An information-based theory of financial intermediation*

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Abstract

We advance a theory of how private information and heterogeneous screening ability across market participants shapes trade in decentralized asset markets. We solve for the equilibrium market structure and show that the investors who intermediate trade the most and interact with the largest set of counterparties must have the highest screening ability. That is, the primary intermediaries are those with superior information - screening experts. We provide empirical support for the model's predictions using transaction-level micro data and information disclosure requirements. Finally, we study the connection between screening ability and efficiency, and observe that a market where all investors are screening experts –and thus, a market with no private information– may be dominated in terms of welfare by a market with no screening experts.

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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 often involve a core set of institutions serving as intermediaries.[1] Understanding how decentralized asset markets function thus requires understanding the determinants of intermediation. In this paper, we build a theory of intermediation based on a key friction inherent in decentralized trade: market participants possess private information about their willingness to pay for assets.

The theory predicts that if there is heterogeneity in the ability of participants to learn the information of their counterparties, what we refer to as screening ability, then those that intermediate assets the most must be the most informed. In other words, the core is endogenously comprised of experts. We then provide empirical evidence, using transaction-level micro-data, to support this and other key predictions of the theory as well as illustrate that the interaction of private information and the incentive to intermediate assets is an important determinant of efficiency in decentralized trade.

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, traders can agree about the risk an asset pays off, but still do not know of each others' hedging, liquidity, or order-flow needs. Second, we assume that 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 institutions can 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 endogenously linked to screening ability. We

[1] This is often referred to as a core-periphery market structure and has been widely documented in the literature, for instance, 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.

define a concept of an investor's centrality in the market that measures the fraction of trade volume they account for. 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, who we call experts. We also show that, relative to those with low screening ability and similar valuation for the underlying asset, experts endogenously trade more often and with a larger pool of investors.

To understand the intuition for why the investors most central in intermediating assets are experts, it is helpful to describe a few features of bilateral trade in partial equilibrium. Consider a meeting between a buyer and seller, and 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.[2] If the investor making the offer also observes the type of 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 and destroys some efficient trades. In partial equilibrium, in the sense that we keep the investor's valuation for the asset constant, investors with higher screening ability are less likely to resort to setting distortive prices and so endogenously have a higher probability of trade. As a result, screening ability is a force that increases an investor's trading speed, increases their set of potential counterparties, and increases their expected profits from trade. In other words, in partial equilibrium, higher screening ability implies an investor possesses a better trading technology.

The intuition is more complicated in general equilibrium as an investor's screening ability affects their asset valuation, which in turn affects the extent to which they intermediate. Experts with too-low or too-high a flow valuation for the asset may still overwhelmingly serve as sellers and buyers, respectively. However, we show that the investors who intermediate assets the most, and form the core of the market, must be experts.

In the second part of the paper, we provide empirical evidence that supports the primary result that heterogeneity in information leads to differences in intermediation activity. To do so, we use transaction-level data on the OTC market for credit-default-swap (CDS) indexes and examine the differential effects of information disclosure on an

[2] 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 total surplus and obtain the same qualitative results.

institution's trade with the core versus periphery. 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. Since (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, we consider a 13-F filing as exogenous variation in the information the market possess about the institution's motives to trade CDS.[3]

We first extend the model to include a set of investors that file 13-F. 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 the filer's probability of 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 show these predictions hold in the CDS index market. 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, classes of CDS indexes, and types of institutions. We also show that a 13-F filing temporarily increases the probability of trade with the periphery 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 trade motives are less relevant in more competitive 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.

Finally, we explore the connection between screening ability and efficiency in OTC

[3]See Section 6 for a detailed discussion.

markets. We consider a version of the model with only experts and uninformed investors. The efficient fraction of experts strikes a balance between two forces: a larger fraction can increase welfare through a lowering the distortion in bilateral trade, but a larger fraction can also decrease welfare through causing a higher distortion in intermediation and issuance incentives, as explored in Bethune et al. (2019). We construct numerical examples where this trade-off is apparent. In some cases, having only experts maximizes welfare, and so it is optimal for the market to function under complete information. However, we also provide examples where the opposite is true having all investors with no screening expertise maximizes welfare. These results show that the effect of private information on the incentive to intermediate assets is central in understanding if there are benefits to increase transparency in 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), Golosov, Lorenzoni, and Tsyvinski (2014), Guerrieri and Shimer (2014a), Lester, Shourideh, Venkateswaran, and Zetlin-Jones (2015), Glode and Opp (2016), Malamud and Rostek (2017), and Babus and Kondor (2018), 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]

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.

[4] Exceptions are Duffie (2012), Guerrieri and Shimer (2014b) and Chang (2017) that consider both private and common values and Guerrieri et al. (2010), 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.

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.[6] 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.

2 Environment

Time is continuous and infinite and there is a measure one of infinitely-lived investors that discount the future at rate $r > 0$. There is transferable utility across investors and 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.[7] The screening ability α determines the probability by which an investor learns the utility type of their counterparty. 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 $\hat{\alpha}$.[8]

[6]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).

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

[8]A natural question is whether one investor knows what the other investor knows in the meeting—

Types are fixed over time, are independent across investors, and are 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 for a given α^i. 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 $\int \nu^2 dF < \infty$ for technical reasons.

We assume 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. Investors can freely dispose of assets at any time. 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 it does not provide additional insights so we do not incorporate this feature.

3 Price determination, asset valuations, and allocations

In this section, we study price determination, provide expressions for value functions and the distribution of assets among investors, and define an equilibrium and prove its existence. We restrict attention to steady-state equilibria and omit the time t from 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 $\Phi_n(\theta)$, respectively, and the measure of assets by $s = \int d\Phi_o$. 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 $\Delta(\theta_n)$.

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 counterparty 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 counterparty or not.

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 $\xi_o \in (0,1)$ 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.

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 A.1 and A.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 buying and selling 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 D, we study this case and obtain similar results regarding the main implications of our theory of financial intermediation.

The choice of ask and bid prices depend on whether or not the investor making an offer observes the utility type of their counterparty, which occurs with probability α, the investor's own screening ability. Since screening ability is public information, when an investor learns the utility type of their counterparty, they also learn their reservation value. Hence, when an investor gets to set the terms of trade and is informed, they set their ask and bid price to extract the entire gains from trade, if positive. Let Δ_o and Δ_n be the reservation values of an owner and non-owner, respectively, in a meeting. The optimal ask price, ask_o, solves $ask_o = \Delta_n$ if $\Delta_o \leq \Delta_n$ and $ask_o = \Delta_o$ otherwise. Similarly, the optimal bid solves $bid_n = \Delta_o$ if $\Delta_o \leq \Delta_n$ and $bid_n = \Delta_n$ otherwise. In words, when investors are informed they extract the entire gains from trade when making the offer.

When the investor making an offer does not observe the utility type of their counterparty, they must set their ask and bid prices under private information. First consider the problem of the uninformed owner setting their ask price. The optimal ask price solves

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

where α_n denotes the screening ability of the non-owner counterparty 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 endogenous 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.

A solution to (1) exists if $M_n(\cdot;\alpha_n)$ has no mass points and finite second moments. We conjecture that a solution to this problem exists and later, when proving existence of an equilibrium, we verify that the conjecture applies.[9]

The next lemma provides a useful result: the optimal ask price is strictly above the owner's reservation value whenever there are expected gains from trade. Appendix B contains the proof of this lemma and all proofs that follow.

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 their reservation value. As a result, 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. In other words, private information destroys efficient bilateral trades. This is a well-known, negative result from Myerson and Satterthwaite (1983) where the distributions, M_n and M_o, are exogenous. Here we show the result holds in a general equilibrium model of trade, but the same intuition applies. The following 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 $\epsilon > 0$.*

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

The optimal bid price under private information follows closely to that above, and is given by the solution to

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

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 endogenous 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 with screening ability α_o accept 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), exists in equilibrium.[10]

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 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.*

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, whether the owner or non-owner sets the terms of trade.

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

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

and of a non-owner of type θ_n are given by

$$\pi_n(\theta_n) = \xi_n \int \alpha_n\,(\Delta_n - \Delta_o)\,\mathbb{1}_{\{\Delta_n\geq\Delta_o\}} + (1-\alpha_n)\,(\Delta_n - bid_n)\,\mathbb{1}_{\{bid_n\geq\Delta_o\}} d\frac{\Phi_o(\theta_o)}{s}$$

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

$$+ \xi_o \int (1-\alpha_o)\,(\Delta_n - ask_o)\,\mathbb{1}_{\{\Delta_n \geq ask_o\}} d\frac{\Phi_o(\theta_o)}{s}. \tag{4}$$

Consider (3). 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 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, which occurs with probability $1-\alpha_n$, and (ii) her reservation value 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

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

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,

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

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.

