0.035	-0.021
	(0.072)	(0.057)	(0.051)	(0.048)
Fixed Effects				
Week − index	yes	yes	yes	yes
Institution − quarter	yes	yes	yes	yes
Observations	460,512	458,640	456,768	454,896

Notes: Sample includes trades of US credit default swap indexes by regulated institutions or those trading CDS indexes on regulated institutions, that filed a 13-F report at least once in the sample period, 2013Q1-2017Q4. The independent variables, (1) $F_{j,t-1}$, (2) $F_{j,t-2}$, (3) $F_{j,t-3}$, and (3) $F_{j,t-4}$ are dummies equal to one if institution j filed a 13-F within the previous week, two weeks, three weeks, and four weeks respectively. The two dependent variables are dummies if institution j traded CDS index i in week t with a non-top-5 and top-5 institution, respectively. We normalize the coefficients of each regression by the frequency of trading with each group of investors so that coefficients are comparable. Test on difference: tests whether the normalized coefficients are equal to zero. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

In Table 3, we examine the effect of a 13-F report on trade in the following one-, two-, three- and four-week windows. While Proposition 9 only concerns the effects of a 13-F in the time period immediately following a report, we are interested in investigating the persistence of the shock. Column (1) repeats the results from column (4) in Table 2, which controls for fixed effects by week-index and institution-quarter. The positive effect of 13-F filing on the probability of trade with periphery institutions holds up to two weeks after the filing, but it is not present in the three- and four-week windows. The effect of a 13-F on the probability of trading with a core institutions remains insignificant and with a point estimate close to zero. The difference between the two, or the effect of a 13-F on the probability of trade with periphery versus core institutions is significant and positive up to two weeks after the filing date, with a difference in the change of trading probability of nearly 15%, but vanishes after two weeks. These results are consistent with our theory. As we increase the window length, we also increase the number of trades that we consider as related to filing a report. In theory, by doing so we are adding trades that are less correlated with the revelation of information, thus adding noise and eventually breaking the link between trade activity and filing.

Table 4: Impact of 13-F filing on trade in week(s) after report relative to before.

	$x = 1$ week		$x = 2$ weeks	
	(1)	(2)	(3)	(4)
	Dependent Variable: Trade with Periphery, $\frac{\beta^{periphery}}{Freq^{periphery}}$			
Filed in week $t - x$, $F_{i,t-x}$	0.237***	0.140*	0.271***	0.149**
	(0.075)	(0.074)	(0.059)	(0.060)
Filed in week $t + x$, $F_{i,t+x}$	0.124*	0.027	0.124**	0.018
	(0.075)	(0.074)	(0.059)	(0.060)
Prob>F: $\beta_1 = \beta_2$	0.266	0.259	0.058	0.087
R-squared	0.176	0.198	0.176	0.198
	Dependent Variable: Trade with Core, $\frac{\beta^{core}}{Freq^{core}}$			
Filed in week $t - x$, $F_{i,t-x}$	0.102*	-0.016	0.137***	-0.018
	(0.054)	(0.054)	(0.042)	(0.043)
Filed in week $t + x$, $F_{i,t+x}$	0.053	-0.065	0.130***	-0.022
	(0.054)	(0.054)	(0.043)	(0.043)
Prob>F: $\beta_1 = \beta_2$	0.499	0.497	0.891	0.940
R-squared	0.183	0.204	0.183	0.204
	Dependent Variable: Difference, $\frac{\beta^{periphery}}{Freq^{periphery}} - \frac{\beta^{core}}{Freq^{core}}$			
Filed in week $t - x$, $F_{i,t-x}$	0.135*	0.156**	0.133**	0.167***
	(0.073)	(0.073)	(0.058)	(0.058)
Filed in week $t + x$, $F_{i,t+x}$	0.072	0.092	-0.005	0.040
	(0.073)	(0.073)	(0.058)	(0.058)
Prob>F: $\beta_1 = \beta_2$	0.522	0.516	0.066	0.091
R-squared	0.097	0.119	0.097	0.119
Fixed Effects				
Week − index	yes	yes	yes	yes
Institution	yes	no	yes	no
Institution − quarter	no	yes	no	yes
Observations	458,640	458,640	454,896	454,896

Notes: Sample includes trades of US credit default swap indexes by regulated institutions or those trading CDS indexes on regulated institutions, that filed a 13-F report at least once in the sample period, 2013Q1-2017Q4. The independent variables, $F_{j,t-x}$ and $F_{j,t+x}$, are dummies equal to one if institution j filed a 13-F within the previous x weeks and within the following x weeks, respectively, to week t. The two dependent variables are dummies if institution j traded CDS index i in week t with a periphery and core institution, respectively. We normalize the coefficients of each regression by the frequency of trading with each group so that coefficients are comparable. Test on difference: tests whether the normalized coefficients are equal to zero. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

In Table 4, we add an additional regressor to (18) that controls for trade in the time period *just prior* to a 13-F filing,

$$Y_{ijt} = \beta_1 F_{j,t-x} + \beta_2 F_{j,t+x} + \text{Fixed Effects}_{jit} + \epsilon_{jit}, \tag{19}$$

where, as before, $F_{j,t-x}$ is a dummy equal to one if institution j filed a 13-F report in the x-weeks previous to week t and $F_{j,t+x}$ is a dummy equal to one if institution j filed a 13-F report in the x weeks following week t. The coefficient β_2 should identify trade activity immediately before a report. For instance, if front-running is a concern of 13-F filers that trade CDS indexes, then $\beta_2 > 0$ to indicate that institutions trade relatively higher immediately before reporting. Then, as suggested by Proposition 9, we should find an increase in the probability of trade in the time period after relative to the time period before a report, or $\beta_1 > \beta_2$.

We focus on the sample of filers trading US CDS indexes and report results using the two sets of fixed effects from above. Columns (1) and (2) of Table 4 look at the probability of trade in the week before versus the week after the week of the 13-F filing. Similarly, columns (3) and (4) broaden the horizon to two weeks before and after.

As in Table 2, the first row of the table shows that the probability of trade with periphery institutions increases in the week (two weeks) after a filing. In the week (two weeks) prior to the filing, the probability of trade with non-central institutions is also slightly above the average, but importantly the magnitude is always smaller than in the time period after. In fact, when we control for institution-quarter fixed effects, we find no statistical effect on trade with periphery institutions *just before a report*. However, we find a report increases the probability of trade with non-central institutions by around 14-15% in the week to two weeks *just after a report*.

While we find a significant impact of a 13-F filing on trade with periphery institutions, we find no effect on trade with core institutions. The coefficient estimates for trade in the one or two weeks after a 13-F filing versus before are statistically the same (as shown in the middle panel of Table 4). We test the difference in the probability of trade and find a significant, positive impact of a 13-F on trade with periphery institutions relative to core institutions, which verifies the estimates effects from Tables 2 and 3.

In the theory we provide, what makes private information regarding investors private valuation relevant, is the over-the-counter market. Indeed, if we consider a version of our model with a competitive market, the information structure is irrelevant, investors reservation value is the competitive price independently of their individual valuation. This suggests that in very competitive markets, our results are diminished. An indirect way to control for the competitiveness of the market is by a market's liquidity, for instance as measured by the frequency an asset trades.

Table 5 shows the results from specification 18, run separately for the three groups of CDS index classes with different trade frequencies. IHS Markit's CDX index class on North American entities is by far the most liquid in terms of trading frequency, accounting for roughly 65% of trades in our sample. The second most liquid class is Markit's CMBX indexes referencing commercial mortgage-backed securities, which accounts for a much smaller fraction of 23% of trades. The group "Other" accounts for the remainder and includes indexes that trade infrequently, such as those that reference sub-prime mortgage backed securities or municipal CDSs, swaps referencing interest and principal components of agency pools, or the Dow Jones CDX family.

We find that as an index is traded more frequently in the market, the impact of a 13-F on trade with the periphery is diminished, as well as the effect relative to trade with the core. Using week-index and institution fixed effects, columns (1)-(3), we find that a 13-F filing increases the probability of trade with the periphery by 9.1% in the market for CDX, 29.2% in the market for CMBX, and 59.4% in the remaining markets for low liquidity indexes. We find a differential impact on trade with the periphery relative to the core of 22.8% and 38.8% in the less liquid markets for CMBX and other indexes, but not in the market for CDX. The results the same if we control for institution-quarter fixed effects, in columns (4)-(6).

5.4 Robustness

The results above are robust to alternative specifications and tests. We briefly summarize them here and report the details in Appendix C. First, since our primary sample included only filers, we end up ignoring many trades involving non-filers

Table 5: Impact of 13-F filing on trade, by CDX Index Class

	CDX (1)	CMBX (2)	Other (3)	CDX (4)	CMBX (5)	Other (6)
	Dependent Variable: Trade with Periphery, $\frac{\beta^{periphery}}{Freq^{periphery}}$					
Filed in prev. week, $F_{i,t-x}$	0.091	0.292**	0.594***	0.053	0.178*	0.353*
	(0.089)	(0.116)	(0.188)	(0.089)	(0.102)	(0.185)
R-squared	0.448	0.317	0.111	0.478	0.483	0.148
	Dependent Variable: Trade with Core, $\frac{\beta^{core}}{Freq^{core}}$					
Filed in prev. week, $F_{i,t-x}$	0.122	0.064	0.207*	0.037	-0.045	0.034
	(0.077)	(0.072)	(0.123)	(0.074)	(0.068)	(0.122)
R-squared	0.392	0.362	0.105	0.455	0.452	0.135
	Dependent Variable: Difference, $\frac{\beta^{periphery}}{Freq^{periphery}} - \frac{\beta^{core}}{Freq^{core}}$					
Filed in prev. week, $F_{i,t-x}$	-0.031	0.228*	0.388**	0.016	0.223**	0.318*
	(0.092)	(0.121)	(0.189)	(0.091)	(0.111)	(0.187)
R-squared	0.164	0.240	0.068	0.216	0.111	0.187
Fixed Effects						
Week − index	yes	yes	yes	yes	yes	yes
Institution	yes	yes	yes	no	no	no
Institution − quarter	no	no	no	yes	yes	yes
Observations	38,376	102,336	268,632	38,376	102,336	268,632
Percent of Trades	65.6%	23.4%	11%	65.6%	23.4%	11%

Notes: Sample includes trades of US credit default swap indexes by regulated institutions or those trading CDS indexes on regulated institutions, that filed a 13-F report at least once in the sample period, 2013Q1-2017Q4. The independent variable, $F_{j,t-1}$, is a dummy equal to one if institution j filed a 13-F within the week $t-1$. The two dependent variables are dummies if institution j traded CDS index i in week t with a periphery and core institution, respectively. We normalize the coefficients of each regression by the frequency of trading with each group so that coefficients are comparable. Test on difference: tests whether the normalized coefficients are equal to zero. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

that may provide a useful counter-factual to filers. However, to make the right comparison we need to assign non-filers with filing dates, which we do quarterly using the observed distribution of filing dates. Then, we test to see if there is an effect of a "real" 13-F filing versus a "fake" 13-F fling and find a positive and statistically significant effect. Further, we also find that a "real" filing shifts the probability of trade towards periphery institutions while a "fake" filing does not, in-line with our results above. These results are reported in Tables 6 and 7. In Table 8 we consider how a 13-F filing affects the probability of trade, separately for buyers and sellers. We find the results go through for both sides of the market, in equal magnitude. In Table 9, we show that our results are robust if we consider the 45-day cutoff rule as exogenous variation in filing, unrelated to CDS trading in a given quarter. Hence, even though there is not a strong case to be made for why endogeneity in filing would bias in favor of our results, we show that a reasonable control for this leaves our results unchanged.

5.5 Summary and Discussion

To finish, we briefly summarize our empirical findings and discuss the relationship with other theories of intermediation in OTC markets. We provided evidence that reports that reveal private information about the asset portfolios of CDS index traders increase their trading activity in the time period immediately following a report. Further, this increase is not homogeneous with all participants in the market. Information revelation increases trade with periphery institutions relative to those in the core. Our theory provides an explanation that this result is driven by heterogeneity in the information technology possessed institutions that populate the core relative to institutions that populate the periphery. We develop a theory in which the core is endogenously formed by institutions that posses better information technology, and as a result, are affected less by public information revelation.

As discussed in Section 1, there are recent papers proposing theories of intermediation in OTC markets. Since these theories are built on the assumption of common knowledge, our empirical results should not be seen as a test of these models since they do not provide theoretical predictions about information revelation and market structure. However, we also emphasize that our results imply that information heterogeneity is an important determinant of which institutions populate the core of OTC markets. To our knowledge, there is no existing empirical work that tests other theories of endogenous intermediation nor are there existing theories about private information and endogenous intermediation in OTC markets.

