Endogenous Specialization and Dealer Networks

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September 2015

OTC markets exhibit a core-periphery dealer network: few central dealers trade a lot and with many dealers, while a large number of peripheral dealers trade sparsely and with few dealers. Existing explanations of the core-periphery phenomenon rely on an exogenous dealer heterogeneity. We build a search model of network formation and show that endogenous dealer specialization generates both dealer heterogeneity and the core-periphery network. Dealers specialize in clients by clients’ liquidity need. The dealers that cater to clients with frequent trading needs have a large client base, intermediate more for other dealers, and thus form the core. The dealers that instead specialize in buy-and-hold investors form the periphery. Dealers, as a result, although ex-ante identical, endogenously vary by their network centrality, size, execution speed, and liquidity provision service.

Keywords: Network formation, core-periphery, clientele effect, specialization, intermediation chains, over-the-counter markets, search frictions.

In over-the-counter markets, transactions between dealers exhibit a core-periphery network. Few highly interconnected dealers account for a majority of both dealer-to-dealer and client-to-dealer transactions. These dealers form the core, while a large number of sparsely connected dealers trade infrequently and form the periphery. The core dealers place assets more readily

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and provide greater liquidity; the opposite holds for the peripheral dealers. Li and Schürhoff (2014) document these patterns for the municipal bond market and Neklyudov, Hollifield, and Spatt (2014) for asset-backed securities.

Existing explanations of the core-periphery phenomenon rely on an exogenous heterogeneity among dealers. In Atkeson, Eisfeldt, and Weill (2014) and Zhong (2014), agents that form the core are exogenously large. In Neklyudov (2012), dealers with exogenously superior trading technologies form the core. Network models such as Kondor and Babus (2013) fix agents’ network centrality. While others such as Hugonnier, Lester, and Weill (2014) and Chang and Zhang (2015) assume heterogeneity in agents’ preference for an asset.\footnote{In particular, the heterogeneity is in the mean valuation in Hugonnier, Lester, and Weill (2014) and in the volatility of an agent’s valuation in Chang and Zhang (2015).} Thus, we still need to explain how dealer heterogeneity arises in the first place: how core dealers grow large, how they maintain their size and market share, and why they co-exist with peripheral dealers.

We build a search-based model of network formation. We show that dealer heterogeneity and, consequently, the core-periphery network arise from endogenous dealer specialization: Dealers specialize in clients by clients’ liquidity need. Dealers that attract investors with frequent trading needs have a large customer base, intermediate more for other dealers, and thus form the core. Dealers that instead cater to buy-and-hold investors form the periphery. Dealers, as a result, although ex-ante identical, endogenously vary by their network centrality, size, execution speed, and liquidity provision.

We show this insight with a model that builds on Duffie, Garleanu, and Pedersen (2005) and, in particular, on Vayanos and Wang (2007). We add to their environment dealers and inter-dealer trades. We depart from existing work by modeling clients and dealers separately. Dealers are ex-ante identical, but customers have heterogenous liquidity needs. At one end of the spectrum are liquidity investors who want to buy quickly and turn around and sell quickly. At the other end of the spectrum are buy-and-hold investors. Dealers intermediate directly between customers, but also use the inter-dealer market to supplement their liquidity provision to customers. We assume a fully connected dealer market, but network weights (in particular, transaction volumes between pairs of dealers) are endogenous. In this environment, we show that an asymmetric equilibrium exists and that it features a core-periphery dealer network.

The endogenous dealer specialization works as follows. Clients face a tradeoff between expected round-trip transaction costs and liquidity immediacy. Some dealers offer liquidity immediacy but charge wide bid-ask spreads. Others offer narrow bid-ask spreads but have slow execution speeds. Buy-
ers who expect to sell quickly care more about round-trip transaction costs. They consequently prefer the dealer with narrow bid-ask spreads, despite the slow liquidity immediacy. Buy-and-hold investors, in contrast, worry less about bid-ask spreads and thus choose the dealer with faster liquidity immediacy. Thus, investors with heterogenous liquidity needs endogenously sort across different dealers. The specialization, in turn, generates heterogeneity in dealers’ client size, bid-ask spreads, and liquidity immediacy. The dealers of liquidity investors have frequent turnover among its clients and thus a large client base; the opposite holds for dealers of buy-and-hold investors.