We define the value functions assuming that owners hold the asset until maturity or sell it and non-owners issue a new asset whenever they have an opportunity to do so. If investors have negative value of being an owner, they can freely dispose of the asset and not issue a new asset when an opportunity arrives. These possibilities will be embedded in the equilibrium condition for the law of motion for asset supply, which guarantees that investors with negative value of being an owner do not hold or issue assets in equilibrium.[11]

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

$$\Delta(\theta) = \underbrace{\frac{\nu}{r+\mu+\eta}}_{\substack{\text{fundamental}\\ \text{value}}} + \underbrace{\frac{\lambda(1-s)\pi_o(\theta)}{r+\mu+\eta}}_{\substack{\text{option value}\\ \text{to sell}}} - \underbrace{\frac{\lambda s \pi_n(\theta)}{r+\mu+\eta}}_{\substack{\text{option value}\\ \text{to buy}}}. \tag{7}$$

Equation (7) 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. The second and third components represent the option values of selling and buying the asset, respectively. What is important for the reservation value is the net, or the expected gain in value from buying then selling an asset, or the expected gain from intermediation.

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

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

[11] Alternatively, we could write the value functions as the maximum of the value functions we wrote above and zero. We opt to write it in the way we did because the equilibrium allocations in both formulations are the same, but the notation is heavier in alternative formulation.

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 and fixed, 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

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

4 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 use standard fixed-point arguments. Instead, we show existence by constructing a well-behaved polynomial approximation to the operator and show that 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.

5 Private Information and Market Structure

We now study how private information shapes the market structure. Specifically, we are interested in the relationship between an investor's screening ability and their role in intermediation, or the process by which assets flow from low-value owners to high-value non-owners. Our main result is presented in Propositions 2 and 3, which state that the investors most involved in intermediation, measured as the fraction of total trade volume they account for, have the highest screening ability. In other words, in the core of the endogenous core-periphery market structure, is composed of experts.

We start by defining an investor's trade centrality (or just centrality to keep it short). 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

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

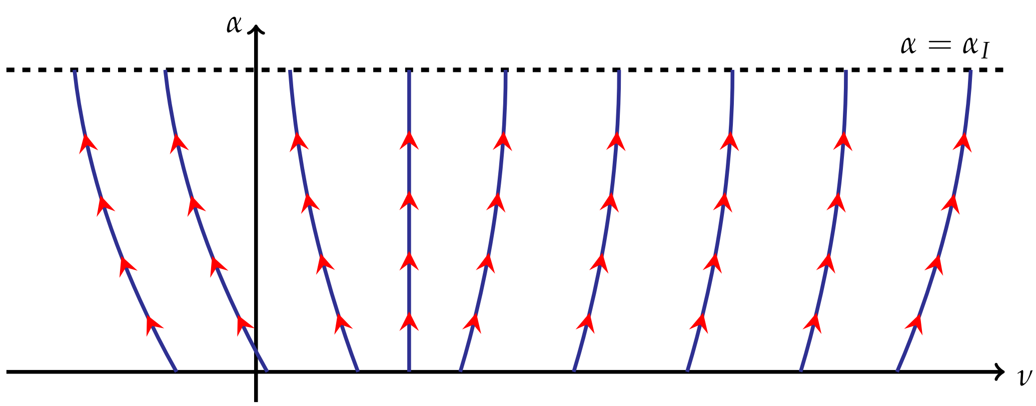
where $Vol = \lambda \int \int q(\theta_o, \theta_n) d\Phi_o(\theta_o) d\Phi_n(\theta_n)$ is total trade volume. Centrality measures the extent an investor of type θ accounts for total trade volume, both as a buyer and a seller. In (14), the expected probabilities of trade are weighted by the fraction of time spent as buyer or seller, ϕ_n/f and ϕ_o/f, respectively. In order to have high centrality an investor must not only have a high probability of trade conditional on a meeting but also have a high rate of meetings with gains from trade. For instance, the investor with the lowest asset valuation will have a high probability of trade in a meeting as an owner, since it is likely that any non-owner they meet will value the asset more than her, but they will spend little time possessing an asset in equilibrium and so seldom get the chance to sell. Further, to have a high centrality an investor must trade frequently as both buyer and seller. Notice that $\int c(\theta)f(\theta)d\theta = 1$.

We start with the following lemma that establishes a partial equilibrium result: if two investors have the same reservation value for an asset, the investor with higher screening ability is more central.

Lemma 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) 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 result in Lemma 3. 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. Conditional on having the same reservation value, an investor with a higher screening ability will have a higher probability of trade in a meeting as either a buyer or seller since it is more likely they trade with efficient mechanisms.[12] Since better information leads to a better trading technology in equilibrium, higher screening ability α implies higher centrality for investors that value the asset the same.

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.

In Figure 1, the reservation value level curves can be upward or downward sloping. The reason is that the reservation value is always increasing in the utility type ν because it represents the flow value of holding an asset. However, the effect of increasing screening ability α depends on its effect on the difference between the option value of selling

[12] See Lemma 14 in the Appendix.

relative to buying, as can be seen in (7). When ν is high, investors are typically buyers in equilibrium as it is very costly for them to give up the utility stream that follows from holding an asset. As a result, screening ability affects their option value of buying more relative to selling since they seldom meet investors who value the asset more but often meet investors who value it less. Hence, in order to keep the reservation value constant as ν increases, the option value of buying must also increase (lowering the reservation value). This requires a higher screening ability α. When ν is low, the opposite is true and α must decrease to keep the reservation value constant.

We now turn to studying how information shapes centrality in general equilibrium.

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

Proposition 2. *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 $\alpha < a_I$.*

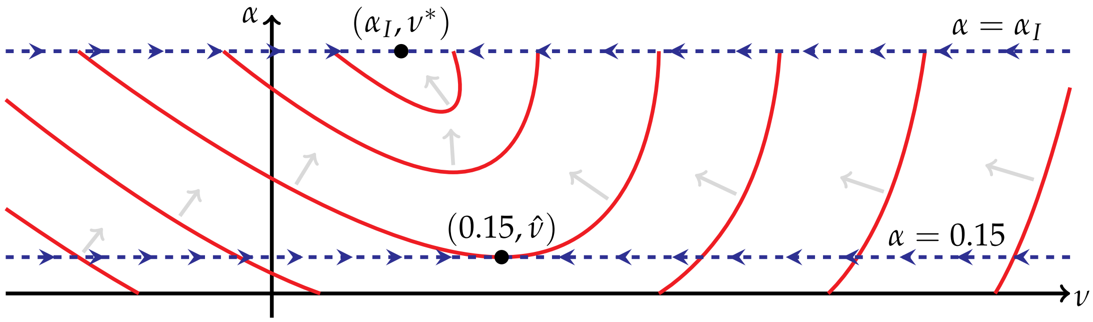
Figure 2 illustrates the results in Proposition 2. It shows the level curves of centrality in a two-dimensional graph, with screening ability α and utility type ν. The investors most central in intermediating assets must have the highest screening ability. Consider any investor $\theta = (\nu, \alpha)$ with $\alpha < \alpha_I$. Using the intuition of Lemma 3, we can always find an investor with $\alpha' > \alpha$ and $\Delta(\theta') = \Delta(\theta)$ that is more central. Since we can do this for any initial θ, the most central investor must be one with $\alpha = \alpha_I$. However, as Figure 2 shows, not all investors with the highest screening ability are most central. Centrality is maximized at $\alpha = \alpha_I$ *and* an intermediate value of ν. Investors with high (low) ν tend to have high (low) reservation value, which implies they seldom engage in selling (buying) assets and tend to only act on one side of the market.

Not only does the most central investor have the highest screening ability, but a measure of investors above a certain centrality threshold do as well. Let $\underline{c} := \frac{1}{2}\sup_{\theta\in\Theta}\{c(\theta)\} + \frac{1}{2}\sup_{\theta\in\Theta}\{c(\theta);\ s.t.\ \alpha \leq \alpha_{I-1}\}$. Then,

Proposition 3. *Consider a symmetric steady-state equilibrium $\{bid_n, ask_o, \Delta, \phi_o, \phi_n, s\}$. Then, $\alpha = \alpha_I$ for all investors type $\theta = (\alpha, \nu) \in \Theta$ such that $c(\theta) \geq \underline{c}$.*

Proposition 3 implies that the group of investors that are most central in intermediating assets all possess the highest screening ability. In other words, those investors satisfying the condition $c(\theta) \geq \underline{c}$ endogenously form a core of a core-periphery market structure. They are the top-p investors in terms of centrality, where $p := \int \mathbb{1}_{\{c(\theta)\geq \underline{c}\}} dF$.

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^*).

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 are involved in a large share of trade volume, as measured by (14), 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. Define the measure of counterparties of an investor of type θ as

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

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

The following proposition shows that in the case with two screening abilities, experts ($\alpha = 1$) and non-experts ($\alpha < 1$), experts trade with a larger set of counterparties and therefore have a larger trade network.

Proposition 4. *Suppose there are only two screening abilities, $\alpha_h = 1$ and $\alpha_l < 1$. 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 $\Delta(\theta) > 0$. We have that $np(\theta) = 1$ if, and only if, $\alpha = \alpha_h = 1$.*

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 if, and only if, they are a screening expert. On the other hand, non-experts distort trade due to private information and do not trade with a set of other investors, $np(\theta) < 1$. Hence, the theory is able to accommodate the empirical finding that central traders both account for a larger trade volume and have a larger network of trade counterparties.