Presumably, other theories of OTC trade with private information but homogeneous information technology could be consistent with predictions (i) and (ii) of Proposition 9 – that revealing information will increase the probability of trade – but would not be consistent with prediction (iii) – that revealing information shifts an institution's trade towards the periphery. In essence, predictions (i) and (ii) suggest private information is relevant in OTC markets and prediction (iii) suggests that information heterogeneity is important in determining which institutions intermediate and comprise the core.

6 Concluding remarks

We propose a theory of financial intermediation based on heterogeneity in the information investors posses about the trading motives of their counterparties. Superior information allows investors to avoid distortive mechanisms and, as a result, these investors (i) trade faster, (ii) trade with a larger pool of investors, and (iii) extract a larger share of the trade surplus and gain a higher profit from intermediation.

We empirically test the central prediction of our model by examining the effect of filing a 13-F form to the SEC, which makes public the institution's holdings of SEC regulated securities, on the probability of trade in the CDS index market. We show that a 13-F filing increases the probability of trade with periphery institutions to a greater extent than with core institutions, and in several specifications we find no effect of a 13-F filing on trade with core institutions. This prediction follows from our theory in which core institutions are already more likely to posses information about the trading motives of filers, but does not follow from other theories of financial market intermediation based on complete information.

The predictions of our model and our empirical results are robust across varying assumptions and specifications. In Appendix B, we show that TIOLI bid and ask prices are the solution to a mechanism design problem that maximizes the expected profits of the investor making the offer, analogous to the one in Myerson (1981). We also show our prediction that screening experts form the core of the market survives if we consider a mechanism that maximizes the expected trade surplus, as in Myerson and Satterthwaite (1983). In Appendix C, we provide additional robustness to our empirical tests.

In recent years, many important theoretical contributions have been made in understanding the driving forces of intermediation in OTC markets. Our paper provides a new theory of intermediation along with empirical support using micro-data that suggests the mechanism we study is relevant. However, further work is needed to combine existing theories of intermediation in order to jointly quantify the relative impact of each mechanism.

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A Appendix: Proofs

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Proof of Lemma 1. Note that, if $obj_o(ask;\alpha_n)$ is smaller or equal to zero for any ask smaller or equal to Δ_o. Since $M_n(\cdot;\alpha_n)$ is a cumulative distribution, and therefore right continuous, and $M_n(\Delta_o;\alpha_n) < 1$, there exists $\hat{ask} > \Delta_o$ such that $M_n(\hat{ask};\alpha_n) < 1$. As a result, we have that $obj_o(ask_o;\alpha_n) \geq obj_o(\hat{ask};\alpha_n) = [\hat{ask} - \Delta_o][1 - M_n(\hat{ask};\alpha_n)] > 0 \Longrightarrow ask_o \nleq \Delta_o$. □

Proof of Corollary 1. Because $1 - M_n(\Delta_o;\alpha_n) \geq M_n(\Delta_o + \bar{\epsilon}/2;\alpha_n) - M_n(\Delta_o;\alpha_n) > 0$, Lemma 1 implies that $ask_o - \Delta_o > 0$. Let $\epsilon = ask_o - \Delta_o - min\{ask_o - \Delta_o, \bar{\epsilon}\}/2 \in (0, \bar{\epsilon})$. Then have that $M_n(ask_o - \epsilon;\alpha_n) - M_n(\Delta_o;\alpha_n) = M_n(\Delta_o + min\{ask_o - \Delta_o, \bar{\epsilon}\}/2) - M_n(\Delta_o;\alpha_n) > 0$. □

Proof of Lemma 2 and Corollary 2. These proofs are analogous to the proofs of Lemma 1 and Corollary 1, and we omit both of them here. □

Proof of Proposition 1. The strategy for our proof is the following. We define an operator to map the reservation value and distribution of types across owners, Δ and Φ, in a new reservation value and distribution, $\hat{\Delta}$ and $\hat{\Phi}$, using the equilibrium conditions (in particular, the optimal bid and ask prices). In principle, such procedure may lead to functions that are discontinuous or not differentiable. We then approximate these outcomes with polynomials of degree k. The approximation in the space of polynomials guarantees that the functions are well behaved and a fixed point exists. As the degree of the polynomials goes to infinity, a sub-sequence of the fixed points and the associated optimal bid/ask must converge. We then can build the other equilibrium objects from this limit.

Consider a truncated version of our economy with preference types $\nu \in [\underline{\nu}, \bar{\nu}]$, where $\bar{\nu} > 0$ is some large constant and $\underline{\nu} < -\lambda\bar{\nu}$. With slight abuse of notation, we use F and f below to denote the cumulative distribution and density of $\theta = (\alpha, \nu)$ truncated in the set $\Theta_M = \Theta \cap [0, 1] \times [\underline{\nu}, \bar{\nu}]$. We first show that an equilibrium for this truncated economy exists. Then we take the limit when $\underline{\nu}$ and $\bar{\nu}$ go to infinity and argue for the convergence to an equilibrium of the original economy.

Defining some objects: Let $a = \frac{\lambda}{\lambda+\mu+\eta+r}$, $b = \frac{1}{\lambda+\mu+\eta+r}$, $\kappa = \frac{1}{1-a}$, $\bar{\kappa} = \frac{\lambda+\eta}{\lambda+\mu+\eta}$, $\underline{\Delta} = \frac{\underline{\nu}}{r}$, $\bar{\Delta} = \frac{\bar{\nu}}{r}$, $\phi(\theta) = \partial\Phi/\partial\nu$, $\Delta_\nu = \partial\Delta/\partial\nu$ and $h(q) = dH/dq$. Define the sets

$$\mathcal{D} = \left\{ \Delta \in \mathcal{C}^1(\Theta_M) \;\middle|\; \underline{\Delta} \le \Delta \le \bar{\Delta} \text{ and } \frac{b}{2} \le \Delta_\nu \le (1+\kappa)b \right\} \text{ and}$$

$$\mathcal{P} = \left\{ \Phi \in \mathcal{C}^1(\Theta_M) \;\middle|\; 0 \le \Phi \le F \text{ and } 0 \le \phi \le \frac{1+\bar{\kappa}}{2} f \right\}.$$

Define the sets

$$\mathcal{D}_j = \left\{ \Delta \in \mathcal{D} \;\middle|\; \forall\, i = 1, \ldots, I:\ \Delta(\alpha_i, \cdot) \in \mathbb{P}_j \right\} \text{ and}$$

$$\mathcal{P}_j = \left\{ \Phi \in \mathcal{P} \;\middle|\; \forall\, i = 1, \ldots, I:\ \Phi(\alpha_i, \cdot) \in \mathbb{P}_j \right\},$$

where $\mathbb{P}_j$ is the space of polynomials of degree j.

Solving for the optimal bid and ask functions: The pair $(\Delta, \Phi) \in \mathcal{D}_j \times \mathcal{P}_j$ is associated with measures of reservation values M_o and M_n (note that in subsection 3.1 we normalize these measures so they integrate to one, but this done for presentation purpose and is not necessary here). Let $p \in \mathbb{P}_j$ be the best monotone approximation of M_o on $[\underline{\Delta}, \bar{\Delta}]$. The polynomial $p \in \mathbb{P}_j$ is uniquely defined (see Kopotun (1998)). Let $\hat{M}_o(x) = (1 - 1/j)\, p(x) + 1/j(x - \underline{\Delta})$ for $x \in [\underline{\Delta}, \bar{\Delta}]$ (the mix guarantees that $\hat{m}_o(x) = \partial M_o(x)/\partial x$ is bounded away from zero). Using $\hat{M}_o$ (and after normalizing them to be probability measures), we obtain the function $\bar{H}_o$ given by (32), which is well defined since $\hat{M}_o$ have a compact support, is differentiable and has density bounded away from zero. Finally, $\bar{H}_o$ uniquely identifies the best buying mechanism as in Proposition 12. We obtain the best selling mechanism in a the same fashion.

Reservation value: Given j and $(\Delta, \Phi) \in \mathcal{D}_j \times \mathcal{P}_j$, define the reservation value $\hat{\Delta}$ as

$$\hat{\Delta}(\theta) = \frac{\nu + \lambda[\Delta(\theta) + (1-s)\pi_o(\theta) - s\pi_n(\theta)]}{\lambda + \mu + \eta L_j(\Delta(\theta)) + r}, \tag{20}$$

where π_o and π_n are given by (3) and (4) associated with the bid and ask defined above based on $\hat{M}_o$ and $\hat{M}_n$, and $L_j(x) = e^{j(x+\sqrt{j})}/(1 + e^{j(x+\sqrt{j})})$ is a variation of the logistic function. We use this variation of the logistic function here as a smooth approximation of the step function $\mathbb{1}_{\{x \geq 0\}}$ since it is continuous on x and $\lim L_j(x) = \mathbb{1}_{\{x \geq 0\}}$ for all $x \in \mathbb{R}$.

Distribution: Given j and $(\Delta, \Phi) \in \mathcal{D}_j \times \mathcal{P}_j$, define the distribution $\hat{\Phi}$ as

$$\hat{\Phi}(\theta) = \int_{\tilde{\theta} \leq \theta} \hat{\phi}(\tilde{\theta}) d\tilde{\theta}, \tag{21}$$

where the density $\hat{\phi}(\theta) = \frac{[\lambda \bar{q}_n(\theta) + \eta] f(\theta)}{\lambda[\bar{q}_o(\theta) + \bar{q}_n(\theta)] + \mu + \eta} L_j(\hat{\Delta}(\theta))$, and (9) and (10) define $\bar{q}_n(\theta)$ and $\bar{q}_o(\theta)$ associated with $\hat{H}_o$ and $\hat{H}_n$.

Operator: Construct the map $T_j : \mathcal{D} \times \mathcal{P} \to \mathcal{D}_j \times \mathcal{P}_j$ in the following way. For each $(\Delta, \Phi) \in \mathcal{D} \times \mathcal{P}$, define the reservation value $\hat{\Delta}$ and the distribution $\hat{\Phi}$ as described above. Then let $T_j(\Delta, \Phi)$ be defined as

$$T_j(\Delta, \Phi) := \underset{(\tilde{\Delta}, \tilde{\Phi}) \in \mathcal{D}_j \times \mathcal{P}_j}{\arg\min} ||\tilde{\Delta} - \hat{\Delta}|| + ||\tilde{\Phi} - \hat{\Phi}||. \tag{22}$$

One observation, given any $(\Delta, \Phi) \in \mathcal{D} \times \mathcal{P}$, the construction of $\hat{\Delta}$ and $\hat{\Phi}$ described above implies that the constraints impose in the sets $\mathcal{D}$ and $\mathcal{P}$ are not binding. That is,

$$\frac{\underline{v}}{r} < \frac{(1+\lambda)\underline{v}}{r(\lambda+\mu+\eta)} \leq \hat{\Delta} \leq \frac{(1+\lambda)\bar{v}}{r(\lambda+\mu+\eta)} < \frac{\bar{v}}{r}, \quad \frac{b}{2} < b \leq \hat{\Delta}_v \leq (a+\kappa)b < (1+\kappa)b, \text{ and } 0 \leq \hat{\phi} \leq \bar{\kappa} f < \frac{1+\bar{\kappa}}{2} f.$$

As a result, for j high enough, the solution to problem (22) is just the best polynomial approximations to $\hat{\Delta}$ and $\hat{\Phi}$. In both cases, the approximation is unique so T_j is a well defined map. From now on, we consider j to be high enough. The next lemma shows that T_j is not only well defined, but it is also a continuous map.

Lemma 3. *The operator T_j, as defined above, is a continuous map.*

Proof. Consider a sequence $\{(\Delta_l, \Phi_l)\}_l \subset \mathcal{D} \times \mathcal{P}$ which converges to $(\Delta^*, \Phi^*) \in \mathcal{D} \times \mathcal{P}$ almost everywhere. We need to show that the sequence $\{T_j(\Delta_l, \Phi_l)\}_l = \{(\hat{\Delta}_l, \hat{\Phi}_l)\}_l$ also converges to $T_j(\Delta^*, \Phi^*) = (\hat{\Delta}^*, \hat{\Phi}^*)$ (we use the L^1 norm unless stated otherwise).

Define M_{ol} and M_{nl} as in subsection 3.1 (note that in subsection 3.1 we normalize these measures so they integrate to one, but this done for presentation purpose and is not necessary here), that is, $M_{ol}(\tilde{\Delta}) = \int \mathbb{1}_{\{\Delta_l \leq \tilde{\Delta},\ \alpha=\alpha_n\}} d\Phi_{nl}$ and $M_{nl}(\tilde{\Delta}) = \int \mathbb{1}_{\{\Delta_l \leq \tilde{\Delta},\ \alpha=\alpha_o\}} d\Phi_{ol}$, where $\Phi_{ol} = \Phi_l$ and $\Phi_{nl} = F - \Phi_l$. It is easy to see that M_{ol} and M_{nl} are continuous on (Δ_l, Φ_l). Therefore, $\lim_l M_{ol} = M_o^*$ and $\lim_l M_{nl} = M_n^*$, where $M_o^*(\tilde{\Delta}) = \int \mathbb{1}_{\{\Delta^* \leq \tilde{\Delta},\ \alpha=\alpha_n\}} d\Phi_n^*$ and $M_n^*(\tilde{\Delta}) = \int \mathbb{1}_{\{\Delta^* \leq \tilde{\Delta},\ \alpha=\alpha_o\}} d\Phi_o^*$.