Importantly, the heterogeneity in dealers’ client size generates dealer heterogeneity on the inter-dealer market. The dealers with a large client base intermediate more for other dealers and thereby form the core. Dealers with fewer clients form the periphery. Thus, dealer specialization generates a core-periphery structure.

On the inter-dealer market, core dealers supply liquidity (by volume and transaction speed) to other dealers but charge wide bid-ask spreads. Peripheral dealers consume that liquidity and pass it on to their clients. They rely relatively more on the inter-dealer market and on long intermediation chains for their liquidity provision service to clients. Thus, bonds cycle through the inter-dealer network, then dealers’ clients, and eventually end with buy-and-hold investors.

Modeling clients and dealers separately offers two additional contributions. First, our model explains the observed network persistence. Existing search models assume that agents trade through random search and match and thus abstract from repeated interactions among agents. Also, to generate trade, agents’ valuations change randomly, suggesting that their identities and equilibrium roles are random. Search models, as a result, imply that OTC networks are random. In practice, networks are highly persistent.

Relaxing these standard, yet unrealistic, assumptions in the literature generates realistic predictions. We assume changes in asset valuations occur with clients, not dealers. Dealers’ identities and their equilibrium roles (e.g., whether they are a core or peripheral), as a result, remain constant. The stability of dealer identities allows us to model explicit network links among

\footnote{In Hugonnier, Lester, and Weill (2014), for example, agents with an intermediate asset valuation resemble core dealers, while agents with extreme valuations resemble peripheral dealers. As agents randomly switch between different valuations, a dealer that is a core dealer one period can randomly become a peripheral dealer the next period and vice versa. Similarly, in Shen, Wei, and Yan (2015), an agent randomly switches between trading like a dealer versus like a client.}

\footnote{Li and Schürhoff (2014) document that the probability of two dealers trading again month-to-month is 65%. In a random network, this probability is 1.4%.
dealers. The links, in turn, mean repeated trades between dealers, hence the persistence in bilateral trades. Moreover, the specialization equilibrium in our model generates even greater network persistence than the symmetric equilibrium.

Second, the client-dealer distinction reconciles a disparity between the stylized facts and existing theory. The core-periphery phenomenon is based on observing dealer-to-dealer transactions. The stylized facts comparing core and peripheral dealers, however, result from observing client-dealer transactions and thus capture a client’s perspective. Li and Schürhoff (2014), for example, compare bid-ask spreads core versus peripheral dealers charge clients, not other dealers. Client-dealer vs. dealer-dealer distinction, however, is absent in existing models that can speak to dealer networks and intermediation chains. Our results show the distinction is important because, first, it allows for a coherent explanation of the observed dealer heterogeneity. Second, we show that core and peripheral dealers’ liquidity provision to clients is the opposite from their liquidity provision to other dealers’. For example, clients face narrow bid-ask spreads from a core dealer, but dealers, in contrast, face wide bid-ask spreads from a core dealer.

Finally, we highlight the effect of dealer interconnectedness. We show that dealer interconnectedness improves bond liquidity: It increases the aggregate volume of transactions, narrows bid-ask spreads, and speeds up transaction times. Greater liquidity, in turn, alleviates misallocations: a larger number of investors with the greatest utility for the bond own the bond. The more efficient asset allocation increases customer welfare, while larger volumes of trade increase dealer profits. The total welfare, as a result, increases.

We proceed as follows. Section 1 presents the model. In Section 2, we derive the clientele equilibrium and compare liquidity and prices that core and peripheral dealers provide to customers and, on the inter-dealer market, to other dealers. Section 3 gives additional results on how dealer interconnectedness and market fragmentation affect customer welfare, dealer profits, bond liquidity, and bond prices. In Section 4, we discuss our assumptions. Section 5 concludes.