Finally, we study the relationship between screening ability, trading speed, and rent extraction. The theoretical literature has shown that intermediation activity in OTC markets can be linked to investors that possess higher trading speed or a better ability to extract rents.[13] Our theory also delivers similar predictions, although both are generated endogenously through differences in screening ability. For instance, in our model investors do not differ in trading speed as a result of heterogeneity in contact rates, λ. Rather, differences in speed are a result of endogenous heterogeneity in the probability of trade conditional on a meeting, $\bar{q}(\theta)$. Since trading speed is given as the product of the meeting rate and the conditional trade probability, i.e. $speed_j(\theta) = \lambda \bar{q}(\theta)$ for $j = \{o, n\}$, for two investors with the same reservation value, the one with higher screening ability will trade faster. Similarly, for these same investors the one with higher screening ability will also extract more rents as a result of their informational advantage. Therefore, they will have larger expected profits from trade, $\pi_o(\theta)$ and $\pi_n(\theta)$.

Lemma 4. *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* $speed_n(\theta) \geq speed_n(\hat{\theta})$, *with strict inequality if* $\Delta(\theta) = \Delta(\hat{\theta}) > 0$, *and*

ii) $\pi_o(\theta) > \pi_o(\hat{\theta})$ *and (ii)* $\pi_n(\theta) \geq \pi_n(\hat{\theta})$, *with strict inequality if* $\Delta(\theta) = \Delta(\hat{\theta}) > 0$.

6 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, investors in the core of the market are experts who serve as natural intermediaries in trade. In this section, we provide empirical evidence of these predictions using trade data on credit default swaps (CDS) indexes and regulatory reports of financial holdings.

Our empirical strategy is the following. A subgroup of investors, which includes managers from banks, insurance companies, broker-dealers, pension funds, and corpo-

[13] See e.g. Rubinstein and Wolinsky (1987), Nosal, Wong, and Wright (2014), Uslu (2016) and Farboodi, Jarosch, and Shimer (2017) who study heterogeneity in contact rates and Farboodi et al. (2017) who study heterogeneity in bargaining power.

rations, 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 so market participants know detailed portfolio information about 13-F filers. However, CDS positions are not reported in the 13-F form.

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 indexes. 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.[14]

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

Before moving to the empirical tests, we first develop a set of model predictions about the effects of information disclosure through 13-F filings, summarized in Proposition 5. We consider a version of the baseline model above, but assume that a fraction of the investors, which we label as "13-F investors", have to publicly disclose information at random future dates through a 13-F filing. Let the distribution of types across 13-F and non-13-F investors be given by F_{13F} and F_{n13F}, respectively. Let $\omega_{13F} \in [0,1]$ be the fraction of 13-F investors, so that $F = \omega_{13F} F_{13F} + (1 - \omega_{13F}) F_{n13F}$. We assume the identities of 13-F investors are common knowledge, but importantly not their utility type.

Starting from some known future date t_0, each 13-F investor draws a filing date $T \geq t_0$ with Poisson arrival $\gamma > 0$. We assume that the filing dates of the investors are independent from each other and that the filing date is not known beforehand. The assumption that filing dates are spread out across time is consistent with the data, where

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

13-F filings are distributed across a 45-day period from the beginning of the quarter.

We assume the information revealed by filing a 13-F is imperfect. Let $\rho \in (0,1]$ be the probability that in any meeting after an investor's filing date T, the 13-F report perfectly reveals the type of the filer 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.[15]

Our key statistic of interest is how a filing impacts a 13-F investor's probability of trade with a "core" investor *relative to* a "periphery" investor, where we define the set of core investors as those with a centrality measure in the top-p percentile as defined in Proposition 3. The following proposition establishes our main set of testable predictions.

Proposition 5. *When a 13-F investor files a 13-F form, there is (i) a strict increase in her probability of trade with periphery investors, (ii) a weak increase in her probability of trade with core investors, and (iii) a shift in trade probability from core investors to periphery investors.*

Parts (i) and (ii) of Proposition 5 establish that information disclosure will at least weakly increase an investor's probability of trade; intuitively more information implies that distortions that follow from pricing under private information are less likely to destroy efficient trades. Further, and more importantly, part (iii) establishes that information disclosure also disproportionately increases an investor's probability of trade with the periphery relative to the core. This result stems from the key prediction of our model. Since the theory predicts that those investors who endogenously populate the core have an informational advantage, public information disclosure will impact them less. The result does not rely on the utility type or screening ability of the 13-F investor, or in turn their centrality. [16] We test these predictions in the remainder of the section.

6.2 Data description and summary statistics

We combine two datasets: 13-F filings from the Securities and Exchange Commission (SEC) and CDS trade-level data from the Trade Information Warehouse (TIW) of the

[15] 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.

[16] The predictions of Proposition 5 are also likely robust to adding additional heterogeneity across investors, for instance in their contact rates, λ. However such a model would predict differences in the probability of trade across investors with the same screening ability but different contact rates. In this case, the results would need to be re-stated by normalizing by the unconditional probability of trade with core and periphery investors.

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).[17] 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 possess 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.[18] 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.[19] 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

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

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

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

SDRs to make all reported data available to appropriate prudential regulators.[20] 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 reference 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

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

because this is where the identifying parts of the institution's name tend to be.[21] 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.[22] 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.

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

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

[22]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.

We observe a total of 4,124 institutions trading U.S. CDS indexes in our sample period, of which 52 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.

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.[23] 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 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

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

delay of 6 days and some institutions delay over the standard limit of 45 days.[24] 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.[25] 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 measure aligns with our measure of centrality in Section 5. 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.

6.3 Empirical results

In this section we test the predictions of our model, as described in Proposition 5, 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:

$$Y_{ijt} = \beta \frac{F_{j,t-1}}{Frequency} + \text{Fixed Effects}_{jit} + \epsilon_{jit} \tag{16}$$

[24] 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.

[25] 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.

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}^{p}, D_{ijt}^{c}, where p stands for periphery and c stands for core. The variable D_{ijt}^{p} 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 6.1, we normalize the dummy $F_{j,t-1}$ in each regression by the frequency of trade in the sample (i.e. frequency of trade involving core and frequency of trade involving periphery investors). 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 differentially affect the probability of trade with core relative to periphery investors. Under the normalization, we can compare the coefficient β across specifications.

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.[26] 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

[26]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 (1)	All index, filers (2)	US index, all inst. (3)	US index, filers (4)
Trade with Periphery, β^p	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, β^c	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, $\beta^p - \beta^c$	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 normalized dummy, where the dummy is 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. Test on difference: tests whether the difference in the coefficients is equal to zero. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

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 5; a 13-F report leads to increased trading activity in the week following the report. However, part (iii) of 5 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 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.[27] Adding institution-quarter fixed effects address both of these concerns by limiting our identifying variation to weeks within an institution's filing quarter. Doing so leads to results that are also 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, β^p	0.137*	0.146**	0.029	-0.058
	(0.074)	(0.058)	(0.052)	(0.049)
Trade with Core, β^c	-0.009	-0.014	-0.006	-0.037
	(0.053)	(0.042)	(0.038)	(0.035)
Test on difference, $\beta^p - \beta^c$	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) $F_{j,t-1}/Frequency$, (2) $F_{j,t-2}/Frequency$, (3) $F_{j,t-3}/Frequency$, and (3) $F_{j,t-4}/Frequency$ are normalized dummies, where the dummies are 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. Test on difference: tests whether the difference in the coefficients is 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 5 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

[27]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.

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.

In Table 4, we add an additional regressor to (16) that controls for trade in the time period *just prior* to a 13-F filing,

$$Y_{ijt} = \beta_1 \frac{F_{j,t-x}}{Frequency} + \beta_2 \frac{F_{j,t+x}}{Frequency} + \text{Fixed Effects}_{jit} + \epsilon_{jit}, \tag{17}$$

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 5, 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,

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, β^p			
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, β^c			
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, $\beta^p - \beta^c$			
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, $F_{j,t-x}/Frequency$ and $F_{j,t+x}/Frequency$, are normalized dummies, where the dummies are 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. Test on difference: tests whether the difference in the coefficients is equal to zero. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

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.

6.4 Market Liquidity and Private Information

In our theory, private information is relevant due to trade frictions that makes assets illiquid. Indeed if we consider the frictionless competitive market version of the model, investors can buy or sell the asset immediately at a fixed transfer, the competitive price. This implies that all investors' reservation values must be equal to the competitive price and are independent of the investors' utility type. As a result, in the competitive case, private information and investors' screening ability are irrelevant.

The competitive market version of the model is similar to the limit when trade frictions vanish, i.e. $\lambda \to \infty$. Naturally, in this extreme case, we should find no difference in the effect of a 13-F on the probability of trading with core vs. periphery investors. Although we do not prove it, it seems reasonable to expect that as frictions are reduced and frequency of trade increases, that private information becomes less relevant in determining trade outcomes. As a result, we expect the differential impact of information disclosure on trade with core versus periphery investors to become weaker. We study if there is such a relationship in the data in Table 5.