The polynomial approximations of M_{ol} and M_{nl}, call them p_{ol} and p_{nl}, also converge to the polynomial approximations of M_o^* and M_n^* (this is the case in every norm since they are polynomials of degree at most j), call them p_o^* and p_n^*. Let us show the result for p_o^*, the result for p_n^* is analogous. $\{p_{ol}\}_l$ is a sequence of polynomials of uniformly bounded degree j on a compact support, so it either has a convergent subsequence or it diverges. If $\{p_{ol}\}_l$ diverges, then we have that $\lim ||p_{ol} - M_{ol}|| \geq \lim ||p_{ol}|| - ||M_o^*|| = \infty$. In this case, $||p_o^* - M_{ol}|| < ||p_{ol} - M_{ol}||$ for l high enough since $\lim ||p_o^* - M_{ol}|| = ||p_o^* - M_o^*|| < \infty$. This cannot happen since p_{ol} is the best polynomial approximation to M_{ol}. If $\{p_{ol}\}_l$ has a convergent subsequence which converges to some $\bar{p}_o \neq p_o^*$, then $\lim ||p_o^* - M_{ol}|| = ||p_o^* - M_o^*|| < ||\bar{p}_o - M_o^*|| = \lim ||p_{ol} - M_{ol}||$, which implies that $||p_o^* - M_{ol}|| < ||p_{ol} - M_{ol}||$ for l high enough. This also cannot happen since p_{ol} is the best polynomial approximation to M_{ol}. As a result, p_{ol} converges to p_o^*. Since the polynomials p_{ol} and p_{nl} converge, then $\hat{M}_{ol}(x) = (1 - {}^1\!/_j)\, p_{ol}(x) + {}^1\!/_j(x - \underline{\Delta})$ and $\hat{M}_{nl} = (1 - {}^1\!/_j)\, p_{nl}(x) + {}^1\!/_j(x - \underline{\Delta})$ must also converge to $\hat{M}_o^*(x) = (1 - {}^1\!/_j)\, p_o^*(x) + {}^1\!/_j(x - \underline{\Delta})$ and $\hat{M}_n^* = (1 - {}^1\!/_j)\, p_n^*(x) + {}^1\!/_j(x - \underline{\Delta})$.

Now let us show that the sequences $\{\bar{H}_{ol}\}_l$ and $\{\bar{H}_{nl}\}_l$, defined using $\{\hat{M}_{ol}\}_l$ and $\{\hat{M}_{nl}\}_l$ and (27) and (32), also converge. Call the limits $\bar{H}_o^*$ and $\bar{H}_n^*$. Let us show for $\{\bar{H}_{ol}\}_l$, the result for $\{\bar{H}_{nl}\}_l$ is analogous. First note that

$$\begin{aligned} H_{ol}(q) &= \int_0^q h_{ol}(r)dr = \int_0^q \hat{M}_{ol}^{-1}(r) + \frac{r}{\hat{m}_{ol}(\hat{M}_{ol}^{-1}(r))} dr \\ &= \int_{\underline{\Delta}}^{\hat{M}_{ol}^{-1}(q)} \tilde{\Delta} d\hat{M}_{ol}(\tilde{\Delta}) + \int_{\underline{\Delta}}^{\hat{M}_{ol}^{-1}(q)} M_{ol}(\tilde{\Delta}) d\tilde{\Delta}, \end{aligned}$$

where the above equality comes from substituting $r = \hat{M}_{ol}(\tilde{\Delta})$. It is easy to see from the above equation that H_{ol} converges almost everywhere to

$$H_o^*(q) = \int_0^q h_o^*(r)dr = \int_0^q \hat{M}_o^{*-1}(q) + \frac{q}{\hat{m}_o^*(\hat{M}_o^{*-1}(q))} dr.$$

By definition, we have that

$$\bar{H}_{ol}(q) = \min_{\substack{\omega, r_1, r_2 \\ \omega r_1 + (1-\omega) r_2 = q}} \{\omega H_{ol}(r) + (1-\omega) H_{ol}(r)\} \;\text{ and }\; \bar{h}_{ol}(q) = \frac{d\bar{H}_{ol}(q)}{dq}.$$

Then, we must have that $\bar{H}_{ol}$ converges to $\bar{H}_o^*$, which is defined as above but using H_o^*. Note also that $\bar{h}_{ol}(q)$ converges to $\bar{h}_o^*(q) = {}^{d\bar{H}_o^*(q)}\!/_{dq}$. This is the case since either $\bar{h}_{ol}(q) = \bar{H}_{ol}(r_1) - \bar{H}_{ol}(r_2)$, for some r_1 and r_2 satisfying $r_1 + (1-\omega) r_2 = q$, or $\bar{h}_{ol}(q) = h_{ol}(q)$. In the former case, $\bar{h}_{ol}(q)$ converges to $\bar{h}_o^*(q) = {}^{d\bar{H}_o^*(q)}\!/_{dq}$ because $barH_{ol}$ converges to $\bar{H}_o^*$. In the later case, $\bar{h}_{ol}(q) = h_{ol}(q)$ must converge a.e. to $\bar{h}_o^*(q) = h_{ol}(q)$ since $\bar{H}_{ol}$ converges to $\bar{H}_o^*$.

Because $\bar{h}_{ol}(q)$ and $\bar{h}_{nl}(q)$ converge a.e. to $\bar{h}_o^*(q)$ and $\bar{h}_n^*(q)$, then we must have that the associated bid and ask sequences, $\{bid_{nl}\}_l$ and $\{ask_{ol}\}_l$, also converge a.e. to $ask_o^*(q)$ and $bid_n^*(q)$ since $ask_{ol} = \bar{h}_{nl}^{-1}(M_{nl}^{-1})$ and $bid_{nl} = \bar{h}_{ol}^{-1}(M_{ol}^{-1})$. Finally, note that both, profits given by (20), and distributions given by (21), are continuous functions of bid, asks, Φ and Δ. Since, by our initial assumption, the sequence $\{(\Delta_l, \Phi_l)\}_l \subset \mathcal{D} \times \mathcal{P}$ converges to $(\Delta^*, \Phi^*) \in \mathcal{D} \times \mathcal{P}$ a.e., and we just argued that $\{bid_{nl}\}_l$ and $\{ask_{ol}\}_l$ also converge a.e. to $ask_o^*(q)$ and $bid_n^*(q)$, then $\{(\hat{\Delta}_l, \hat{\Phi}_l)\}_l$ also converges to $T_j(\Delta^*, \Phi^*)$ almost everywhere. □

Finding the fixed point: For each j (where j is high enough so T_j is a well defined map), T_j is continuous. Since $\mathcal{D}_j \times \mathcal{P}_j$ is convex and compact and T_j is continuous, by the Schauder Fixed Point Theorem, there exists (Δ^j, Φ^j) such that $T_j(\Delta^j, \Phi^j) = (\Delta^j, \Phi^j)$.

Consider a sequence $\{\Delta^j, \Phi^j\}_j$ where $T_j(\Delta^j, \Phi^j) = (\Delta^j, \Phi^j)$. By the Arzelà-Ascoli theorem, $\{\Delta^j, \Phi^j\}_j$ has a converging sub-sequence since it has uniformly bounded derivatives and, therefore, is equicontinuous. Passing to a subsequence if necessary, let $(\Delta^*, \Phi_o^*) := \lim_j(\Delta^j, \Phi^j)$ and $\Phi_n^* = F - \Phi_o^*$. Since the space of polynomials is dense in $\mathcal{C}^1$, we have that Δ^* satisfies (20) with equality and Φ_o^* satisfies (21) with equality.

Define the sequence $\{\bar{H}_o^j, \bar{H}_n^j\}_j$ where, for each j, $\bar{H}_o^j$ and $\bar{H}_n^j$ are given by (27) and (32) using $\hat{M}_o^j$ and $\hat{M}_n^j$ defined for the operator T_j evaluated at the fixed point (Δ^j, Φ^j). Note that investors with negative reservation value won't hold assets in equilibrium. Also, for j high enough, for at least one i we have that $\Delta^j(\alpha_i, \bar{v}) > 0$. As a result, the support of $\hat{M}_o^j$ is an interval $[\max\{0, \min_i\{\Delta(\alpha_i, \underline{v})\}\}, \max_i\{\Delta(\alpha_i, \bar{v})\}]$, and the support of $\hat{M}_n^j$ is the interval $[\min_i\{\Delta(\alpha_i, \underline{v})\}, \max_i\{\Delta(\alpha_i, \bar{v})\}]$. We know that,we can take j sufficiently high so $\{d\bar{H}_o^j/dq, d\bar{H}_n^j/dq\}_j$ are uniformly bounded by

$$\underline{\Delta} - \frac{1}{\mu \inf\{f(\theta)\}/(\lambda+\eta+\mu)} \quad \text{and} \quad \bar{\Delta} + \frac{1}{(\lambda+\eta)\inf\{f(\theta)\}/(\lambda+\eta+\mu)}.$$

As a result, passing to a subsequence if necessary, let $(\bar{H}_o^*, \bar{H}_n^*) := \lim_j(\bar{H}_o^j, \bar{H}_n^j)$.

Constructing the equilibrium: Let us define $\{bid^*, ask^*, \Delta^*, \phi_o^*, \phi_n^*, s^*\}$ in the following way. We know that $\bar{H}_o^*$ and $\bar{H}_n^*$ are convex since they are the limit of convex functions. Therefore, we can define the bid and ask functions, bid^* and ask^*, using propositions 10 and 12. Let ϕ_o^* and ϕ_n^* be the densities associated with the limits Φ_o^* and Φ_n^* discussed above, and $s^* = \Phi_o^*(1, \bar{v})$.

Verifying the equilibrium conditions:

(i) Let us show that the ask price function $ask(\Delta_o)$ solves the owner's problem (1), and the bid price function $bid(\Delta_n)$ solves the non-owner's problem (2), using a counter-positive argument. If the ask price function $ask^*(\Delta_o)$ does not solve the owner's problem (1), then there is an alternative ask price $\hat{ask}$ that generates a strictly higher profit. Since the distribution of reservation values of non-owners, $\hat{M}_n^j$, converges to M_n^*, it must be the case that $\hat{ask}$ also generates a strictly higher profit for the distribution $\hat{M}_n^j$ than the associated $ask^j(\Delta_o)$, which converges to $ask^*(\Delta_o)$. We know that the last statement is false—by construction, $ask^j(\Delta_o)$ maximizes profits. Therefore, the first statement mus be false and we conclude that the ask price function $ask^*(\Delta_o)$ does solve the owner's problem (1). The argument for $bid^*(\Delta_n)$ is analogous.

(ii) First note that Δ^* is a fixed point of (20), which is equivalent to (7). Note also that π_o and π_n, in (20), are given by (3) and (4). We can then conclude that (20) and (7) coincide since we already showed that $ask^*(\Delta_o)$ and $bid^*(\Delta_n)$ are optimal and, therefore, generate the same profits π_o and π_n.

(iii) The density in (21) is just a rewriting of (8) with $\dot{\phi}_o = 0$. Moreover, ϕ_n^* is defined according to (12), and the stock of assets s^* is defined according to (13).

This concludes the proof for the economy with preference types truncated between $\underline{v}$ and $\bar{v}$. Since $\sum_i \int v^2 f(\alpha_i, v) dv < \infty$, it is straightforward to show that the equilibrium of the truncated economy converges to an equilibrium of the original economy as $\bar{v}$ goes to infinity and $\underline{v}$ goes to minus infinity. □

Proof of Proposition 2. First let us state the following lemma.

Lemma 4. *In any symmetric steady-state equilibrium* $\{bid, ask, \Delta, \phi_o, \phi_n, s\}$, *we have that* $\Delta(\cdot)$ *is strictly increasing in* ν.

Proof. For the proof, just note that

$$\Delta(\theta) = \nu - (\mu + \eta \mathbb{1}_{\{\Delta(\theta)\geq 0\}})\Delta(\theta) + \lambda(1-s)\pi_o(\theta) - \lambda s \pi_n(\theta). \tag{23}$$

The above equation must be strictly increasing otherwise the left-hand side of (23) would be decreasing and the right-hand side would be strictly increasing (this by itself is a consequence of π_o been decreasing and π_n increasing in Δ). ☐

First consider the owner's probability to sell an asset in a meeting. From s (11) and (9), we have that

$$\bar{q}_o(\theta) - \bar{q}_o(\hat{\theta}) = (\alpha - \hat{\alpha}) \int \mathbb{1}_{\{ask_o > \Delta_n \geq \Delta_o\}} \phi_n(\theta_n) d\theta_n \geq 0.$$

Since $\Delta(\cdot)$ is continuous and strictly increasing, and $\phi_n(\tilde{\theta})$ is bounded below by $\frac{\mu f(\tilde{\theta})}{\lambda+\mu+\eta}$ for all $\tilde{\theta}$, the distribution of reservation values of non-owners, M_n, satisfies the conditions in Corollary 1. Therefore, trade probabilities must be distorted in meeting where the seller does not know the type of the counterparty.