Related Literature

We highlight additional comparisons with existing work.

We depart from Duffie, Garleanu, and Pedersen (2005) (DGP) in an important way: from the perspective of clients, dealers are segmented. In DGP, end-customers trade with one another directly through random search and match, but also frictionlessly with any dealer. Thus, the implicit assumption
in DGP is a zero cost of forming a client-dealer relationship. Their environment is effectively an environment with one dealer. In contrast, our model features dealer segmentation; thus, it implicitly assumes a cost of forming a client-dealer relationship. We therefore model and study in a meaningful way (1) clients’ endogenous choice over dealers, (2) multiple dealers, (3) the intermediation chain among dealers, and (4) dealer heterogeneity.

We close the gap between the network and search literatures: We build a model of dealer networks and network formation in a search setting.\textsuperscript{4} We relax the most unrealistic assumption in the search literature that trade occurs random search and match. Clients in our model choose dealers and trade repeatedly with their dealers. Similarly, because we explicitly model network links between dealers, dealers trade with each other repeatedly.

In the network literature, a large strand studies networks in the interbank lending market.\textsuperscript{5} We instead develop a model with a broader application to any OTC market. The model, as a result, allows us to study transaction volumes, bid-ask spreads, and liquidity provision. Other network models, such as Kondor and Babus (2013), are based on asymmetric information. In contrast, we (1) offer a search-based network model and (2) allow for endogenous network weights.\textsuperscript{6}

In our model, some dealers in equilibrium intermediate more dealer-to-dealer trades than other dealers. Bonds also go through longer intermediation chains with peripheral dealers than with core dealers. Thus, our paper relates to models of intermediation chains (e.g., Glode and Opp (2014), Gofman (2011), Colliard and Demange (2014), and Shen, Wei, and Yan (2015)).

\section{Model}

Time is continuous and goes from zero to infinity. Agents are risk neutral, infinitely lived, and discount the future at a constant rate $r > 0$. A bond is an asset with supply $S$ and pays a coupon flow $\delta$.

Two sets of agents populate the economy: investors and three dealers. Dealers are indexed by $i \in N$, where $N = \{1, 2, 3\}$ is the set of dealers. A

\textsuperscript{4}A paper related to ours is Malamud and Rostek (2013); they provide a general model of OTC markets and networks. For search models see, for example, Duffie, Garleanu, and Pedersen (2005), Weill (2008), Vayanos and Weill (2008), Lagos and Rocheteau (2009), and Duffie, Malamud, and Manso (2009).

\textsuperscript{5}For recent network models specific to the interbank loan market, see, for example, Farboodi (2014) and Wang (2014).

\textsuperscript{6}The dealer network in our model is part exogenous and part endogenous. It is exogenous in that we assume a fully connected dealer network and dealers do not choose who to link to. Thus, we implicitly assume a zero cost of forming a link. It is endogenous in that, once linked, link strengths (that is, network weights) are endogenous.
flow of investors enter the economy as buyers, choose a dealer, and, upon buying a bond through a dealer, become bond owners. Bond owners enjoy the full value of the bond coupon flow until they experience a liquidity shock and become sellers. Bonds yield sellers a flow utility \( \delta - x \), where \( x > 0 \) is sellers' disutility of holding the bond. Upon selling the bond, the investor exits the economy.

Buyers differ in the intensity with which they receive the liquidity shock, denoted by \( k \). After purchasing a bond, a \( k \)-type buyer expects to hold the bond for a period of \( \frac{1}{k} \). Thus, buyers are heterogenous in their trading horizon. Those with a high switching rate (\( k \)) have a short trading horizon (\( \frac{1}{k} \)) and expect to have to sell quickly, while buyers with a small \( k \) expect to hold the bond for a long time. The distribution of buyers is characterized by the density function \( \hat{f}(k) \) with support \([k, \bar{k}]\). The flow of buyers with switching rates in \([k, k + dk]\) is then \( \hat{f}(k)dk \).