Table 5 shows the results from specification (16), run separately for 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 trades (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).

While the previous section showed that private information and screening ability

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

	CDX	CMBX	Other	CDX	CMBX	Other
	(1)	(2)	(3)	(4)	(5)	(6)
Percent of Trades	65.6%	23.4%	11%	65.6%	23.4%	11%
	Dependent Variable: Trade with Periphery, β^p					
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, β^c					
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, $\beta^p - \beta^c$					
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

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, $F_{j,t-1}/Frequency$, is a normalized dummy, where the dummy equals 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. Test on difference: tests whether the difference in the coefficients is equal to zero. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

are features that affect the probability of trade conditional on a meeting, and hence the overall market structure, this section provides evidence that trading delay is also a relevant friction in OTC markets. When delay is severe, private information shapes the market's structure to a greater extent than when delay is less severe.

6.5 Robustness

The empirical results in Tables 2 through 5 are robust to alternative specifications and tests. We briefly summarize them here and report the details in Appendix E. First, since our primary sample included only filers, we end up ignoring many trades involving non-filers 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 lead to bias in the direction of our results, we show that a reasonable control for this leaves our results unchanged.

7 The efficient amount of screening

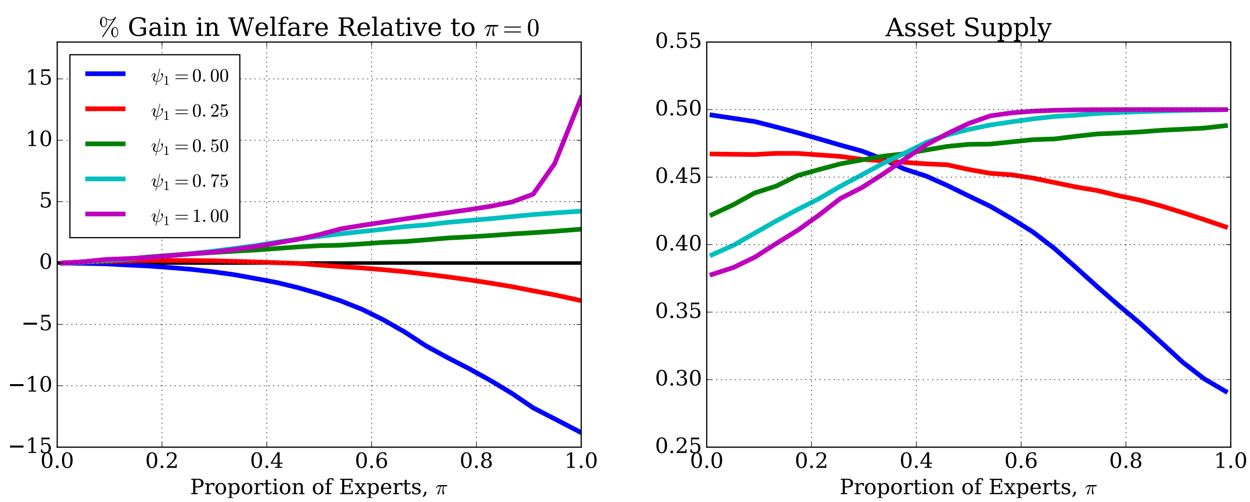
The previous sections explored how private information shapes the structure of trade in decentralized markets. In this section we explore the connection between screening ability and efficiency in OTC markets with private information.

A natural implication of private information is that there are important gains for those investors with superior information. Not only do these investors get high rewards from their expertise, i.e. high expected intermediation profits, but also they improve efficiency in bilateral trade. Meetings involving an investor with high screening ability are more likely to result in trade, and as a result, allow assets to flow faster from low-valuation to high-valuation investors, improving efficiency. Then is it always better, in terms of aggregate welfare, to have more information in the market by endowing all investors with $\alpha = 1$? The answer is, it depends. Welfare may rise or fall with more information as a result of how it reallocates the gains from trade.

Why would the market running under full information be inefficient? As explored in Bethune et al. (2019), OTC markets with asset creation feature a double-sided hold-up problem. The first hold-up problem is standard. Sellers create surplus when obtaining an asset, either through buying from lower valuation investors or issuing, and then selling it to high-valuation investors. However because trade occurs after the seller acquires the asset, if they only receive a fraction of the gains from trade, they face a hold-up problem and undervalue assets. The second hold-up problem is on the buyer side and is more specific to models of intermediation. Buyers also create surplus by making an “investment” in not acquiring or creating an asset, and waiting to purchase it in the future. If they only receive a fraction of the future gains from trade, they face a hold-up problem and overvalue assets. As argued in Bethune et al. (2019), the double-sided hold-up problem implies that the equilibrium in the market is always inefficient in the sense that there is no way to split the surplus between buyer and seller that restores efficiency. Interestingly, private information can help alleviate the inefficiencies that follow from the double-sided hold-up problem, as it allows for a mechanism to transfer surplus from buyer to seller, and vice-versa, through informational rents.

To illustrate this, consider a version of the model where screening ability can take only two values, $\alpha = \{0, 1\}$. Let $\pi \in [0, 1]$ be the fraction of investors with $\alpha = 1$, which we will call *experts*. Figure 3 illustrates the effects of changing π on welfare, $\mathcal{W} = \int \int V_n(\theta) d\Phi_n(\theta) + V_o(\theta) d\Phi_o(\theta)$, and asset supply, s, in a numerical example. We assume $r = 0.03$, $\mu = \eta = 1/10$, $\lambda = 6$, $\nu \sim N(1, 25)$, and report results for varying values of ψ_1, the probability an owner makes an offer. Notice in this example a fraction of agents have $\nu < 0$ which implies they will only create assets in order to sell them, and as the results in Section 5 show, these trades will typically occur with better informed agents serving as intermediaries.

Figure 3: The effects of information on welfare and the supply of assets.

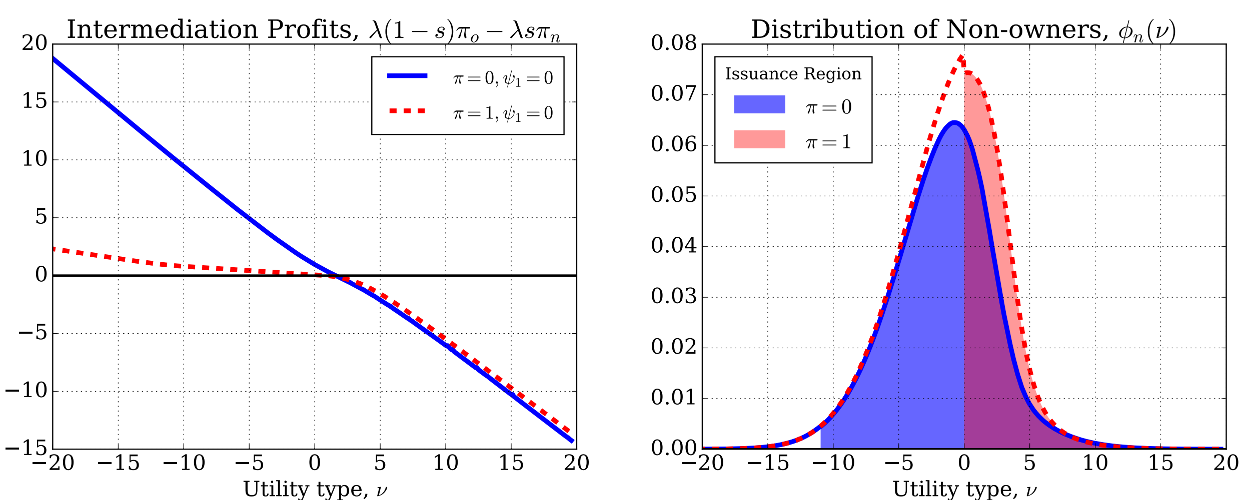


Notes: The examples above assume $\alpha \in \{0, 1\}$, where $\pi \in [0, 1]$ is the fraction of experts $\alpha = 1$. Each line represents a separate owner offer rate, ψ_1. The remaining parameters are $r = 0.03$, $\mu = \eta = 1/10$, $\lambda = 6$, and $\nu \sim N(1, 25)$.

The left-panel in Figure 3 illustrates the percentage change in welfare from introducing experts. Welfare may rise or fall with information, depending on the value of ψ_1. When $\psi_1 = 1$, owners always get to make the offer, and so when an investor gets an issuance opportunity they understand the gains from re-selling will only depend on their own screening ability and not the screening ability of any counterparty they meet. When π is low, the gain from creating an asset to resell is low because owners will often be making uninformed offers and giving up informational rents. When π increases, it spurs asset creation because the gains from re-selling rise. In turn, asset supply rises (right panel of Figure 3) and welfare rises.

Alternatively, consider when $\psi_1 = 0$ so that non-owners always get to make the offer. In this case, when an investor gets an issuance opportunity the only gain from creating an asset and re-selling is given by any informational rents they get when their counterparty is uninformed. When π is low, informational rents are high and so the incentive to create assets is high. When π increases, informational rents and asset issuance fall, and as a result asset supply and welfare fall.