The proof for the non-owner's case follow a similar logic. The difference is that, in equilibrium, ϕ_o is zero when $\Delta(\theta) < 0$. This implies that non-owners with reservation value below zero all have zero probability to buy an asset. That is why the strict inequality only holds when $\Delta(\theta) = \Delta(\hat{\theta}) > 0$. ☐

Proof of Corollary 3. The result is immediate since speed is λ times q_o/q_n. ☐

Proof of Proposition 3. We can write $\pi_o(\theta) - \pi_o(\hat{\theta})$ from (3) as

$$\begin{aligned}\pi_o(\theta) - \pi_o(\hat{\theta}) &= (\alpha - \hat{\alpha}) \int (\Delta_n - \Delta_o) \mathbb{1}_{\{\Delta_n \geq \Delta_o\}} - (ask_o - \Delta_o) \mathbb{1}_{\{\Delta_n \geq ask_o\}} d\frac{\Phi_n}{1-s} \\ &= (\alpha - \hat{\alpha}) \int (\Delta_n - ask_o) \mathbb{1}_{\{\Delta_n \geq ask_o\}} + (\Delta_n - \Delta_o) \mathbb{1}_{\{ask_o > \Delta_n \geq \Delta_o\}} d\frac{\Phi_n}{1-s} > 0.\end{aligned}$$

Therefore, $\alpha > \hat{\alpha}$ implies $\pi_o(\theta) > \pi_o(\hat{\theta})$. The argument for π_n is analogous. The only difference for π_n is that, in equilibrium, ϕ_n is zero when $\Delta(\theta) < 0$. This implies that non-owners with reservation value below zero all have zero probability to buy an asset. That is why the strict inequality only holds when $\Delta(\theta) = \Delta(\hat{\theta}) > 0$. $\square$

Proof of Proposition 4. Consider the case with $\xi_o = 1$ and suppose, by the way of contradiction, that $\Delta(\theta)$ is decreasing in α.

We can write $\pi_o(\theta)$ from (3) as

$$\pi_o(\theta) = \int \alpha\,(\Delta_n - \Delta)\,\mathbb{1}_{\{\Delta_n \geq \Delta\}} + (1-\alpha)\,(ask - \Delta)\,\mathbb{1}_{\{\Delta_n \geq ask\}} d\frac{\Phi_n}{1-s}$$

From the above expression we can see that $\pi_o(\theta)$, as a function of α and Δ, is strictly increasing in α and decreasing in Δ. Therefore, since we assumed by contradiction that $\Delta(\theta)$ is decreasing in α, we conclude that $\pi_o(\theta)$ is strictly increasing in α.

Similarly, we can write $\pi_n(\theta)$ from (4) as

$$\pi_n(\theta) = \int (1-\alpha_o)[\Delta - ask_o]\mathbb{1}_{\{\Delta \geq ask_o\}} d\frac{\Phi_o}{s}.$$

From the above expression, we can see that $\pi_n(\theta)$ is constant in α and increasing in Δ. Therefore, since we assumed by contradiction that $\Delta(\theta)$ is decreasing in α, we conclude that $\pi_n(\theta)$ is decreasing in α.

Now let us look at the for Δ,

$$(r+\mu)\Delta(\theta) + \eta \max\{\Delta(\theta), 0\} = \nu + \lambda(1-s)\pi_o(\theta) - \lambda s \pi_n(\theta).$$

By assumption the left-hand side of the above equation is decreasing in α, while we concluded that the right-hand side is strictly increasing—a contradiction. Therefore, $\Delta(\theta)$ is strictly increasing in α. The proof for $\xi_n = 1$ is analogous. $\square$

Proof of Proposition 5. If $\Delta(\theta) = \Delta(\theta) < 0$, then in a stationary equilibrium we must have that $\phi_o(\theta) = 0$ and $\bar{q}_n(\theta) = 0$. That is, there is no owner with negative reservation value holding assets in equilibrium because they would not issue new assets nor buy from investors with non-negative reservation value. So any existing assets would mature and disappear. This implies that $c(\theta) = c(\hat{\theta}) = 0$ when $\Delta(\theta) = \Delta(\theta) < 0$.

For $\Delta(\theta) = \Delta(\theta) \geq 0$ we have the following. Replacing the equilibrium condition of ϕ_o and ϕ_n in (14) we obtain

$$c(\theta) = \frac{\lambda}{2Vol} \times \frac{[\eta + \lambda \bar{q}_n(\theta)]\bar{q}_o(\theta) + [\mu + \lambda \bar{q}_o(\theta)]\bar{q}_n(\theta)}{\eta + \mu + \lambda[\bar{q}_o(\theta) + \bar{q}_n(\theta)]},$$

It is easy to verify that $\frac{[\eta+\lambda\bar{q}_n(\theta)]\bar{q}_o(\theta)+[\mu+\lambda\bar{q}_o(\theta)]\bar{q}_n(\theta)}{\eta+\mu+\lambda[\bar{q}_o(\theta)+\bar{q}_n(\theta)]}$ is strictly increasing in $\bar{q}_o(\theta)$ and $\bar{q}_n(\theta)$, and, from Proposition 2, we know that $\bar{q}_o(\theta) > \bar{q}_o(\hat{\theta})$ and $\bar{q}_n(\theta) \geq \bar{q}_n(\hat{\theta})$. Therefore, we conclude that $c(\theta) > c(\hat{\theta})$. □

Proof of Proposition 6. It is easy to see that the most central investor cannot satisfy $\Delta(\theta^*) < 0$ since that would imply $c(\theta^*) = 0$. Then, we must $\Delta(\theta^*) \geq 0$. This implies that α^* equals 1, otherwise we could pick θ' such that $\alpha' = 1$ and $\Delta(\theta') = \Delta(\theta^*)$. Then, by Proposition 5, we would have $c(\theta') > c(\theta^*)$—a contradiction. By a similar argument, we must also $c(\theta^*) > c(\theta)$ for any θ such that $\alpha < \alpha^* = 1$. □

Proof of Proposition 7. We can consider two cases. If $\sup_{\theta\in\Theta}\{c(\theta)\} > \sup_{\theta\in\Theta}\{c(\theta);\ s.t.\ \alpha \leq \alpha_{I-1}\}$, the results is trivial. For any θ, $c(\theta) \geq \underline{c}$ implies that $c(\theta) > \sup_{\theta\in\Theta}\{c(\theta);\ s.t.\ \alpha \leq \alpha_{I-1}\}$. Therefore, by the definition of sup, we cannot have $\alpha \leq \alpha_{I-1}$. If $\sup_{\theta\in\Theta}\{c(\theta)\} = \sup_{\theta\in\Theta}\{c(\theta);\ s.t.\ \alpha \leq \alpha_{I-1}\}$, then $c(\theta) \geq \underline{c}$ implies that $c(\theta) = \sup_{\theta\in\Theta}\{c(\theta);\ s.t.\ \alpha \leq \alpha_{I-1}\}$. But this is a contradiction since, by Proposition 5, there would exist θ' such that $\alpha' = 1$, $\Delta(\theta') = \Delta(\theta)$ and $c(\theta') > c(\theta) \geq \underline{c} = \sup_{\theta\in\Theta}\{c(\theta)\}$. □

Proof of Proposition 8. Pick any $\theta = (\alpha, \nu)$ such that $\Delta(\theta) > 0$. First, let us consider the case where $\alpha = \alpha_h$. Then, the investor buys an asset with probability one whenever he has the bargaining power and there are gains from trade. In the same way, he sells an asset with probability one whenever he has the bargaining power and there are gains from trade. For any other $\hat{\theta}$, either we have $\Delta(\theta) > \Delta(\hat{\theta})$, $\Delta(\theta) < \Delta(\hat{\theta})$ or $\Delta(\theta) = \Delta(\hat{\theta})$. The measure of cases in which $\Delta(\theta) = \Delta(\hat{\theta})$ is zero. In the other two cases, we have that $q(\theta, \hat{\theta})$ is bounded below by $\xi_o > 0$ and $q(\hat{\theta}, \theta)$ is bounded below by $\xi_n > 0$. So we can conclude that $np(\theta) = 1$.

Now, let us consider the case where $\alpha = \alpha_l$. Then, by lemma 1, we know that $ask_o(\alpha_l, \Delta(\theta)) > \Delta(\theta)$. Define $\theta_\epsilon = \theta + (\alpha, \nu) = (\alpha, nu + \epsilon)$. Note that we can take $\bar{\epsilon} > 0$ small enough such that $bid_n(\alpha_l, \Delta(\theta_\epsilon)) < \Delta(\theta)$ for all $\epsilon \in (0, \bar{\epsilon})$. That is because the objective function that defines the bid is continuous and $bid_n(\alpha_l, \Delta(\theta_\epsilon))$ is increasing in the reservation value, which is increasing in ν. As a result, the investor type $\theta = (\alpha, \nu)$ won't sell or buy to any investor type θ_ϵ for $\epsilon \in (0, \bar{\epsilon})$. Since F has positive density everywhere, we then have that $np(\theta) < 1$. □

B Appendix: Optimal Mechanisms

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B.1 The optimal selling mechanism as an ask price

We conjectured that it is optimal for the owner to use an ask price to sell the asset when she does not observe the type of the non-owner in a meeting. In this section, we show that an ask price is in fact an optimal selling mechanism for the owner.

To keep the presentation simple, we assume for now that the distribution of reservation values of non-owners, $M_n(\cdot; \alpha_n)$, has a non-empty support $[\underline{\Delta}, \bar{\Delta}]$ and a continuous density $m_n(\cdot; \alpha_n)$ which is bounded away from zero. In the equilibrium we construct, these conditions may not hold but using an ask price is still optimal. We omit the argument α_n from $M_n(\cdot; \alpha_n)$ and $m_n(\cdot; \alpha_n)$ to keep the notation short.

Owners choose a mechanism to maximize their expected gains from trade. It is without loss of generality to focus on direct mechanisms due to the revelation principle. A direct mechanism for an owner with reservation value Δ_o is a pair of functions $m = (p, x) : [\underline{\Delta}, \bar{\Delta}] \to [0, 1] \times \mathbb{R}$, where, for given reservation value Δ_n of the non-owner, $p(\Delta_n)$ represents the probability of transferring the asset from the owner to the non-owner, and $x(\Delta_n)$ represents the transfer from the non-owner to the owner. The problem of an owner with reservation value Δ_o is

$$\max_m \int [x(\Delta_n) - p(\Delta_n)\Delta_o] \, m_n(\Delta_n) d\Delta_n \tag{24}$$

subject to

$$IR: \quad p(\Delta_n)\Delta_n - x(\Delta_n); \geq 0 \text{ and} \tag{25}$$

$$IC: \quad p(\Delta_n)\Delta_n - x(\Delta_n) \geq p(\hat{\Delta}_n)\Delta_n - x(\hat{\Delta}_n); \tag{26}$$

for all Δ_n and $\hat{\Delta}_n$.

The solution to the problem (24)-(26) is associated with an ask price. Define the functions

$$\bar{H}_n(q) = \min_{\substack{\omega, r_1, r_2 \\ \omega r_1 + (1-\omega) r_2 = q}} \{\omega H_n(r) + (1-\omega) H_n(r)\} \text{ and } \bar{h}_n(q) = \frac{d\bar{H}_n(q)}{dq}, \tag{27}$$

where $h_n(q) = M_n^{-1}(q) - \frac{1-q}{m_n(M_n^{-1}(q))}$ and $H_n(q) = \int_0^q h_n(r)dr$.

Proposition 10. *Let the distribution of non-owners, M_n, have a non-empty support $[\underline{\Delta}, \bar{\Delta}]$ and a continuous density m_n that is bounded away from zero. Define the functions*

$$c_n(\Delta) = \bar{h}_n\left(M_n(\Delta)\right) \quad \text{and} \quad c_n^{-1}(\Delta) = \inf\{\Delta_n \in [\underline{\Delta}, \bar{\Delta}]; c_n(\Delta_n) \geq \Delta\}.$$

Then, for given $\Delta_o \in [\underline{\Delta}, \bar{\Delta}]$ the direct mechanism

$$m(\Delta_n) = \big(p(\Delta_n), x(\Delta_n)\big) = \begin{cases} \big(1, c_n^{-1}(\Delta_o)\big) & \text{if } c_n(\Delta_n) \geq \Delta_o \\ (0,0) & \text{otherwise} \end{cases}$$

achieves the maximum in problem (28).