Upon entering the economy, a \( k \)-type buyer chooses dealer \( i \) with probability \( \nu_i(k) \) according to

\[
\nu_i(k) = \begin{cases} 
1 & V^b_i(k) > \max_{j \neq i} V^b_j(k) \\
[0, 1] & V^b_i(k) = \max_{j \neq i} V^b_j(k) \\
0 & V^b_i(k) < \min_{j \neq i} V^b_j(k), 
\end{cases}
\]

where \( V^b_i(k) \) denotes the expected utility of a \( k \)-type buyer who is a customer of dealer \( i \), and \( \sum_{i \in N} \nu_i(k) = 1 \). Once a buyer chooses a dealer, we assume he remains a client of that dealer throughout his life-cycle. In particular, if he has to sell at a later date, he can sell only through his dealer. Figure 1 illustrates the life-cycle of clients.

\footnote{If buyers get the liquidity shock before they buy, they exit the economy.}
Figure 1: Clients of dealer $i$: buyers, owners, and sellers

The figure illustrates in dashed (black) lines clients’ life-cycle from a buyer to an owner to a seller. Solid (blue) lines represent bond transaction flows intermediated through a dealer.

We denote by $\mu^s_i$, $\mu^b_i$, and $\mu^o_i$ the total measure of sellers, buyers, and owners of dealer $i$, where

$$
\mu^b_i \equiv \int_k^k \hat{\mu}_i^b(k) dk
$$

(2)

$$
\mu^o_i \equiv \int_k^k \hat{\mu}_i^o(k) dk.
$$

(3)

The functions $\hat{\mu}_i^b(k)$ and $\hat{\mu}_i^o(k)$ are such that $\hat{\mu}_i^b(k) dk$ and $\hat{\mu}_i^o(k) dk$ are the measures of buyers and owners with switching rates $k$ in $[k, k + dk]$. For later reference, we denote the aggregate mass of sellers and buyers as:

$$
\mu^s_N \equiv \sum_{i \in N} \mu^s_i.
$$

(4)

$$
\mu^b_N \equiv \sum_{i \in N} \mu^b_i.
$$

(5)

**Dealers and Intermediations**

Dealers intermediate bond transactions for customers who, otherwise, face an infinitely large search cost of directly finding another customer. Dealer $i$ produces matches among her buyers and sellers according to

$$
M_i \equiv \lambda \mu^s_i \mu^b_i.
$$

(6)
where $\lambda$ is an exogenous efficiency of her matching ability. Adopting the notation from Li & Schurhoff (2014) and Neklyudov, Hollifield, and Spatt (2014), these are CDC (Client-Dealer-Client) intermediations, where the first C is the end-seller client, and the last C is the end-buyer client. We assume dealers do not hold inventory. They buy a bond from one client and instantly sell to another client only after they have pre-arranged the match.

A dealer supplements her liquidity provision to customers through dealers in her network. Dealer $i$’s network, denoted by $N_i$, is the set of dealers that dealer $i$ is connected to. We assume each dealer is connected to every other dealer, $N_i = \{ j \in N : j \neq i \}$ for all $i$. We define two dealers $i$ and $j$ as connected if they share their clients with each other. A link with dealer $j$ gives dealer $i$ access to dealer $j$’s masses of sellers and buyers, $\mu^s_j$ and $\mu^b_j$. It is symmetric for dealer $j$. Using dealer $j$’s buyers, dealer $i$ produces $\lambda \mu^s_i \mu^b_j$ matches; in particular, CDDC chains, where dealer $i$ is the first D. Symmetrically, using her own buyers and dealer $i$’s sellers, dealer $j$ also produces $\lambda \mu^s_i \mu^b_j$. Thus, dealer $i$ intermediates a total of $2\lambda \mu^s_i \mu^b_j$ CDDC chains, where he is the first D. Half of it is produced by him; the other half is produced by $j$, but dealer $i$ still takes a cut from the intermediation surplus. By an analogous argument, dealer $i$ intermediates a total of $2\lambda \mu^s_j \mu^b_i$ CDDC chains, where he is now the second D. Aggregating masses of sellers and buyers across dealer $i$’s entire network,