Figure 4: The effects of information on intermediation profits and issuance.



Notes: The examples above assume $\alpha \in \{0, 1\}$, where $\pi \in [0, 1]$ is the fraction of experts $\alpha = 1$ and non-owners possess make all the offers, $\psi_1 = 0$. The remaining parameters are $r = 0.03, \mu = \eta = 1/10, \lambda = 6$, and $\nu \sim N(1, 25)$.

Figure 4 illustrates how more information can distort the incentive to create assets for the case when $\psi_1 = 0$. The left panel shows the net profits from intermediating assets, as given in (7), as a function of the utility type. Moving from an economy with no experts to an economy with all experts implies a lower incentive to create assets for agents with low ν. The right panel shows the distribution of non-owners for both economies, ϕ_n. The shaded region represents which non-owners will create an asset. When $\pi = 0$, almost every non-owner with $\nu < 0$ creates an asset since the gain from intermediating overcomes the utility loss from holding. However when $\pi = 1$, only non-owners with

$\nu > 0$ create assets. This example shows how in a second-best economy, improving information may distort the gains from trade and lead to lower welfare.

8 Concluding remarks

We propose a theory of financial intermediation based on heterogeneity in the information investors possess about the trading motives of their counterparties. Superior information allows investors to avoid distortive mechanisms and, as a result, the investors who are the most central in trade must be endowed with superior information. We provide empirical evidence in line with this central prediction of our theory by examining the effect of filing a 13-F form to the SEC, which makes public the institution's holdings of SEC regulated securities public information, 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 possess information about the trading motives of filers, but does not follow from other theories of financial market intermediation based on complete information. Further, we show that better information, in the sense of providing higher screening ability to all investors, is not always desirable in OTC markets with intermediation.

The predictions of our model and our empirical results are robust across varying assumptions and specifications. In Appendix A, 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 E, we provide additional robustness to our empirical tests.

In recent years, many important theoretical contributions have been advanced with the goal of understanding the driving forces of intermediation in OTC markets. Our paper provides a new theory of intermediation along with empirical support using microdata that suggests the mechanism we study is relevant. Since these other 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.

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A Appendix: Optimal Mechanisms

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. Likewise, it is optimal for a non-owner to use a bid price when uninformed. In this section, we show that these are in fact optimal selling and buying mechanisms.[28]

A.1 The optimal selling mechanism as an ask price

First consider the problem of an owner designing a mechanism to maximize their expected gains from trade. It is without loss of generality to focus on direct mechanisms

[28] It is worth mentioning that many variations of the techniques and results we discuss in this section are standard in the mechanism design literature, and can be found in, for example, textbooks such as Mas-Colell et al. (1995). They are included in this section for completeness of the manuscript. Readers that have familiarity with this literature can skip this section without loss in understanding of the proofs we present in Appendix B.

due to the revelation principle. A direct mechanism for an owner with reservation value Δ_o is a pair of functions $m = (p, x) : [\underline{\Delta}, \bar{\Delta}] \rightarrow [0, 1] \times \mathbb{R}$, 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.

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.

The problem of an owner with reservation value Δ_o is

$$\max_{m} \int \left[x(\Delta_n) - p(\Delta_n)\Delta_o \right] m_n(\Delta_n) d\Delta_n \tag{18}$$

subject to

$$IR: \quad p(\Delta_n)\Delta_n - x(\Delta_n); \geq 0 \text{ and} \tag{19}$$

$$IC: \quad p(\Delta_n)\Delta_n - x(\Delta_n) \geq p(\hat{\Delta}_n)\Delta_n - x(\hat{\Delta}_n); \tag{20}$$

for all Δ_n and $\hat{\Delta}_n$.

We will show a solution to (18)-(20) is associated with an ask price. To do so, it is helpful to start with the following lemmas.

Lemma 5. *A mechanism $m = (p, x)$ satisfies (19) and (20) 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 (20) for a non-owner with reservation value Δ_n implies that

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

The IC constraint (20) 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

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

Because $m = (p, x)$ satisfies the IR constraint (19), $U(\Delta_n) \geq 0$ 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

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

That is, the IC constraint (20) is satisfied. This concludes the proof of the lemma. □

Lemma 6. *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 (18) if, and only if, it solves problem*

$$\max_m \int p(\Delta_n) \left[\Delta_n - \frac{1 - M_n(\Delta_n)}{m_n(\Delta_n)} - \Delta_o \right] m_n(\Delta_n) d\Delta_n \tag{21}$$

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. Using Lemma 5, we can rewrite the objective function given by problem (18) as

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

We can then apply integration by parts in the following term

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

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 7, for the mechanism to satisfy the IC constraint we must have that $p(\Delta_n)$ is non-increasing. □

Now we can state the result that an ask price is an optimal selling mechanism under incomplete information. Define the functions

$$\bar{H}_n(q) = \min_{\substack{\omega, r_1, r_2 \\ \omega r_1 + (1-\omega) r_2 = q}} \{\omega H_n(r) + (1-\omega) H_n(r)\} \quad \text{and} \quad \bar{h}_n(q) = \frac{d\bar{H}_n(q)}{dq}, \tag{22}$$

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 6. *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*

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

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

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

achieves the maximum in problem (21).

Proof. We can write the objective function as

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

Let us consider the last term of the above equation.

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

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 (21). □

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.

A.2 The optimal buying mechanism as a bid price

Now consider the problem of a non-owner designing a mechanism to maximize their expected gains from trade. Similar to subsection A.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 given by

$$\max_{m} \int \left[p(\Delta_o)\Delta_n - x(\Delta_o)\right] m_o(\Delta_o) d\Delta_o \tag{23}$$

subject to

$$IR: \quad x(\Delta_o) - p(\Delta_o)\Delta_o \geq 0 \ \text{ and} \tag{24}$$

$$IC: \quad x(\Delta_o) - p(\Delta_o)\Delta_o \geq x(\hat{\Delta}_o) - p(\hat{\Delta}_o)\Delta_o; \tag{25}$$

for all Δ_o and $\hat{\Delta}_o$.

We will show the solution to problem (23) - (25) is associated with a bid price. To do so, we will use the results in the following lemmas, which are analogs to Lemmas 5 and

6.

Lemma 7. *A mechanism $m = (p, x)$ satisfies (24) and (25) 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 (25) for an owner with reservation value Δ_o implies that

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

The IC constraint (25) 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

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

Because $m = (p, x)$ satisfies the IR constraint (24), $U(\Delta_o) \geq 0$ 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

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

That is, the IC constraint (25) is satisfied. This concludes the proof of the lemma. □

Lemma 8. *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 (23) if, and only if, it* *solves problem*

$$\max_m \int p(\Delta_o)\left[\Delta_n - \Delta_o - \frac{M_o(\Delta_o)}{m_o(\Delta_o)}\right] m_o(\Delta_o) d\Delta_o \tag{26}$$

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. Using Lemma 7, we can rewrite the objective function given by problem (23) as

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

We can then apply integration by parts in the following term

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

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

We are now ready to state the result that the optimal buying mechanism is a bid price. Define the functions

$$\bar{H}_o(q) = \min_{\substack{\omega, r_1, r_2 \\ \omega r_1 + (1-\omega) r_2 = q}} \{\omega H_o(r) + (1-\omega) H_o(r)\}, \;\; \bar{h}_o(q) = \frac{d\bar{H}_o(q)}{dq} \tag{27}$$

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 7. *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*

$$c_o(\Delta) = \bar{h}_o\left(M_o(\Delta)\right) \;\; \textit{and} \;\; c_o^{-1}(\Delta) = \sup\{\Delta_o \in [\underline{\Delta}, \bar{\Delta}]; c_o(\Delta_o) \le \Delta\}.$$

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

$$m(\Delta_o) = \left(p(\Delta_o), x(\Delta_o)\right) = \begin{cases} \left(1, c_o^{-1}(\Delta_n)\right) & \textit{if} \;\; c_o(\Delta_o) \le \Delta_n \\ (0,0) & \textit{otherwise} \end{cases}$$

achieves the maximum in problem (26).

Proof. We can write the objective function as

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

Let us consider the last term of the above equation.

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

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

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

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 (26). □

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 **??**.