For the owner, asking the price $c_n^{-1}(\Delta_o)$ and selling the asset whenever the non-owner has a reservation value higher than the ask price is an optimal mechanism. Therefore, it coincides with the optimal ask price analyzed in Section 3.1.1.

B.1.1 Proof of Proposition 10

We start characterizing the solution to problem 24.

Proposition 11. *Let the distribution of non-owners, M_n, have a non-empty support $[\underline{\Delta}, \bar{\Delta}]$ and a continuous density m_n that is bounded away from zero. A direct mechanism $m^* = (p^*, x^*)$ solves problem (24) if, and only if, it solves problem*

$$\max_m \int p(\Delta_n) \left[\Delta_n - \frac{1 - M_n(\Delta_n)}{m_n(\Delta_n)} - \Delta_o\right] m_n(\Delta_n) d\Delta_n \tag{28}$$

subject to $p(\Delta_n)$ being increasing and $U(\Delta_n) := p(\Delta_n)\Delta_n - x(\Delta_n) = \int_{\underline{\Delta}}^{\Delta_n} p(\Delta) d\Delta$.

Proof. It is useful to begin by stating the following lemma.

Lemma 5. *A mechanism $m = (p, x)$ satisfies (25) and (26) if, and only if, $p(\Delta_n)$ is non-decreasing and $U(\Delta_n) = U(\underline{\Delta}) + \int_{\underline{\Delta}}^{\Delta_n} p(\Delta)d\Delta$ with $U(\underline{\Delta}) \geq 0$.*

Proof. Let us start showing the necessity part. The IC constraint (26) for a non-owner with reservation value Δ_n implies that

$$U(\Delta_n) \geq p(\hat{\Delta}_n)\Delta_n - x(\hat{\Delta}_n) = U(\hat{\Delta}_n) + p(\hat{\Delta}_n)[\Delta_n - \hat{\Delta}_n]$$
$$\implies U(\Delta_n) - U(\hat{\Delta}_n) \geq p(\hat{\Delta}_n)[\Delta_n - \hat{\Delta}_n].$$

The IC constraint (26) for a non-owner with reservation value $\hat{\Delta}_n$ implies that

$$U(\hat{\Delta}_n) - U(\Delta_n) \geq p(\Delta_n)[\hat{\Delta}_n - \Delta_n].$$

Reorganizing the two inequalities above, we have that

$$p(\Delta_n)[\Delta_n - \hat{\Delta}_n] \geq U(\Delta_n) - U(\hat{\Delta}_n) \geq p(\hat{\Delta}_n)[\Delta_n - \hat{\Delta}_n].$$

And we can conclude that p is non-decreasing. Moreover, because p is monotone, it has at most countable many discontinuities. Therefore,

$$p(\Delta_n) \geq \frac{U(\Delta_n) - U(\hat{\Delta}_n)}{\Delta_n - \hat{\Delta}_n} \geq p(\hat{\Delta}_n)$$

implies that U is differentiable almost everywhere and it must satisfy

$$U'(\Delta_n) = p(\Delta_n) \quad \implies \quad U(\Delta_n) = U(\underline{\Delta}) + \int_{\underline{\Delta}}^{\Delta_n} p(\Delta)d\Delta.$$

Because $m = (p, x)$ satisfies the IR constraint (25), $U(\Delta_n) \geq 0$ for all Δ_n. Hence, we must have that $U(\underline{\Delta}) \geq 0$.

For the sufficient part, first that, if $U(\Delta_n) = U(\underline{\Delta}) + \int_{\underline{\Delta}}^{\Delta_n} p(\Delta)d\Delta$ and $U(\underline{\Delta}) \geq 0$, then $U(\Delta_n) \geq 0$ for all Δ_n since $p(\Delta_n) \in [0, 1]$. Hence, the mechanism satisfies individual rationality. For incentive compatibility note that

$$U(\Delta_n) - U(\hat{\Delta}_n) = \int_{\hat{\Delta}_n}^{\Delta_n} p(\Delta)d\Delta_n.$$

Since p is non-decreasing, we have that

$$U(\Delta_n) \geq U(\hat{\Delta}_n) + p(\hat{\Delta}_n)[\Delta_n - \hat{\Delta}_n] \implies U(\Delta_n) \geq p(\hat{\Delta}_n)\Delta_n - x(\hat{\Delta}_n).$$

That is, the IC constraint (26) is satisfied. This concludes the proof of the lemma.

□

Now we can prove proposition 11. Using Lemma 5, we can rewrite the objective function given by problem (24) as

$$\int [x(\Delta_n) - p(\Delta_n)\Delta_o]\, m_n(\Delta_n) d\Delta_n =$$
$$\int p(\Delta_n)\, [\Delta_n - \Delta_o]\, m_n(\Delta_n) d\Delta_n - \int U(\Delta_n) m_n(\Delta_n) d\Delta_n =$$
$$\int p(\Delta_n)\, [\Delta_n - \Delta_o]\, m_n(\Delta_n) d\Delta_n - \int \int_{\underline{\Delta}}^{\Delta_n} p(\Delta) d\Delta m_n(\Delta_n) d\Delta_n - U(\underline{\Delta}).$$

We can then apply integration by parts in the following term

$$\int_{\underline{\Delta}}^{\bar{\Delta}} \int_{\underline{\Delta}}^{\Delta_n} p(\Delta) d\Delta m_n(\Delta_n) d\Delta_n$$
$$= \int_{\underline{\Delta}}^{\Delta_n} p(\Delta) d\Delta M_n(\Delta_n) \Big|_{\underline{\Delta}}^{\bar{\Delta}} - \int p(\Delta_n) M_n(\Delta_n) d\Delta_n = \int p(\Delta_n)[1 - M_n(\Delta_n)] d\Delta_n.$$

Combining the above equations, we have that the objective function is

$$\int p(\Delta_n) \left[\Delta_n - \frac{1 - M_n(\Delta_n)}{m_n(\Delta_n)} - \Delta_o\right] m_n(\Delta_n) d\Delta_n - U(\underline{\Delta}).$$

For the last, by Lemma 6, for the mechanism to satisfy the IC constraint we must have that $p(\Delta_n)$ is non-creasing. This concludes the proof of the proposition. □

Now we can prove proposition 10.

Proof. We can write the objective function as

$$\int p(\Delta_n) \left[\Delta_n - \frac{1 - M_n(\Delta_n)}{m_n(\Delta_n)} - \Delta_o\right] dM_n = \int p(\Delta_n)\, [h_n(M_n(\Delta_n)) - \Delta_o]\, dM_n$$
$$= \int p(\Delta_n)\, [c_n(\Delta_n) - \Delta_o]\, dM_n + \int p(\Delta_n) \left[h_n(M_n(\Delta_n)) - \bar{h}_n(M_n(\Delta_n))\right] dM_n.$$

Let us consider the last term of the above equation.

$$\int p(\Delta_n) \left[h_n(M_n(\Delta_n)) - \bar{h}_n(M_n(\Delta_n))\right] dM_n$$
$$= p(\Delta_n)\, [H_n(M_n(\Delta_n)) - \bar{H}_n(M_n(\Delta_n))]_{\underline{\Delta}}^{\bar{\Delta}} - \int [H_n(M_n(\Delta_n)) - \bar{H}_n(M_n(\Delta_n))]\, dp(\Delta_n).$$

Since $\bar{H}_n$ is the convex-hull of H_n, they coincide at the boundary points $\underline{\Delta}$ and $\bar{\Delta}$, and we conclude that the first term of the final expression is equal to 0. The objective function equals

$$\int p(\Delta_n)\left[c_n(\Delta_n) - \Delta_o\right] dM_n - \int \left[H_n(M_n(\Delta_n)) - \bar{H}_n(M_n(\Delta_n))\right] dp(\Delta_n).$$

It is easy to see that our proposed mechanism maximizes the first term since, by construction, $p(\Delta_n) = 1$ whenever $c_n(\Delta_n) \geq \Delta_o$. Also, the proposed mechanism maximizes the second term. To see this, note that the second term is nonpositive for any weakly increasing $p(\Delta_n)$. In our proposed mechanism, this term is exactly zero because whenever $H_n(M_n(\Delta_n)) - \bar{H}_n(M_n(\Delta_n)) > 0$ the derivative $g(q) = \frac{\bar{H}_n G(q)}{dq}$ is constant due the convex hull and, as a result, $dp(\Delta_n)$ is zero. Thus, the proposed mechanism achieves the maximum in problem (28). □

B.2 The optimal buying mechanism as a bid price

We conjectured that it is optimal for the non-owner to use a bid price to sell the asset when she does not observe the type of the owner in the meeting. In this section, we show that a bid price is the optimal mechanism for the non-owner.

Similar to subsection B.1, to keep the presentation simple, we assume the distribution of reservation values of owners, $M_o(\cdot;\alpha_o)$, has a non-empty support $[\underline{\Delta}, \bar{\Delta}]$ and a continuous density $m_o(\cdot;\alpha_o)$. The results do not depend on these conditions in equilibrium. We also omit the argument α_o from $M_o(\cdot;\alpha_o)$ and $m_o(\cdot;\alpha_o)$ to keep the notation short.

Non-owners choose a mechanism to maximize their expected gains from trade. Without loss of generality, we focus on direct mechanisms due to the revelation principle. As before, a direct mechanism is a pair of functions $m = (p, x)$: $[\underline{\Delta}, \bar{\Delta}] \to [0, 1] \times \mathbb{R}$, where, for given reservation value Δ_o of the owner, $p(\Delta_o)$ represents the probability of transferring the asset from the owner to the non-owner, and $x(\Delta_o)$ represents the transfer from the non-owner to the owner. The problem of a non-owner with reservation value Δ_n is

$$\max_m \int \left[p(\Delta_o)\Delta_n - x(\Delta_o)\right] m_o(\Delta_o) d\Delta_o \tag{29}$$

subject to

$$IR: \quad x(\Delta_o) - p(\Delta_o)\Delta_o \geq 0 \text{ and} \tag{30}$$

$$IC: \quad x(\Delta_o) - p(\Delta_o)\Delta_o \geq x(\hat{\Delta}_o) - p(\hat{\Delta}_o)\Delta_o; \tag{31}$$

for all Δ_o and $\hat{\Delta}_o$.

The solution to problem (29) - (31) is associated with a bid price. Define the functions

$$\bar{H}_o(q) = \min_{\substack{\omega, r_1, r_2 \\ \omega r_1 + (1-\omega) r_2 = q}} \{\omega H_o(r) + (1-\omega) H_o(r)\}, \quad \bar{h}_o(q) = \frac{d\bar{H}_o(q)}{dq} \tag{32}$$

where $h_o(q) = M_o^{-1}(q) + \frac{q}{m_o(M_o^{-1}(q))}$ and $H_o(q) = \int_0^q h_o(r)dr$.

Proposition 12. *Let the distribution of owners, M_o, have a non-empty support $[\underline{\Delta}, \bar{\Delta}]$ and a continuous density m_o. Define the functions*

$$c_o(\Delta) = \bar{h}_o(M_o(\Delta)) \quad \text{and} \quad c_o^{-1}(\Delta) = \sup\{\Delta_o \in [\underline{\Delta}, \bar{\Delta}]; c_o(\Delta_o) \leq \Delta\}.$$

Then, for given $\Delta_n \in [\underline{\Delta}, \bar{\Delta}]$ the direct mechanism

$$m(\Delta_o) = \big(p(\Delta_o), x(\Delta_o)\big) = \begin{cases} \big(1, c_o^{-1}(\Delta_n)\big) & \text{if } c_o(\Delta_o) \leq \Delta_n \\ (0,0) & \text{otherwise} \end{cases}$$

achieves the maximum in problem (33).

For the non-owner, biding the price $c_o^{-1}(\Delta_n)$ and buying the asset whenever the owner has a reservation value lower than the bid price is an optimal mechanism. Therefore, it coincides with the optimal bid price analyzed in Section 3.1.2.

B.2.1 Proof of Proposition 12

We start characterizing the solution to problem 29.

Proposition 13. *Let the distribution of non-owners, M_o, have a non-empty support $[\underline{\Delta}, \bar{\Delta}]$ and a continuous density m_o. A direct mechanism $m^* = (p^*, x^*)$ solves problem (29) if, and only if, it solves problem*

$$\max_m \int p(\Delta_o) \left[\Delta_n - \Delta_o - \frac{M_o(\Delta_o)}{m_o(\Delta_o)}\right] m_o(\Delta_o) d\Delta_o \tag{33}$$

subject to $p(\Delta_n)$ being decreasing and $U(\Delta_n) := x(\Delta_o) - p(\Delta_o)\Delta_o = \int_{\Delta_o}^{\bar{\Delta}} p(\Delta)d\Delta$.