$$\mu^s_{N_i} \equiv \sum_{j \in N_i} \mu^s_j$$

and

$$\mu^b_{N_i} \equiv \sum_{j \in N_i} \mu^b_j,$$

the total number of bonds dealer $i$ intermediates on the inter-dealer market is

$$M_{N_i} \equiv 2\lambda \mu^s_i \mu^b_{N_i} + 2\lambda \mu^s_{N_i} \mu^b_i. \quad (7)$$

The two terms are the number of CDDC chains where dealer $i$ is the first and

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8A general functional form for the matching functions would be $M(\mu^b, \mu^s) = \lambda (\mu^b)^{\alpha_b} (\mu^s)^{\alpha_s}$. Thus, we have implicitly assumed that $\alpha_s = \alpha_b = 1$. Although constant returns to scale is standard in search models applied to labor markets, in the context of OTC financial markets, the standard assumption is increasing returns to scale. Weill (2008) shows that comparative statics from a model with increasing returns to scale fit better the stylized facts regarding, for example, liquidity and asset supply.

9CDDC means Client-Dealer-Dealer-Client chain, where the ordering captures the direction of the bond flow. The first C is the end-seller client, and the last C is the end-buyer client. The first D is the dealer buying from the end-seller and selling to the second dealer, and the second D is the dealer buying from the first D and selling to the end-buyer client.
the second D, respectively. Comparing (7) with (6), intermediation chains involving two dealers are more efficient than those involving just one dealer. This specification implies that if a dealer has a small client base and thus relies more on inter-dealer market, she executes client trades more quickly.

In our environment, trading frictions manifest as waiting periods after a dealer or a client has submitted an order with a dealer. Customers and dealers can instantly contact other dealers and submit their orders. But, after receiving orders, dealers take time in producing the actual matches, thus creating wait times for clients and other dealers. Our specification is realistic. In practice, customers and dealers can easily call up and put an order through dealers, but immediate transactions are not guaranteed.

Figure 2: Clients, Dealers, and Inter-Dealer Trades
The figure illustrates the model environment. Dashed (black) lines represent clients’ life-cycle between different types (buyer, owner, and seller). Solid (blue) lines represent bond transaction flows. The size of circles represent the size of client measures.

Market Clearing
The supply of bonds circulating among customers of dealer \( i \), denoted by \( s_i \), equals the measure of customers who currently hold the bond:

\[
\int_{k}^{\bar{k}} \tilde{\mu}_i^k dk + \mu_i^s = s_i.
\]
For market clearing, the number of bonds circulating across all dealers has to equal the aggregate supply of the bond, $S$:

$$\sum_{i \in N} s_i = S. \quad (9)$$

**Inter-dealer Trades**

We ensure that, in the steady state, a dealer is not growing or shrinking. The total number of bonds dealer $i$ sells and buys on the inter-dealer market are $2\lambda \mu_s^i \mu_{N_i}^b$ and $2\lambda \mu_s^i \mu_i^b$, respectively. Equating the two ensures that she is neither a net buyer or a seller on the inter-dealer market:

$$2\lambda \mu_s^i \mu_{N_i}^b = 2\lambda \mu_s^i \mu_i^b. \quad (10)$$

**Transitions**

To ensure that population measures are constant in the steady state, a flow of investors switching to a particular type has to equal the flow of investors switching out of that type.