B Appendix: Main proofs

B.1 Bilateral trade

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.*

Proof. Note that $obj_o(ask; \alpha_n)$ 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 $obj_o(ask_o; \alpha_n) \geq obj_o(\hat{ask}; \alpha_n) = [\hat{ask} - \Delta_o][1 - M_n(\hat{ask}; \alpha_n)] > 0 \Longrightarrow ask_o \nleq \Delta_o$. □

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 strictly positive probability the non-owner has a higher reservation value than the owner and they do not trade. That is, we have that $M_n(ask_o - \epsilon; \alpha_n) - M_n(\Delta_o; \alpha_n) > 0$ for some $\epsilon > 0$.*

Proof. 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 $M_n(ask_o - \epsilon; \alpha_n) - M_n(\Delta_o; \alpha_n) = M_n(\Delta_o + min\{ask_o - \Delta_o, \bar{\epsilon}\}/2) - M_n(\Delta_o; \alpha_n) > 0$. □

Lemma (2). *Consider a non-owner's reservation value Δ_n and an owner's screening ability α_o. If there is a positive measure of owners with screening ability α_o and reservation value below Δ_n, that is, $lim_{\Delta \nearrow \Delta_n} M_o(\Delta; \alpha_o) > 0$, then bid_n is strictly below Δ_n.*

Proof. It is analogous to the proof of Lemma 1 and we omit it here. □

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, we have that $M_o(\Delta_n - \epsilon; \alpha_o) - M_o(bid_n; \alpha_o) > 0$ for some $\epsilon > 0$.*

Proof. It is analogous to the proof of Corollary 1 and we omit it here. □

B.2 Equilibrium

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

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 j. 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 set $\mathcal{D} \subset \mathcal{C}^0(\Theta_M)$ as the set of functions $\Delta \in \mathcal{C}^0(\Theta_M)$ satisfying

$$\underline{\Delta} \leq \Delta(\alpha,\nu) \leq \bar{\Delta} \;\text{ and }\; \frac{b}{2} \leq \frac{\Delta(\alpha,\hat{\nu}) - \Delta(\alpha,\nu)}{\hat{\nu}-\nu} \leq (1+\kappa)b$$

for all $(\alpha,\nu),(\alpha,\hat{\nu}) \in \Theta_M$. Similarly, define the set $\mathcal{P} \subset \mathcal{C}^0(\Theta_M)$ as the set of functions $\Phi \in \mathcal{C}^0(\Theta_M)$ satisfying

$$0 \leq \Phi(\alpha,\nu) \leq F(\alpha,\nu) \;\text{ and }\; 0 \leq \frac{\Phi(\alpha,\hat{\nu}) - \Phi(\alpha,\nu)}{\hat{\nu}-\nu} \leq \frac{F(\alpha,\hat{\nu}) - F(\alpha,\nu)}{\hat{\nu}-\nu}$$

for all $(\alpha,\nu),(\alpha,\hat{\nu}) \in \Theta_M$.

Note that any sequence $\{\Delta^j, \Phi^j\}_j \subset \mathcal{D} \times \mathcal{P}$ is equicontinuous and by the Arzelà-Ascoli theorem has a converging sub-sequence and the limit is continuous. Moreover, it is easy to show that $\mathcal{D} \times \mathcal{P}$ is convex. Therefore, $\mathcal{D} \times \mathcal{P}$ is a compact and convex subspace of $\mathcal{C}^0(\Theta_M) \times \mathcal{C}^0(\Theta_M)$. We use this result later in the proof when applying the Schauder fixed point theorem.

Solving for the optimal bid and ask functions: The pair $(\Delta, \Phi) \in \mathcal{D} \times \mathcal{P}$ 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 is done for presentation purpose and is not necessary here). Fix an integer $j \geq 1$ and let $p \in \mathbb{P}_j$ be the best monotone approximation of M_o on $[\underline{\Delta}, \bar{\Delta}]$. Note that the polynomial $p \in \mathbb{P}_j$ is uniquely defined (see Lorentz (1971)). 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 (27), 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 7. We obtain the best selling mechanism in a the same fashion.

Note that these best buying/selling mechanism are approximations that depend on the parameter j. The operator we define now will depend on j and later we will take the limit as j goes to infinity. It is easy to show that, not only the polynomial approximations of M_o and M_n converge uniformly as j goes to infinity, but the implied profit and trade probabilities will also converge.

Reservation value: Given $j \geq 1$ and $(\Delta, \Phi) \in \mathcal{D} \times \mathcal{P}$, define $\hat{\Delta}$ as

$$\hat{\Delta}(\theta) = \frac{\nu + \lambda[\Delta(\theta) + (1-s)\pi_o(\theta) - s\pi_n(\theta)]}{\lambda + \mu + \eta + r}, \tag{28}$$

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 $\hat{M}_n$.

Lemma 9. *The function $\hat{\Delta}$ defined above belongs to $\mathcal{D}$.*

Proof. First note that $\hat{\Delta} \in \mathcal{C}^0(\Theta_M)$ since $\Delta \in \mathcal{C}^0(\Theta_M)$ and π_o and π_n, given by (3) and (4), are max functions, which preserve continuity. We need to show that

$$\underline{\Delta} \leq \Delta(\alpha, \nu) \leq \bar{\Delta} \text{ and } \frac{b}{2} \leq \frac{\Delta(\alpha, \hat{\nu}) - \Delta(\alpha, \nu)}{\hat{\nu} - \nu} \leq (1+\kappa)b.$$

Let us start showing that $\hat{\Delta} \leq \bar{\Delta} := \bar{v}/r$. We have that

$$\hat{\Delta}(\theta) = \frac{\nu + \lambda[\Delta(\theta) + (1-s)\pi_o(\theta) - s\pi_n(\theta)]}{\lambda + \mu + \eta + r} \leq \frac{\nu + \lambda[\Delta(\theta) + (1-s)(\bar{\Delta} - \Delta(\theta))]}{\lambda + \mu + \eta + r}.$$

The inequality comes from two reasons. First, the highest profit of an owner is achieved if he sells the asset to the highest valuation investor with probability one, which implies that $\pi_o(\theta) \leq \bar{\Delta} - \Delta(\theta)$. Second, the lowest profit a non-owner can make is zero, which implies that $-\pi_n(\theta) \leq 0$. Rearranging the above inequality and using that $\Delta \leq \bar{\Delta} = \bar{v}/r$, we have

$$\hat{\Delta}(\theta) \leq \frac{\nu + \lambda[\Delta(\theta) + (1-s)(\bar{\Delta} - \Delta(\theta))]}{\lambda + \mu + \eta + r} \leq \frac{r + \lambda}{\lambda + \mu + \eta + r}\bar{\Delta} \leq \bar{\Delta}.$$

Let us now show that $\frac{\hat{\Delta}(\alpha,\hat{\nu}) - \hat{\Delta}(\alpha,\nu)}{\hat{\nu}-\nu} \leq (1+\kappa)b$. Without loss of generality, assume that $\hat{\nu} > \nu$, then we have that

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

Note that the profit an owner makes must be decreasing in his reservation value. That is because when selling the asset, the owner gives up his reservation value. As a result, since $\hat{\nu} > \nu$ and Δ is increasing in ν, we have that $\pi_o(\alpha, \hat{\nu}) - \pi_o(\alpha, \nu) \leq 0$. For a similar reason we know that $\pi_n(\alpha, \hat{\nu}) - \pi_n(\alpha, \nu) \geq 0$. Then we have that

$$\hat{\Delta}(\alpha, \hat{\nu}) - \hat{\Delta}(\alpha, \nu) \leq \frac{\hat{\nu} - \nu + \lambda[\Delta(\alpha, \hat{\nu}) - \Delta(\alpha, \nu)]}{\lambda + \mu + \eta + r}.$$

Note now that $\Delta \in \mathcal{D}$ and, therefore, $\frac{\Delta(\alpha,\hat{\nu}) - \Delta(\alpha,\nu)}{\hat{\nu} - \nu} \leq (1 + \kappa)b$. As a result,

$$\begin{aligned} \frac{\Delta(\alpha, \hat{\nu}) - \Delta(\alpha, \nu)}{\hat{\nu} - \nu} &\leq \frac{1 + \lambda(1 + \kappa)b}{\lambda + \mu + \eta + r} = \left[1 + a\left(1 + \frac{1}{1 - a}\right)\right] b \\ &= \frac{1 - a + a(1 - a) + a}{1 - a} b = \left(a + \frac{1}{1 - a}\right) b \leq (1 + \kappa)\, b. \end{aligned}$$

The proofs that $\hat{\Delta}(\alpha, \hat{\nu}) \geq \underline{\Delta}$ and $\frac{\hat{\Delta}(\alpha,\hat{\nu}) - \hat{\Delta}(\alpha,\nu)}{\hat{\nu} - \nu} \geq \frac{b}{2}$ are similar and we omit them here to keep this section shorter. □

Distribution: Given $j \geq 1$ and $(\Delta, \Phi) \in \mathcal{D} \times \mathcal{P}$, define the density $\hat{\phi}$ as

$$\hat{\phi}(\theta) = \frac{\lambda \bar{q}_n(\theta) + \eta}{\lambda[\bar{q}_o(\theta) + \bar{q}_n(\theta)] + \mu + \eta} \mathbb{1}_{\{\hat{\Delta}(\theta) \geq 0\}} f(\theta), \tag{29}$$

and the distribution $\hat{\Phi}$ as

$$\hat{\Phi}(\theta) = \int_{\tilde{\theta} \leq \theta} \hat{\phi}(\tilde{\theta}) d\tilde{\theta}, \tag{30}$$

where we obtain $\bar{q}_n(\theta)$ and $\bar{q}_o(\theta)$ from equations (9) and (10) using the functions $\hat{H}_o$ and $\hat{H}_n$ from the solutions to the optimal bid and ask we discussed above.