Proof. It is useful to begin by stating the following lemma.

Lemma 6. *A mechanism $m = (p, x)$ satisfies (30) and (31) if, and only if, $p(\Delta_n)$ is decreasing and $U(\Delta_n) = U(\underline{\Delta}) + \int_{\Delta_o}^{\bar{\Delta}} p(\Delta)d\Delta$ with $U(\underline{\Delta}) \geq 0$.*

Proof. Let us start showing the necessity part. The IC constraint (31) for an owner with reservation value Δ_o implies that

$$U(\Delta_o) \geq x(\hat{\Delta}_o) - p(\hat{\Delta}_o)\Delta_o = U(\hat{\Delta}_o) - p(\hat{\Delta}_o)[\Delta_o - \hat{\Delta}_o]$$
$$\implies U(\Delta_o) - U(\hat{\Delta}_o) \geq -p(\hat{\Delta}_o)[\Delta_o - \hat{\Delta}_o].$$

The IC constraint (31) for an owner with reservation value $\hat{\Delta}_o$ implies that

$$U(\hat{\Delta}_o) - U(\Delta_o) \geq -p(\Delta_o)[\hat{\Delta}_o - \Delta_o].$$

Reorganizing the two inequalities above, we have that

$$-p(\Delta_o)[\Delta_o - \hat{\Delta}_o] \geq U(\Delta_o) - U(\hat{\Delta}_o) \geq -p(\hat{\Delta}_o)[\Delta_o - \hat{\Delta}_o].$$

And we can conclude that p is decreasing. Moreover, because p is monotone, it has at most countable many discontinuities. Therefore,

$$-p(\Delta_o) \geq \frac{U(\Delta_o) - U(\hat{\Delta}_o)}{\Delta_o - \hat{\Delta}_o} \geq -p(\hat{\Delta}_o)$$

implies that U is differentiable almost everywhere and it must satisfy

$$U'(\Delta_o) = -p(\Delta_o) \quad \implies \quad U(\Delta_o) = U(\bar{\Delta}) + \int_{\Delta_o}^{\underline{\Delta}} p(\Delta)d\Delta.$$

Because $m = (p, x)$ satisfies the IR constraint (30), $U(\Delta_o) \geq 0$ for all Δ_o. Hence, we must have that $U(\bar{\Delta}) \geq 0$.

For the sufficient part, note that, if $U(\Delta_o) = U(\bar{\Delta}) + \int_{\Delta_o}^{\underline{\Delta}} p(\Delta)d\Delta$ and $U(\bar{\Delta}) \geq 0$, then $U(\Delta_o) \geq 0$ for all Δ_n since $p(\Delta_n) \in [0, 1]$. Hence, the mechanism satisfies individual rationality. For incentive compatibility note that

$$U(\Delta_o) - U(\hat{\Delta}_o) = -\int_{\hat{\Delta}_o}^{\Delta_o} p(\Delta)d\Delta_n.$$

Since p is decreasing, we have that

$$U(\Delta_o) \geq U(\hat{\Delta}_o) - p(\hat{\Delta}_o)[\Delta_o - \hat{\Delta}_o] \implies U(\Delta_n) \geq x(\hat{\Delta}_o) - p(\hat{\Delta}_o)\Delta_o.$$

That is, the IC constraint (31) is satisfied. This concludes the proof of the lemma.

□

Now we can prove proposition 13. Using Lemma 6, we can rewrite the objective function given by problem (29) as

$$\int [p(\Delta_o)\Delta_n - x(\Delta_o)]\, m_o(\Delta_o)d\Delta_o =$$
$$\int p(\Delta_o)\,[\Delta_n - \Delta_o]\, m_o(\Delta_o)d\Delta_o - \int U(\Delta_o)m_o(\Delta_o)d\Delta_o =$$
$$\int p(\Delta_o)\,[\Delta_n - \Delta_o]\, m_o(\Delta_o)d\Delta_o - \int \int_{\Delta_o}^{\bar{\Delta}} p(\Delta)d\Delta m_o(\Delta_o)d\Delta_o - U(\bar{\Delta})$$

We can then apply integration by parts in the following term

$$\int_{\underline{\Delta}}^{\bar{\Delta}} \int_{\Delta_o}^{\bar{\Delta}} p(\Delta)d\Delta m_o(\Delta_o)d\Delta_o$$
$$= \int_{\Delta_o}^{\bar{\Delta}} p(\Delta)d\Delta M_o(\Delta_o)\Big|_{\underline{\Delta}}^{\bar{\Delta}} + \int p(\Delta_o)M_o(\Delta_o)d\Delta_o = \int p(\Delta_o)M_o(\Delta_o)d\Delta_o.$$

Combining the above equations, we have that the objective function is

$$\int p(\Delta_o)\left[\Delta_n - \Delta_o - \frac{M_o(\Delta_o)}{m_o(\Delta_o)}\right] m_o(\Delta_o)d\Delta_o - U(\bar{\Delta}).$$

For the last, by Lemma 6, for the mechanism to satisfy the IC constraint we must have that $p(\Delta_o)$ is decreasing. This concludes the proof of the proposition. □

Now we can prove proposition 12.

Proof. We can write the objective function as

$$\int p(\Delta_o)\left[\Delta_n - \Delta_o - \frac{M_o(\Delta_o)}{m_o(\Delta_o)}\right] m_o(\Delta_o)d\Delta_o = \int p(\Delta_o)\,[\Delta_n - h_o(M_o(\Delta_o))]\, dM_o$$
$$= \int p(\Delta_o)\,[\Delta_n - c_o(\Delta_o)]\, dM_o - \int p(\Delta_o)\left[h_o(M_o(\Delta_o)) - \bar{h}_o(M_o(\Delta_o))\right] dM_o.$$

Let us consider the last term of the above equation.

$$\int p(\Delta_o)\left[h_o(M_o(\Delta_o)) - \bar{h}_o(M_o(\Delta_o))\right] dM_o$$
$$= p(\Delta_o)\,[H_o(M_o(\Delta_o)) - \bar{H}_o(M_o(\Delta_o))]_{\underline{\Delta}}^{\bar{\Delta}} - \int [H_o(M_o(\Delta_o)) - \bar{H}_o(M_o(\Delta_o))]\, dp(\Delta_o).$$

Since $\bar{H}_o$ is the convex-hull of H_o, they coincide at the boundary points $\underline{\Delta}$ and $\bar{\Delta}$, and we conclude that the first term of the final expression is equal to 0. The objective function equals

$$\int p(\Delta_o)\,[\Delta_n - c_o(\Delta_o)]\,dM_o + \int [H_o(M_o(\Delta_o)) - \bar{H}_o(M_o(\Delta_o))]\,dp(\Delta_o).$$

It is easy to see that our proposed mechanism maximizes the first term since, by construction, $p(\Delta_o) = 1$ whenever $\Delta_n \geq c_o(\Delta_o)$. Also, the proposed mechanism maximizes the second term. To see this, note that the second term is nonpositive for any weakly decreasing $p(\Delta_o)$. In our proposed mechanism, this term is exactly zero because whenever $H_o(M_o(\Delta_o)) - \bar{H}_o(M_o(\Delta_o)) > 0$ the derivative $h_o(q) = \frac{\bar{H}_o(q)}{dq}$ is constant due the convex hull and, as a result, $dp(\Delta_o)$ is zero. Thus, the proposed mechanism achieves the maximum in problem (33). □

B.3 An alternative trade mechanism

In this section, we explore a mechanism that maximizes the expected trade surplus in the bilateral meeting, as in Myerson and Satterthwaite (1983). The mechanism we currently use—ask and bid prices that maximize the owner's and non-owner's expected surplus, respectively—does not maximize trade surplus for two reasons. The first reason is the following. Consider a meeting where the owner designs the trade mechanism, but she does not observe the type of the non-owner, while the non-owner does observe the type of the owner. In this case, the owner will distort trade in order to maximize her trade profits, as described in Corollary 1. However, if the non-owner would have been chosen to design the mechanism, trade surplus would have been maximized, as the non-owner observes the type of the owner.

The second reason the mechanism we use does not maximize trade surplus relates to the incentives faced by investors. In a meeting where both owner and non-owner do not observe the type of their counterparty, Myerson and Satterthwaite (1983) show that there is no mechanism that implements the ex-post efficient allocation. When either owner or non-owner is chosen to design the trade mechanism—the owner with probability ξ_o or the non-owner with probability ξ_n—they are both willing to give up total surplus in order to maximize their individual surplus.

Whenever owner or non-owner observes the type of their trade counterparty, ex-post efficiency can be achieved by assigning all the gains from trade to the informed party. When neither side is informed, the trade mechanism used is the one in Myerson and Satterthwaite (1983). We show our main results remain unchanged using this alternative mechanism.[24]

B.3.1 Bilateral trade

We consider a mechanism that maximizes the total gains from trade, or trade surplus, in a meeting. In any meeting, there are four possible information structures:

i. both owner and non-owner know each other types;

ii. the owner knows the non-owner's type and the non-owner does not know the owner's type;

iii. the owner does not know the the non-owner's type and the non-owner knows the owner's type; and

iv. neither owner or non-owner know each other types.

In case i, we can directly apply Nash bargaining since we have complete information. In this case, we use the same notation as before to represent the bargaining power of investors, with ξ_o denoting the owner's bargaining power and $\xi_n = 1 - \xi_o$ denotes the non-owner's bargaining power. In case ii, to maximize the total surplus in the trade the mechanism just gives all the bargain power to the owner. Since the owner knows the type of the non-owner, she will sell the asset whenever the reservation value of the non-owner is above her own and will extract all the surplus. In a similar way, in case iii, the mechanism just gives all the bargain power to the non-owner. Since the non-owner knows the type of the owner, she will buy the asset whenever the reservation value of the owner is below her own and will extract all the surplus in the trade.

In case iv, we have two-sided incomplete information so we apply the mechanism propose by Myerson and Satterthwaite (1983), which maximizes the expected gains from trade in a meeting. In order to characterize the outcomes from such mechanism, it is without loss of generality to focus on direct mechanisms due to the revelation principle. A direct mechanism is a pair of functions $m = (p, x)$:

[24] All proofs in this section are variations of previous proofs or directly derived from Myerson and Satterthwaite (1983), so we omit these proofs here. They are available upon request.

$[\underline{\Delta}, \bar{\Delta}] \times [\underline{\Delta}, \bar{\Delta}] \rightarrow [0,1] \times \mathbb{R}$, where, for given reservation values Δ_o and Δ_n of owner and non-owner, $p(\Delta_o, \Delta_n)$ is the probability of transferring the asset from the owner to the non-owner, and $x(\Delta_o, \Delta_n)$ is the transfer from the non-owner to the owner. The mechanisms are also going to be a function of the screening expertise α_o and α_n in equilibrium, but we omit this argument here to keep the notation short.

Let $M_o(\cdot; \alpha_o)$ and $M_n(\cdot; \alpha_n)$ be the cumulative distribution of reservation values of owner and non-owner conditional on α_o and α_n, and $m_o(\cdot; \alpha_o)$ and $m_n(\cdot; \alpha_n)$ the respective densities. As before, we omit the argument α_o and α_n from the distributions above to keep the notation short. The mechanism that maximizes the expected gains from trade in the meeting solves

$$\max_{m} \int \int p(\Delta_o, \Delta_n) \left[\Delta_n - \Delta_o\right] dM_o(\Delta_o) dM_n(\Delta_n) \tag{34}$$

subject to

$$IR_o: \quad x_o(\Delta_o) - p_o(\Delta_o)\Delta_o \geq 0; \tag{35}$$

$$IC_o: \quad x_o(\Delta_o) - p_o(\Delta_o)\Delta_o \geq x_o(\hat{\Delta}_o) - p_o(\hat{\Delta}_o)\Delta_o; \tag{36}$$

$$IR_n: \quad p_n(\Delta_n)\Delta_n - x_n(\Delta_n) \geq 0 \text{ and} \tag{37}$$

$$IC_n: \quad p_n(\Delta_n)\Delta_n - x_n(\Delta_n) \geq p_n(\hat{\Delta}_n)\Delta_n - x_n(\hat{\Delta}_n); \tag{38}$$

where

$$x_o(\Delta_o) = \int x(\Delta_o, \Delta_n) m_n(\Delta_n) d\Delta_n, \quad p_o(\Delta_o) = \int p(\Delta_o, \Delta_n) m_n(\Delta_n) d\Delta_n,$$

$$x_n(\Delta_n) = \int x(\Delta_o, \Delta_n) m_o(\Delta_o) d\Delta_o \quad \text{and} \quad p_n(\Delta_n) = \int p(\Delta_o, \Delta_n) m_o(\Delta_o) d\Delta_o.$$

Equations (35) and (37) are the usual individual rationality constraints. They guarantee that the mechanism generates enough incentives for both agents to participate. Equations (36) and (38) are the usual incentive compatibility constraints. They guarantee that the mechanism generates enough incentives for both agents to truthfully reveal their reservation values.