A flow of $\hat{f}(k)\nu_i(k)dk$ of type $k \in [k, k + dk]$ investors become buyers of dealer $i$. Among $k$-type buyers, some experience a liquidity shock and exit the economy with intensity $k$; others buy a bond through the dealer with intensity $\lambda(\mu_s^i + 2\mu_{N_i}^b)$. Thus, the population measure of $k$-type buyers is determined by

$$\nu_i(k)\hat{f}(k)dk = k\hat{\mu}_i^b(k)dk + \lambda \left( \sum_{j \in N} \rho_{ij} \mu_j^b \right) \hat{\mu}_i^b(k)dk, \quad (11)$$

where $\rho_{ij} \equiv 2$ if $i \neq j$; otherwise, $\rho_{ij} \equiv 1$. Similarly, the population measure of $k$-type owners is given by

$$\lambda \left( \sum_{j \in N} \rho_{ij} \mu_j^s \right) \hat{\mu}_i^o(k) = k\hat{\mu}_i^o(k). \quad (12)$$

The left hand side is the flow of buyers that turn into $k$-type owners of dealer $i$; the right hand side reflects the flow of owners that experience a liquidity shock and switch to sellers.

**Prices**

Prices arise from bargaining. The end-seller and the end-buyer each capture $z(n)$ fraction of the total gains from trade, where $z(n)$ is a customer’s bar-
gaining power, and \( n \) is the number of dealers involved in the intermediation chain. Dealers split equally the remaining \( 1 - 2z(n) \) fraction.

Figure 3 depicts the characterization of prices. We denote by \( V^s_i \), \( V^b_i(k) \), and \( V^o_i(k) \) the expected utility of a seller, \( k \)-type buyer, and \( k \)-type bond owner, respectively, who are customers of dealer \( i \). From Nash-bargaining, a seller of dealer \( i \) sells to his dealer at the bid price

\[
\hat{p}^{\text{bid}}_{i,j}(k) = (1 - z(n))V^s_i + z(n) (V^o_j(k) - V^b_j(k))
\]

(13)

if the buyer at the other end of the intermediation chain is a \( k \)-type buyer of dealer \( j \). Dealer \( i \) turns around and sells to dealer \( j \) at the inter-dealer price:

\[
\hat{P}_{i,j}(k) = \frac{1}{2}V^s_i + \frac{1}{2} (V^o_j(k) - V^b_j(k)).
\]

(14)

We denote dealer-to-dealer prices with capital letters (\( P \)) and client-to-dealer prices with small letters (\( p \)). After purchasing the bond from dealer \( i \), dealer \( j \) sells to his buyer at the ask price

\[
\hat{p}^{\text{ask}}_{i,j}(k) = z(n)V^s_i + (1 - z(n)) (V^o_j(k) - V^b_j(k)).
\]

(15)

If \( j = i \), the intermediation is among a buyer and seller of the same dealer \( i \), and the inter-dealer price \( \hat{P}_{i,j}(k) \) is irrelevant. If \( j \in N_i \), the bond transaction instead involves an inter-dealer trade, and the end-buyer and seller are customers of different dealers.

Figure 3: Prices from Bargaining
The total gains from trade is the difference between the end-buyer and end-seller’s reservation values. Prices are such that the two end-customers each capture \( z(n) \) fraction of the total surplus; dealers split equally the remaining \( 1 - 2z(n) \) fraction.
Value Functions

The expected utility of a $k$-type buyer who is a customer of dealer $i$ is given by

$$rV^b_i(k) = k \left( 0 - V^b_i(k) \right) + \sum_{j \in N} \rho_{ij} \lambda \hat{\mu}_j^b \left( V^o_i(k) - V^b_i(k) - \hat{p}_{ij}^{ask}(k) \right) \tag{16}$$

The first term reflects the change in the buyer’s utility if he gets a liquidity shock before he is able to buy. In the second term, if $j = i$, the transaction is with another customer of the same dealer. If $j \in N_i$, the transaction instead involves an inter-dealer intermediation chain, and the end-seller is a customer of another dealer $j$.