Similarly to the result for $\hat{\Delta}$, the construction of $\hat{\Phi}$ implies that the constraints we impose in the set $\mathcal{P}$ are satisfied.

Lemma 10. *The function $\hat{\Phi}$ defined above belongs to $\mathcal{P}$.*

Proof. First note that $\hat{\Phi} \in \mathcal{C}^0(\Theta_M)$ since it is the integral of the function $\hat{\phi}$ which is bounded. So we just need to show that

$$0 \leq \Phi(\alpha, \nu) \leq F(\alpha, \nu) \ \text{ and } \ 0 \leq \frac{\hat{\Phi}(\alpha, \hat{\nu}) - \hat{\Phi}(\alpha, \nu)}{\hat{\nu} - \nu} \leq \frac{F(\alpha, \hat{\nu}) - F(\alpha, \nu)}{\hat{\nu} - \nu}$$

for all $(\alpha, \nu), (\alpha, \hat{\nu}) \in \Theta_M$. All the above inequalities come from the fact that $\hat{\Phi} = \int \hat{\phi}$ and that $\hat{\phi} = \frac{[\lambda \bar{q}_n + \eta] \mathbb{1}_{\{\hat{\Delta} \geq 0\}}}{\lambda[\bar{q}_o + \bar{q}_n] + \mu + \eta} \times f$, where f is the density of F and the function $\frac{[\lambda \bar{q}_n + \eta] \mathbb{1}_{\{\hat{\Delta} \geq 0\}}}{\lambda[\bar{q}_o + \bar{q}_n] + \mu + \eta} \in [0, 1]$. It is easy to see how these imply that $\hat{\Phi}$ is non-negative, bounded by F, and that changes in $\hat{\Phi}$ are bounded by changes in F.

For example, without loss of generality consider $\hat{\nu} > \nu$, then

$$\begin{aligned}\hat{\Phi}(\alpha,\hat{\nu}) - \hat{\Phi}(\alpha,\nu) &= \int_{\nu}^{\hat{\nu}} \hat{\phi}(\alpha,\tilde{\nu})d\tilde{\nu} \\ &= \int_{\nu}^{\hat{\nu}} \underbrace{\frac{[\lambda\bar{q}_n(\alpha,\tilde{\nu})+\eta]\mathbb{1}_{\{\hat{\Delta}(\alpha,\tilde{\nu})\geq 0\}}}{\lambda[\bar{q}_o(\alpha,\tilde{\nu})+\bar{q}_n(\alpha,\tilde{\nu})]+\mu+\eta}}_{\text{belongs to the interval } [0,1]} f(\alpha,\tilde{\nu})d\tilde{\nu} \\ &\leq \int_{\nu}^{\hat{\nu}} f(\alpha,\tilde{\nu})d\tilde{\nu} = F(\alpha,\hat{\nu}) - F(\alpha,\nu),\end{aligned}$$

which implies that $\frac{\hat{\Phi}(\alpha,\hat{\nu})-\hat{\Phi}(\alpha,\nu)}{\hat{\nu}-\nu} \leq \frac{F(\alpha,\hat{\nu})-F(\alpha,\nu)}{\hat{\nu}-\nu}$. The other inequalities can be obtained in a similar manner and we omit them here. $\square$

Operator: Define the map $T_j : \mathcal{D}\times\mathcal{P} \to \mathcal{D}\times\mathcal{P}$ that maps $(\Delta,\Phi) \in \mathcal{D}\times\mathcal{P}$ into $(\hat{\Delta},\hat{\Phi}) \in \mathcal{D}\times\mathcal{P}$ defined by equations (28) and (30). Lemmas 9 and 10 imply that $T_j(\Delta,\Phi) \in \mathcal{D}\times\mathcal{P}$, so the map is well defined. The next lemma shows that T_j is not only well defined, but it is also a continuous map.

Lemma 11. *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 $(\Delta^*,\Phi^*) \in \mathcal{D}\times\mathcal{P}$ in the sup norm. We need to show that the sequence $\{T_j(\Delta_l,\Phi_l)\}_l = \{(\hat{\Delta}_l,\hat{\Phi}_l)\}_l$ also converges to $T_j(\Delta^*,\Phi^*) = (\hat{\Delta}^*,\hat{\Phi}^*)$.

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 (22) and (27), 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

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

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 in the sup norm 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

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

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 $\bar{h}_o^*(q) = d\bar{H}_o^*(q)/dq$ in the L^1 norm. 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 $\bar{H}_{ol}$ converges to $\bar{H}_o^*$. In the later case, $\bar{h}_{ol}(q) = h_{ol}(q)$ must converge in the L^1 norm 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 to $\bar{h}_o^*(q)$ and $\bar{h}_n^*(q)$ in the L^1 norm, then we must have that the associated bid and ask sequences, $\{bid_{nl}\}_l$ and $\{ask_{ol}\}_l$, also converge to $ask_o^*(q)$ and $bid_n^*(q)$ in the L^1 norm 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 (28), and distributions given by (30), are integral 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 $(\Delta^*, \Phi^*) \in \mathcal{D} \times \mathcal{P}$ in the sup, and we just argued that $\{bid_{nl}\}_l$ and $\{ask_{ol}\}_l$ converge to $ask_o^*(q)$ and $bid_n^*(q)$ in the L^1 norm, then $\{(\hat{\Delta}_l, \hat{\Phi}_l)\}_l$ converges to $T_j(\Delta^*, \Phi^*)$ in the sup norm. □

Now we can conclude that T_j has a fixed point.

Lemma 12. *For every integer $j \geq 1$, the map T_j defined above has a fixed point.*

Proof. This is a direct application of the Schauder Fixed Point Theorem. $\mathcal{D} \times \mathcal{P}$ is convex and compact, and T_j is continuous, so a fixed point exists. $\square$

Finding the fixed point: By the previous lemma, for each $j \geq 0$, $T_j : \mathcal{D} \times \mathcal{P} \to \mathcal{D} \times \mathcal{P}$ has a fixed point. That is, there is (Δ^j, Φ^j) such that $T_j(\Delta^j, \Phi^j) = (\Delta^j, \Phi^j)$.

Let us construct the sequence of fixed points of the T_js. That is, a sequence $\{\Delta^j, \Phi^j\}_j$ such that $T_j(\Delta^j, \Phi^j) = (\Delta^j, \Phi^j)$. Since $\{\Delta^j, \Phi^j\}_j \subset \mathcal{D} \times \mathcal{P}$, it is equicontinuous and by the Arzelà-Ascoli theorem, $\{\Delta^j, \Phi^j\}_j$ has a converging sub-sequence. 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 (28) with equality and Φ_o^* satisfies (30) 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 (22) and (27) 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 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 (6) and (7). 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 must 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 (28), which is equivalent to (7). Note also that π_o and π_n, in (28), are given by (3) and (4). We can then conclude that (28) 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 (30) 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 $\underline{\nu}$ and $\bar{\nu}$. Since $\sum_i \int \nu^2 f(\alpha_i, \nu) d\nu < \infty$, it is straightforward to show that the equilibrium of the truncated economy converges to an equilibrium of the original economy as $\bar{\nu}$ goes to infinity and $\underline{\nu}$ goes to minus infinity. □

B.3 Private Information and Market Structure

We build to the results in Lemmas 3 and 4 and Propositions 2 through 4 by first introducing a few helpful Lemmas.

Lemma 13. *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

$$\Delta(\theta) = \nu - (\mu + \eta)\Delta(\theta) + \lambda(1-s)\pi_o(\theta) - \lambda s \pi_n(\theta). \tag{31}$$

The above equation must be strictly increasing otherwise the left-hand side of (31) 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). □

Lemma 14. *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)* $\bar{q}_o(\theta) \geq \bar{q}_o(\hat{\theta})$*, and (ii)* $\bar{q}_n(\theta) \geq \bar{q}_n(\hat{\theta})$*, both with strict inequality if* $\Delta(\theta) = \Delta(\hat{\theta}) > 0$*.*

Proof. 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 $\Delta(\theta) = \Delta(\hat{\theta}) > 0$. □

Lemma (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) 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* $c(\theta) > c(\hat{\theta}) > 0$*.*

Proof. 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 14, 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 $c(\theta) > c(\hat{\theta})$. □

Proposition (2)**.** *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 $\alpha < a_I$.

Proof. 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 3, 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 $\alpha < \alpha^* = 1$. □

Proposition (3). *Consider a symmetric steady-state equilibrium* $\{bid_n, ask_o, \Delta, \phi_o, \phi_n, s\}$. *Then,* $\alpha = \alpha_I$ *for all investors type* $\theta = (\alpha, \nu) \in \Theta$ *such that* $c(\theta) \geq \underline{c}$.

Proof. 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 3, there would exist θ' such that $\alpha' = 1$, $\Delta(\theta') = \Delta(\theta)$ and $c(\theta') > c(\theta) \geq \underline{c} = \sup_{\theta\in\Theta}\{c(\theta)\}$. □

Proposition (4). *Suppose there are only two screening abilities,* $\alpha_h = 1$ *and* $\alpha_l < 1$. *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* $\Delta(\theta) > 0$. *We have that* $np(\theta) = 1$ *if, and only if,* $\alpha = \alpha_h = 1$.