B.3.2 Expected gains from trade

The expected gains from trade of a type θ_o owner in a meeting is

$$\pi_o(\theta_o) = \int \Big\{ \alpha_o \left(1 - \alpha_n + {}^{\alpha_n}/2\right) \left[\max(\Delta_o, \Delta_n) - \Delta_o\right] \\ + (1-\alpha_o)(1-\alpha_n) \left[x(\Delta_o, \Delta_n) - p(\Delta_o, \Delta_n)\Delta_o\right] \Big\} d\frac{\Phi_n(\theta_n)}{1-s}, \quad (39)$$

and the expected gains from trade of a type θ_n non-owner in a meeting is

$$\pi_n(\theta_n) = \int \Big\{ \alpha_n \left(1 - \alpha_o + {}^{\alpha_o}/2\right) \left[\max(\Delta_o, \Delta_n) - \Delta_o\right] \\ + (1-\alpha_n)(1-\alpha_o) \left[p(\Delta_o, \Delta_n)\Delta_n - x(\Delta_o, \Delta_n)\right] \Big\} d\frac{\Phi_o(\theta_o)}{s}. \quad (40)$$

The expected gains from trade described in (39) and (40) are analogous to the ones described in (39) and (40). The difference is how investors split the trade surplus. Here, trade occurs according to the arrangement discussed in subsection B.3.1, where transfers are designed to maximize expected surplus.

B.3.3 Value functions and reservation value

In this section we describe the value functions for owners and non-owners and we provide an expression for the reservation value Δ. These objects are analogous to the ones derived in subsection 3.3. The difference here is that we use the expected gains from trade of owners and non-owners, π_o and π_o, that we computed in subsection B.3.2 instead of the one in subsection 3.2. The value function for an owner of a type θ is given by

$$rV_o(\theta) = v - \mu\big[V_o(\theta) - V_n(\theta)\big] + \lambda(1-s)\pi_o(\theta). \quad (41)$$

Likewise, the value function for a non-owner of type θ is,

$$rV_n(\theta) = \eta\big[\max\{V_o(\theta), V_n(\theta)\} - V_n(\theta)\big] + \lambda s \pi_n(\theta). \quad (42)$$

Using equations (41)-(42), we can compute the reservation value function for an investor of type θ, $\Delta(\theta) \equiv V_o(\theta) - V_n(\theta)$. The reservation value $\Delta(\theta)$ solves

$$r\Delta(\theta) = v - \mu\Delta(\theta) - \eta \max\{\Delta(\theta), 0\} + \lambda(1-s)\pi_o(\theta) - \lambda s \pi_n(\theta). \quad (43)$$

B.3.4 The distribution of assets

The change over time in the density of owners with type θ is

$$\dot{\phi}_o(\theta) = \eta\phi_n(\theta)\mathbb{1}_{\{\Delta(\theta)\geq 0\}} - \mu\phi_o(\theta) - \lambda\phi_o(\theta)\bar{q}_o(\theta) + \lambda\phi_n(\theta)\bar{q}_n(\theta), \quad (44)$$

where

$$q(\theta_o, \theta_n) = [1-(1-\alpha_o)(1-\alpha_n)]\mathbb{1}_{\{\Delta_n \geq \Delta_o\}} + (1-\alpha_o)(1-\alpha_n)p(\Delta_o, \Delta_n) \quad (45)$$

is the probability of trade between a type θ_o owner and a type θ_n non-owner,

$$\bar{q}_o(\theta) = \int q(\theta, \theta_n)\phi_n(\theta_n)d\theta_n \quad (46)$$

is the probability that a type θ owner sells an asset in a meeting, and

$$\bar{q}_n(\theta) = \int q(\theta_o, \theta)\phi_o(\theta_o)d\theta_o \quad (47)$$

is the probability that a type θ non-owner buys an asset in a meeting. The difference between the law of motion in (8) and (44) comes from the use the Myerson and Satterthwaite (1983) trade mechanism. We can see this from the equations for $q(\Delta_o, \Delta_n)$ in the two different settings.

As in subsection 3.4, we can obtain an expression for the density of non-owners of type θ from the equilibrium condition

$$\phi_o(\theta) + \phi_n(\theta) = f(\theta), \quad (48)$$

and an expression for total asset supply is given by

$$s = \int \phi_o(\theta)d\theta. \quad (49)$$

B.3.5 Equilibrium

We focus on symmetric steady-state equilibrium.

Definition 2. *A family of direct mechanism, reservation values and distributions,* $\{m = (p,x), \Delta, \phi_o, \phi_n, s\}$, *constitutes a symmetric steady-state equilibrium if it satisfies:*

i. the mechanism $m = (p,x)$ *solves problem* (34)*;*

ii. the reservation value of investors $\Delta(\cdot)$ is continuous and satisfies (43), where π_o and π_n are given by (39) and (40); and

iii. the density of owners ϕ_o satisfies (44) with $\dot{\phi}_o = 0$, the measure of non-owners ϕ_n satisfies (48), and the stock of assets s satisfies (49).

As in section 3.5, the equilibrium definition does not include the value functions V_o and V_n because we can recover them from (41) and (42).

Proposition 14. *There exists a symmetric steady-state equilibrium.*

B.3.6 Intermediation

The trade protocol used here differs from the one used in Section 4, but our results regarding trading speed and centrality are the same.

Efficient ex-post trade in a bilateral meeting means that the buyer acquires the asset whenever her reservation value is above the reservation value of the seller. That is, if trade is ex-post efficient, then the probability of trade is $\mathbb{1}_{\{\Delta_n \geq \Delta_o\}}$. The Myerson and Satterthwaite (1983) implies that, under private information,[25] efficient ex-post trade cannot be achieved.

Proposition 15. *Consider a symmetric steady-state equilibrium $\{m = (p, x), \Delta, \phi_o, \phi_n, s\}$. Then, efficient ex-post trade in the bilateral meetings is not achieved. That is, $p(\Delta_o, \Delta_n) < \mathbb{1}_{\{\Delta_n \geq \Delta_o\}}$ for a positive measure of Δ_o and Δ_n. Moreover,*

- *$\int p(\Delta_o, \Delta_n) dM_n < \int \mathbb{1}_{\{\Delta_n \geq \Delta_o\}} dM_n$, and*
- *$\int p(\Delta_o, \Delta_n) dM_o \leq \int \mathbb{1}_{\{\Delta_n \geq \Delta_o\}} dM_o$, with strict inequality if $\Delta_n > 0$.*

The probability of trade between a type θ_o owner and a type θ_n non-owner is

$$q(\theta_o, \theta_n) = [1 - (1 - \alpha_o)(1 - \alpha_n)]\mathbb{1}_{\{\Delta_n \geq \Delta_o\}} + (1 - \alpha_o)(1 - \alpha_n) p(\Delta_o, \Delta_n).$$

[25] To be more specific, without common knowledge of gains from trade and connected support for valuations.

Since α_o and α_n are smaller than one with positive probability, Proposition 15 implies that $q(\theta_o, \theta_n)$ is smaller than one for a positive measure of θ_o and θ_n. Moreover, keeping the reservation value constant, we have that

$$\frac{q(\theta_o, \theta_n)}{\partial \alpha_o}\Big|_{\Delta(\theta_o)=\bar{\Delta}} = (1 - \alpha_n)\left[\mathbb{1}_{\{\Delta_n \geq \Delta_o\}} - p(\Delta_o, \Delta_n)\right].$$

In a similar way,

$$\frac{q(\theta_o, \theta_n)}{\partial \alpha_n}\Big|_{\Delta(\theta_n)=\bar{\Delta}} = (1 - \alpha_o)\left[\mathbb{1}_{\{\Delta_n \geq \Delta_o\}} - p(\Delta_o, \Delta_n)\right].$$

This brings us to our next result.

Proposition 16. *Consider a symmetric steady-state equilibrium* $\{m = (p, x), \Delta, \phi_o, \phi_n, s\}$, *and let the types* $\theta = (\alpha, \nu)$ *and* $\hat{\theta} = (\hat{\alpha}, \hat{\nu})$ *satisfy* $\Delta(\theta) = \Delta(\hat{\theta})$ *and* $\alpha > \hat{\alpha}$. *Then,*

- $\bar{q}_o(\theta) > \bar{q}_o(\hat{\theta})$, *and*
- $\bar{q}_n(\theta) \geq \bar{q}_n(\hat{\theta})$, *with strict inequality if* $\Delta(\theta) = \Delta(\hat{\theta}) > 0$.

Proposition 16 is intuitive. We know from Proposition 15 that trade is distorted in meetings under private information—that is, $p(\Delta_o, \Delta_n) < \mathbb{1}_{\{\Delta_n \geq \Delta_o\}}$ for a positive measure of Δ_o and Δ_n. Since investors with higher screening expertise are less likely to be in those meetings, they are less likely to have their trades distorted.

From Proposition 16 we can derive our main centrality result below.

Proposition 17. *Consider a symmetric steady-state equilibrium* $\{m = (p, x), \Delta, \phi_o, \phi_n, s\}$, *and let the types* $\theta = (\alpha, \nu)$ *and* $\hat{\theta} = (\hat{\alpha}, \hat{\nu})$ *satisfy* $\Delta(\theta) = \Delta(\hat{\theta})$ *and* $\alpha > \hat{\alpha}$. *Then,*

- *if* $\Delta(\theta) = \Delta(\hat{\theta}) < 0$, *we have that* $c(\theta) = c(\hat{\theta}) = 0$, *and*
- *if* $\Delta(\theta) = \Delta(\hat{\theta}) \geq 0$, *we have that* $c(\theta) > c(\hat{\theta}) > 0$.

Moreover, if an investor type $\theta^* = (\alpha^*, \nu^*)$ *is the most central, then* $\alpha^* = 1$ *and* $c(\theta^*) > c(\theta)$ *for all* $\theta \in \Theta$ *satisfying* $\alpha < 1$.

C Appendix: Additional Empirical Results

*FOR ONLINE PUBLICATION

Alternative Empirical Specification. Our primary specification examined the probability of trade conditional on reporting in the previous week(s) versus not reporting. Alternatively, by Bayes' rule we could test the reverse, the probability of reporting in a given week conditional on observing a trade. However since not all investors file a report, we do not know what the filing date would be if they did file. As a result, for each quarter, only some trades at a particular date t can be linked to a prior filing of form 13-F that quarter by one of the two trade participants, but other trades cannot. In order to test the incidence of filing a report, we need to assign a filing date for investors that do not file in a particular quarter.

For every investor present in the dataset that did not file the form in a particular quarter, we impose a fake filing date, with delay drawn from the observed empirical distribution of delays in filling. Doing so implies that every investor-quarter pair is linked to a filing, although some are real and some are fake. The real versus fake distinction is crucial for our test. For a given trade between a buyer j and a seller $\tilde{j}$, we can link for both j and $\tilde{j}$ the trade with a filing that occurred in the N weeks prior to the trade. After appropriately controlling for unobservables using fixed effects, we study the connection between trade activity and real versus fake filings. That is, we test whether a trade is more likely when a real report happened in the previous N weeks using compared to when a fake filing occurred in the previous N weeks.

Let $investor \in \{buyer,\ seller\}$. Our empirical model is the following,

$$R^N_{j,i,k,t} = \gamma_1 real_{j,i} + \gamma_2 real_{j,i} \times core_{j,i} + FE_j + FE_k + FE_t + \varepsilon_{j,i,k,t}, \qquad (50)$$

where $R^N_{j,i,k,t}$ equals 1 if institution j in trade i, trading a CDS-index class k at date t, filed a 13-F within N weeks before the trade date t and equals 0 otherwise, $real_{j,i}$ equals 1 if investor j's 13-F report associated with trade i is real, and equals 0 otherwise, $core_{j,i}$ equals 1 if the counterparty of investor j in trade i is in the core, top-5 in centrality, and equals 0 otherwise. Finally, FE_j accounts for the institution fixed effects, FE_k accounts for CDS-index-class fixed effects, and FE_t accounts for time fixed effects.

Our theory predicts that the probability of trade increases after a 13-F report. In our empirical approach, this maps to testing whether a real filing, instead of a fake one, precedes the trade within a window of size N, which implies $\gamma_1 > 0$. Our theory also predicts that this effect should be smaller when the institution's counterparty is in the core, which implies $\gamma_2 < 0$.

Table 6 presents the results of (50) restricting attention to U.S. CDS indexes and Table 7 presents the results for all CDS indexes. The top panel in each table presents the results for buying activity, while the bottom panel presents the results for selling activity. Columns (1)-(2) use a window of one week, columns (3)-(4) use a window of two weeks, and columns (5)-(6) use a window of three weeks. For each window, we report results with and without fixed effects.