Analogously, the expected utility of a $k$-type bond owner who is a customer of dealer $i$ is given by

$$rV^o_i(k) = \delta + k \left( V^s_i - V^o_i(k) \right) \tag{17}$$

The expected utility of a seller who is a customer of dealer $i$ is given by

$$rV^s_i = \delta - x + \sum_{j \in N} \left( \int_0^k \rho_{ij} \lambda \tilde{\mu}_j^b(k)(\tilde{p}_{ij}^{bid}(k) - V^s_i)dk \right) \tag{18}$$

**Definition.** A steady state equilibrium is expected utilities $\{V^o_i(k), V^b_i(k), V^s_i\}_{i \in N}$, population measures $\{\hat{\mu}_i^o(k), \hat{\mu}_i^b(k), \mu_i^s\}_{i \in N}$, the distribution of bond supply across dealers $\{s_i\}_{i \in N}$, prices $\{\hat{p}_{ij}^{bid}(k), \hat{p}_{ij}^{ask}(k), \tilde{P}_{ij}(k)\}_{i,j \in N}$, and entry decisions $\{\nu_i(k)\}_{i \in N}$ such that

1. Value functions solve investors’ optimization problems (16)–(18).

2. Population measures and the distribution of bonds across dealers solve inflow-outflow equations (11)–(12), market clearing conditions (8)–(9), and inter-dealer transactions equations (10).

3. Prices arise from bargaining (13)–(15).

4. Entry decisions $\{\nu_i(k)\}_{i \in N}$ solve (1) and $\sum_{i \in N} \nu_i(k) = 1$.

**Prices and Liquidity from Clients’ Perspective** Before we derive our main results in the next section, we first characterize, from a client’s perspective, bid-ask spreads and liquidity immediacy. Since prices are specific to dealer-pairs and to customer types, we aggregate prices as follows. A $k$-type buyer of dealer $i$ expects to pay:
\[
\hat{p}_i^{\text{ask}}(k) \equiv \frac{1}{\mu_{i,N_i}} \sum_{j \in N} \rho_{ij} \mu_j^{\text{ask}} \hat{p}_{j,i}(k),
\]
(19)

where \(\mu_{i,N_i} \equiv \mu_i + 2 \mu_{N_i}\) and \(\mu_{i,N_i}^{\text{ask}} \equiv \mu_i + 2 \mu_{N_i}^{\text{ask}}\). Averaging across buyers of dealer \(i\), an average buyer of dealer \(i\) expects to buy at: \(^{10}\)

\[
p_i^{\text{ask}} \equiv E_i^b \left[ \hat{p}_i^{\text{ask}}(k) \right].
\]
(20)

The price a seller of dealer \(i\) expects to sell at is the weighted average price across buyers of dealer \(i\) and buyers of dealers in dealer \(i\)'s network (that is, across all buyers in the economy):

\[
p_i^{\text{bid}} \equiv \frac{1}{\mu_{i,N_i}} \sum_{j \in N} \rho_{ij} \mu_j^{\text{bid}} E_j^b \left[ \hat{p}_{i,j}^{\text{bid}}(k) \right],
\]
(21)

where \(E_j^b \left[ \hat{p}_{i,j}^{\text{bid}}(k) \right]\) is the weighted average price across buyers of dealer \(j\).

We define the expected round-trip transaction cost from the perspective of a \(k\)-type buyer of dealer \(i\) as the expected ask price minus the expected bid price normalized by the mid-point:

\[
\hat{\phi}_i(k) \equiv \frac{\hat{p}_i^{\text{ask}}(k) - p_i^{\text{bid}}}{0.5(\hat{p}_i^{\text{ask}}(k) + p_i^{\text{bid}})}.
\]
(22)

Similarly, the round-trip transaction cost that an average buyer of dealer \(i\) expects is:

\[
\phi_i \equiv \frac{p_i^{\text{ask}} - p_i^{\text{bid}}}{0.5(p_i^{\text{ask}} + p_i^{\text{bid}})}.
\]
(23)

The transaction speed is the time a dealer takes to place a bond with a client. A buyer purchases a bond through her dealer with intensity \(\lambda_{i,n}^{\text{ask}} = \lambda \mu_{i,N_i}^{\text{ask}}\), where the numerator is the total number of bonds dealer \(i\) places with buyers. The buyer’s wait time is then \(\tau_i^{\text{b}} \equiv \frac{1}{\lambda \mu_{i,N_i}^{\text{ask}}}\). Similarly, a seller’s wait time is \(\tau_i^{\text{s}} \equiv \frac{1}{\lambda \mu_{i,N_i}^{\text{bid}}}\).