Proof. 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 $np(\theta) < 1$. □

Lemma (4). *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* $speed_n(\theta) \geq speed_n(\hat{\theta})$*, with strict inequality if* $\Delta(\theta) = \Delta(\hat{\theta}) > 0$*, and*

ii) $\pi_o(\theta) > \pi_o(\hat{\theta})$ *and (ii)* $\pi_n(\theta) \geq \pi_n(\hat{\theta})$*, with strict inequality if* $\Delta(\theta) = \Delta(\hat{\theta}) > 0$*.*

Proof. The result in part (i) is immediate from Lemma 14 since speed is λ times q_o or q_n.

For part (ii), we can write $\pi_o(\theta) - \pi_o(\hat{\theta})$ from (3) as

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

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 $\Delta(\theta) = \Delta(\hat{\theta}) > 0$. □

C Extension with 13-F investors

In this section we provide a formal derivation of the results discussed in Section 6.1. As a reminder, the distribution of types across 13-F and non-13-F investors is given by $F = \omega_{13} F_{13} + \omega_{n13} F_{n13}$. Each 13-F investor draws a filing date $T \geq t_0$ with Poisson arrival $\gamma > 0$. Filing dates are independent from each other and are not known beforehand. The information revealed by filing a 13-F is imperfect. In a meeting after a 13-F investor files, $\rho \in (0, 1]$ is the probability that the report perfectly reveals the type of the 13-F investor to the counterparty. This shock is independent and identically distributed across 13-F investors and meetings and is independent from other shocks.

We consider how a filing affects the 13-F investor's conditional probability of trade with a given set of counterparties, $\hat{\Theta} \subseteq \Theta$. CAN THESE BE EITHER 13-F or NON-13-F? The conditional probability the 13-F investor trades with counterparties in $\hat{\Theta}$ at time t is given by

$$\bar{q}_t^{13F}(\theta; \hat{\Theta}) = \omega_o\, \bar{q}_{ot}^{13F}(\theta; \hat{\Theta}) + \omega_n\, \bar{q}_{nt}^{13F}(\theta; \hat{\Theta}), \tag{32}$$

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.[29] 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. That is, consider a investor who received a Poisson shock to file the 13-F at time $t = T$. In this case, we can write the discontinuity in trade probability in closed form as,

$$D_T^{13F}(\theta;\hat{\Theta}) = \omega_o \xi_n \mathbb{E}_{\hat{\Theta}}\Big\{\rho(1-\alpha_n)\mathbb{1}_{\{\Delta_n \geq bid_T^{13F}(\Delta_n)\}}\Big\} + \omega_n \xi_o \mathbb{E}_{\hat{\Theta}}\Big\{\rho(1-\alpha_o)\mathbb{1}_{\{ask_T^{13F}(\Delta_o) \geq \Delta_o\}}\Big\}. \tag{33}$$

The expectation operator in the first and second term of (33) are conditional expectations over $\theta_n \in \hat{\Theta}$ and $\theta_o \in \hat{\Theta}$, respectively. The effect of a 13-F filing depends 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: for a 13-F investor who files 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.

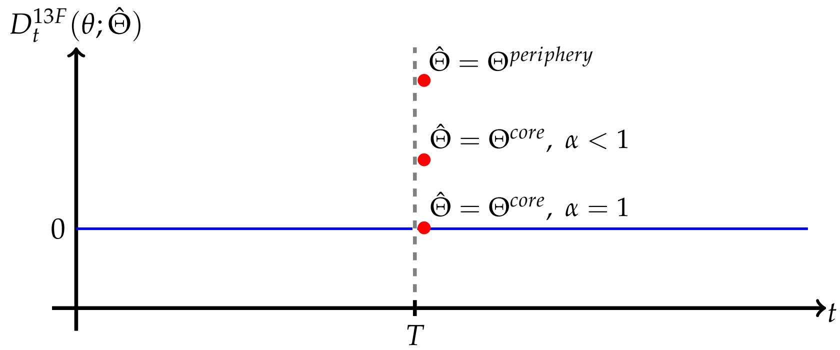
Proposition 8. *Let $\epsilon > 0$ be an arbitrarily small number. Then, if $\alpha_I \in [1-\epsilon, 1]$, then: (i) $D_T^{13F}(\theta;\Theta^{periphery}) > 0$, (ii) $D_T^{13F}(\theta;\Theta^{core}) \geq 0$, and (iii) $D_T^{13F}(\theta;\Theta^{periphery}) - D_T^{13F}(\theta;\Theta^{core}) > 0$, where $\Theta^{core} = \{\theta \in \Theta : c(\theta) \geq \underline{c}\}$, $\Theta^{periphery}$ is its complement, and $\underline{c}$ is defined in Proposition 3.*

Proposition 8 considers the set of core investors as those with a centrality measure in the top-p percentile, which Proposition 3 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.

This result, illustrated in Figure 5, is the key prediction of our model. If central traders do indeed possess a better screening technology then we would expect to find that public information revelation impacts them less.

[29]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 $\hat{\Theta}$.

Figure 5: 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.

D 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.[30]

D.0.1 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 $m = (p, x) : [\underline{\Delta}, \bar{\Delta}] \times [\underline{\Delta}, \bar{\Delta}] \to [0, 1] \times \mathbb{R}$, 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.

[30] 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.

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

$$\max_m \int\int p(\Delta_o, \Delta_n)\,[\Delta_n - \Delta_o]\, dM_o(\Delta_o) dM_n(\Delta_n) \tag{34}$$

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.

D.0.2 Expected gains from trade

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

$$\pi_o(\theta_o) = \int \Big\{ \alpha_o \left(1 - \alpha_n + {}^{\alpha_n}/_2\right) [\max(\Delta_o, \Delta_n) - \Delta_o] + (1-\alpha_o)(1-\alpha_n)\,[x(\Delta_o, \Delta_n) - p(\Delta_o, \Delta_n)\Delta_o] \Big\} d\frac{\Phi_n(\theta_n)}{1-s}, \tag{39}$$

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

$$\pi_n(\theta_n) = \int \Big\{ \alpha_n \left(1 - \alpha_o + {}^{\alpha_o}/_2\right) [\max(\Delta_o, \Delta_n) - \Delta_o] + (1-\alpha_n)(1-\alpha_o)\,[p(\Delta_o, \Delta_n)\Delta_n - x(\Delta_o, \Delta_n)] \Big\} d\frac{\Phi_o(\theta_o)}{s}. \tag{40}$$

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 D.0.1, where transfers are designed to maximize expected surplus.

D.0.3 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 D.0.2 instead of the one in subsection 3.2. The value function for an owner of a type θ is given by

$$rV_o(\theta) = \nu - \mu\big[V_o(\theta) - V_n(\theta)\big] + \lambda(1-s)\pi_o(\theta). \tag{41}$$

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

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

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

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

D.0.4 The distribution of assets

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

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

where

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

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

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

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

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

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

$$\phi_o(\theta) + \phi_n(\theta) = f(\theta), \tag{48}$$

and an expression for total asset supply is given by

$$s = \int \phi_o(\theta) d\theta. \tag{49}$$

D.0.5 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 4, the equilibrium definition does not include the value functions V_o and V_n because we can recover them from (41) and (42).

Proposition 9. *There exists a symmetric steady-state equilibrium.*

D.0.6 Intermediation

The trade protocol used here differs from the one used in Section 5, 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,[31] efficient ex-post trade cannot be achieved.

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

Proposition 10. *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

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

Since α_o and α_n are smaller than one with positive probability, Proposition 10 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 11. *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 11 is intuitive. We know from Proposition 10 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 11 we can derive our main centrality result below.

Proposition 12. *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* $\alpha < 1$*.*

E Appendix: Additional Empirical Results

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,

$$R^N_{j,i,k,t} = \beta_1 real_{j,i} + \beta_2 real_{j,i} \times core_{j,i} + FE_j + FE_k + FE_t + \varepsilon_{j,i,k,t}, \tag{50}$$

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 $\beta_1 > 0$. Our theory also predicts that this effect should be smaller when the institution's counterparty is in the core, which implies $\beta_2 < 0$.

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.

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. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

First, consider Table 6. For both buyers and sellers reporting 13-F, for all windows, and regardless of controlling for fixed effects, we observe $\beta_1 > 0$ 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 β_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 6. 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, (16), where we now define the dependent variables $D_{ijt}^{core/periphery}$ as dummies equal to one if institution j traded CDS index i in week t *a*s 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 5 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 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 the sample we lose power so the standard errors increase.

Exploiting the 45-day delay rule As discussed in Section 6, 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

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.

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 (16) 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

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 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, β^p			
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, β^c			
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, $\beta^p - \beta^c$			
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, $F_{j,t-x}/Frequency$ and $F_{j,t+x}/Frequency$, are normalized dummies, where the dummies are 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. Test on difference: tests whether the difference in the coefficients is equal to zero. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.