First, consider Table 6. For both buyers and sellers reporting 13-F, for all windows, and regardless of controlling for fixed effects, we observe $\gamma_1 > 0$ and significant as indicated in the first row of each panel. There is a higher probability of observing an institution trading CDS indexes when that institution filed a report prior to trade. For example in column(1), filing a report is associated with a 3.7% increase in the probability of buying a CDS index. Likewise, filing a report is associated with a 3.0% increase of selling a CDS index. The unconditional probability that we observe a trade and a prior filing (either real or fake) within the one week is 3.7% for both buyers and sellers. Hence a filing doubles the probability of the event of observing a trade. As the window size increases to two and three weeks, the impact of a filing relative to the unconditional probability of observing a trade and prior filing falls but is still positive and significant.

The second row of each panel shows the coefficient estimates of γ_2. We find the coefficient on a real report given we observe a trade with a counterparty in the core to be negative and significant. That is, the increase in the probability that we observe trade after a filing is lower when they are trading with core institutions. These results are consistent with those in Section 5. Table 7 repeats the analysis for trades of all CDS indexes and the results remain consistent; filing a 13-F increases the probability of trade, but less so with core institutions

The effect of 13-F on buying versus selling. In Table 8, we report the results of the baseline regressions, (18), where we now define the dependent variables

Table 6: The impact of a 13-F filing on trade, U.S. CDS indexes

	N=1 week		*N*=2 weeks		*N*=3 weeks	
Panel A: Buyers filing	(1)	(2)	(3)	(4)	(5)	(6)
$real_{buyer}$	0.0374***	0.0278***	0.111***	0.0910***	0.130***	0.107***
	(0.00277)	(0.00308)	(0.00373)	(0.00413)	(0.00450)	(0.00498)
$real_{buyer} * core_{seller}$	-0.0163***	-0.0122***	-0.0601***	-0.0575***	-0.0320***	-0.0482***
	(0.00319)	(0.00347)	(0.00429)	(0.00466)	(0.00518)	(0.00562)
Constant	0.0377***		0.0702***		0.107***	
	(0.000338)		(0.000455)		(0.000549)	
R-squared	0.001	0.016	0.004	0.027	0.006	0.030
Observations	348,903	348,012	348,903	348,012	348,903	348,012
Fixed Effects	none	instit., qtr., index	none	instit., qtr., index	none	instit., qtr., index

Panel B: Sellers filing						
$real_{seller}$	0.0304***	0.0299***	0.0954***	0.0832***	0.120***	0.103***
	(0.00288)	(0.00323)	(0.00385)	(0.00431)	(0.00469)	(0.00524)
$real_{seller} * core_{buyer}$	-0.00731**	-0.0107***	-0.0412***	-0.0427***	-0.0295***	-0.0403***
	(0.00329)	(0.00361)	(0.00440)	(0.00482)	(0.00536)	(0.00586)
Constant	0.0377***		0.0689***		0.107***	
	(0.000337)		(0.000450)		(0.000548)	
R-squared	0.001	0.015	0.003	0.021	0.005	0.025
Observations	348,903	348,205	348,903	348,205	348,903	348,205
Fixed Effects	none	instit., qtr., index	none	instit., qtr., index	none	instit., qtr., index

Sample includes trades of US credit default swap indexes by regulated institutions or those trading CDS indexes on regulated institutions during 2013Q1-2017Q4. The independent variable is a dummy equal to one if in trade *i* of CDS index *k* at date *t*, institution *j* filed a 13-F in the previous *N* weeks. The independent variable *real* is equal to one if the filing was real and zero if it was fake. The independent variable *core* is equal to one if the filer's counterparty is in the top-5 in terms of centrality. The top panel provides the regression results for the case where the buyers are those filing, while the bottom panel present the results for the case where the sellers are those filing. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

$D_{ijt}^{core/periphery}$ as dummies equal to one if institution j traded CDS index i in week t as a buyer or seller, respectively. We are interested if the effect of trading CDS is active both on the buy and sell side of the market, or is dominated by one side. The proof of Proposition 9 suggests that our results should hold *for at least one side of the market*, but not necessarily both depending on the weights ξ_o and ξ_n. For instance if $\xi_o = 1$, then we should only see the effects of a 13-F report on

Table 7: The impact of a 13-F filing on trade, All CDS indexes

	N=1 week		*N*=2 weeks		*N*=3 weeks	
Panel A: Buyers filing	(1)	(2)	(3)	(4)	(5)	(6)
$real_{buyer}$	0.0481***	0.0484***	0.109***	0.0999***	0.130***	0.111***
	(0.00168)	(0.00197)	(0.00225)	(0.00264)	(0.00270)	(0.00316)
$real_{buyer} * top_{seller}$	-0.0253***	-0.0204***	-0.0480***	-0.0414***	-0.0256***	-0.0240***
	(0.00200)	(0.00211)	(0.00268)	(0.00281)	(0.00321)	(0.00337)
Constant	0.0370***		0.0680***		0.102***	
	(0.000212)		(0.000284)		(0.000341)	
R-squared	0.001	0.009	0.004	0.015	0.006	0.019
Observations	865,094	864,092	865,094	864,092	865,094	864,092
Fixed Effects	none	instit., qtr., index	none	instit., qtr., index	none	instit., qtr., index

Panel B: Sellers filing						
$real_{seller}$	0.0365***	0.0436***	0.0981***	0.0985***	0.123***	0.128***
	(0.00170)	(0.00204)	(0.00227)	(0.00272)	(0.00272)	(0.00326)
$real_{seller} * top_{buyer}$	-0.0174***	-0.0127***	-0.0448***	-0.0378***	-0.0298***	-0.0214***
	(0.00203)	(0.00215)	(0.00270)	(0.00286)	(0.00324)	(0.00342)
Constant	0.0392***		0.0711***		0.107***	
	(0.000217)		(0.000289)		(0.000347)	
R-squared	0.001	0.009	0.003	0.013	0.005	0.017
Observations	865,094	864,265	865,094	864,265	865,094	864,265
Fixed Effects	none	instit., qtr., index	none	instit., qtr., index	none	instit., qtr., index

Sample includes trades of all credit default swap indexes by regulated institutions or those trading CDS indexes on regulated institutions during 2013Q1-2017Q4. The independent variable is a dummy equal to one if in trade *i* of CDS index *k* at date *t*, institution *j* filed a 13-F in the previous N weeks. The independent variable *real* is equal to one if the filing was real and zero if it was fake. The independent variable *core* is equal to one if the filer's counterparty is in the top-5 in terms of centrality. The top panel provides the regression results for the case where the buyers are those filing, while the bottom panel present the results for the case where the sellers are those filing. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

the buyer-side of the market. The intuition is if sellers always make the offer, or $\xi_o = 1$, then an institution's private information is only valuable when they trade with a seller, as a buyer. The opposite is true when $\xi_n = 1$.

We see that the effect of a 13-F report on trade with the periphery is positive and similar whether on the buy- or sell-side of the market. The effect of a 13-F on trade with the core is always below the effect with the periphery, although splitting

Table 8: Impact of a 13-F filing on trade, buy-side vs. sell-side

	Buy-side		Sell-side	
	(1)	(2)	(3)	(4)
Trade with Periphery, $\frac{\beta^{periphery}}{Freq^{periphery}}$	0.232***	0.146*	0.244**	0.150*
	(0.088)	(0.087)	(0.089)	(0.089)
R-squared	0.150	0.171	0.148	0.167
Trade with Core, $\frac{\beta^{core}}{Freq^{core}}$	0.097	-0.007	0.134**	0.025
	(0.067)	(0.066)	(0.065)	(0.065)
R-squared	0.145	0.163	0.144	0.162
Test on difference, $\frac{\beta^{periphery}}{Freq^{periphery}} - \frac{\beta^{core}}{Freq^{core}}$	0.135	0.153*	0.110	0.125
	(0.089)	(0.089)	(0.089)	(0.089)
Fixed Effects				
$Week - index$	yes	yes	yes	yes
Institution	yes	no	yes	no
$Institution - quarter$	no	yes	no	yes
Observations	460,512	460,512	460,512	460,512

Sample includes trades of US credit default swap indexes by regulated institutions or those trading CDS indexes on regulated institutions, that filed a 13-F report at least once in the sample period, 2013Q1-2017Q4. The independent variable is a dummy equal to one if institution j filed a 13-F in the previous week. The two dependent variables are dummies if institution j traded CDS index i in week t as a buyer or seller with a periphery or core institution, respectively. We normalize the coefficients of each regression by the frequency of trading with each group so that coefficients are comparable. Test on difference: tests whether the difference in the normalized coefficients are equal to zero. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

the sample we lose power so the standard errors increase.

Exploiting the 45-day delay rule As discussed in Section 5, the SEC requires institutions to file form 13-F within 45-days of the first business day of the quarter. As discussed earlier, we do not believe endogeneity in delay is causing selection on unobservables that are correlated with trading CDS-indexes after filing date. The finance literature suggests the primary reason institutions delay is worry about front-running, which would only lead to bias in the opposite direction of our tests, that trade activity should *fall* in the time period after a filing. However, for robustness, we can exploit the 45-day cutoff rule as exogenous variation in reporting. If the number 45 is randomly-chosen, then institutions close to the cut-off day are exogenously required to file, even if the incentive to delay longer are correlated with CDS trading.

Table 9 reports the results of (18) where we define the independent variable $F_{j,t-x}$ to be a dummy variable equal to one if institution j filed a 13-F report in the x-weeks previous to week t *and* that report was made between 42 and 48 days from the beginning of the quarter, a symmetric window around the cutoff. We extend to 48 days because sometimes the deadline falls on a weekend or holiday. In these cases, the SEC extends the deadline to the first business day after 45 days past the beginning of the quarter.

We find that narrowing the test of a 13-F to only those around the deadline *strengthens* our previous results. Whether looking at windows of one or two weeks and regardless of controlling for trade in the time period just before a report, we find a positive and significant impact of a 13-F filing on trade with periphery institutions and no effect on trade with core institutions. The coefficient estimates increase, nearly doubling in most specifications. For instance, if we compare column (1) in Table 9 to column (4) in Table 2, we find that narrowing the focus to 13-F reports around the deadline increases the impact of a 13-F report on trade with the periphery from 13.8 percentage points to 21.4 percentage points. Similarly the differential effect on trade with the periphery relative to the core increases from 14.8 percentage points to 25.8 percentage points. As much as these regressions control for endogeneity in filing delay, we see the bias in our previous results was working against us, consistent with the notion of front-running being the primary incentive to delay.

Table 9: Impact of a 13-F filing on trade (42-48 day filing delay).

	$x = 1$ week		$x = 2$ weeks	
	(1)	(2)	(3)	(4)
	Dependent Variable: Trade with Periphery, $\frac{\beta^{periphery}}{Freq^{periphery}}$			
Filed in week $t-x$, $F_{i,t-x}$	0.214**	0.216**	0.281***	0.281***
	(0.106)	(0.107)	(0.080)	(0.080)
Filed in week $t+x$, $F_{i,t+x}$		0.017		0.005
		(0.107)		(0.081)
R-squared	0.198	0.198	0.198	0.198
	Dependent Variable: Trade with Core, $\frac{\beta^{core}}{Freq^{core}}$			
Filed in week $t-x$, $F_{i,t-x}$	-0.043	-0.050	0.008	0.003
	(0.077)	(0.077)	(0.057)	(0.058)
Filed in week $t+x$, $F_{i,t+x}$		-0.092		-0.027
		(0.077)		(0.058)
R-squared	0.204	0.204	0.204	0.204
	Dependent Variable: Difference, $\frac{\beta^{periphery}}{Freq^{periphery}} - \frac{\beta^{core}}{Freq^{core}}$			
Filed in week $t-x$, $F_{i,t-x}$	0.256**	0.266**	0.273***	0.278***
	(0.104)	(0.104)	(0.078)	(0.079)
Filed in week $t+x$, $F_{i,t+x}$		0.107		0.032
		(0.104)		(0.079)
R-squared	0.119	0.119	0.119	0.119
Fixed Effects				
Week − index	yes	yes	yes	yes
Institution − quarter	yes	yes	yes	yes
Observations	460,512	458,712	458,640	455,040

Sample includes trades of US credit default swap indexes by regulated institutions or those trading CDS indexes on regulated institutions, that filed a 13-F report at least once in the sample period, 2013Q1-2017Q4. The independent variables, $F_{j,t-x}$ and $F_{j,t+x}$, are dummies equal to one if institution j filed a 13-F within the previous x weeks and within the following x weeks, respectively, to week t, conditional on filing near the filing deadline defined as 42 to 48 days past the beginning of the quarter. The two dependent variables are dummies if institution j traded CDS index i in week t with a periphery and core institution, respectively. We normalize the coefficients of each regression by the frequency of trading with each group so that coefficients are comparable. Test on difference: tests whether the normalized coefficients are equal to zero. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.