**Prices and Liquidity on the Inter-Dealer Market**  We characterize prices and bid-ask spreads that an arbitrary dealer, indexed \(d\), faces from a core \((i)\) versus from a peripheral dealer \((j)\). We denote prices and bid-ask spreads from dealer-to-dealer transactions with capital letters, \(P\) and \(\Phi\), to contrast them from client-to-dealer transactions, \(p\) and \(\phi\), that are in lower case.

\(^{10}\)In particular, for some function \(f(k)\), \(E_i^b \left[ f(k) \right] = \int_k \frac{\mu_i^{\text{ask}}(k)}{\mu_i^{\text{bid}}} f(k) dk\).
Dealer $d$ buys from dealer $i \in N_d$ at price $\hat{P}_{i,d}(k)$, defined in (14), if dealer $d$’s client is a $k$-type buyer. The weighted average price across all dealer $d$’s buyers is

$$P_{i}^{\text{buy}} = E_d^{b}[\hat{P}_{i,d}(k)].$$

Conversely, a dealer sells to dealer $i$ at price $\hat{P}_{d,i}(k)$ if the other dealer’s client is a $k$-type buyer. The weighted average price across buyers of the other dealer is

$$P_{i}^{\text{sell}} = E_i^{b}[\hat{P}_{d,i}(k)].$$

We define the bid-ask spread as the expected purchase price minus the expected sale price normalized by the midpoint:

$$\Phi_i = \frac{P_{i}^{\text{buy}} - P_{i}^{\text{sell}}}{0.5P_{i}^{\text{buy}} + 0.5P_{i}^{\text{sell}}}.$$ 

Although $P_{i}^{\text{buy}}$, $P_{i}^{\text{sell}}$, and $\Phi_i$ are specific to dealer $d$, for exposition, we suppress their dependence on $d$.

2 Main Results

Asymmetric Specialization Equilibrium

In this section, we numerically derive results using the parameter values in Table 1. Most of the proofs for below propositions and lemmas remain to be completed. The following lemma shows that a symmetric equilibrium exists, where dealers are identical.

Lemma 1 (Symmetric Equilibrium). A symmetric equilibria exists. In it, dealers’ client sizes and consequently the dealers are identical.

We focus on the asymmetric equilibrium of Proposition 1. Without loss of generality, we label the dealer that endogenously attracts the slowest buyers (that is, the most buy-and-hold investors) as dealer 1, the dealer that attracts clients with intermediate liquidity needs as dealer 2, and the dealer that attracts clients with greatest liquidity need as dealer 3. Other asymmetric equilibria have identical properties, but indices on the dealers are reversed.

Proposition 1 (Specialization Equilibrium). There exists a unique asymmetric equilibrium. It is characterized by cutoffs \( \{k_1^*, k_2^*, k_3^*\}\), where \( k < k_1^* < k_2^* < k_3^* \), buyers with \( k < k_1^* \) choose dealer 1, with \( k \in [k_1^*, k_2^*] \) choose dealer 2, and with \( k > k_2^* \) choose dealer 3. Buyers at the cutoff \( k = k_1^* \) are indifferent between dealers 1 and 2: \( V_1^b(k_1^*) = V_2^b(k_1^*) \), and buyers at the cutoff \( k = k_2^* \) are indifferent between dealers 2 and 3: \( V_2^b(k_2^*) = V_3^b(k_2^*) \).
Table 2 shows the numerical values of the equilibrium cutoffs \( \{k_1^*, k_2^*\} \), and Figure 4 illustrates the result.

**Figure 4: Cutoffs \( \{k_1^*, k_2^*\} \)**

<table>
<thead>
<tr>
<th>customers of dealer 1</th>
<th>customers of dealer 2</th>
<th>customers of dealer 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k )</td>
<td>( k_1^* )</td>
<td>( k_2^* )</td>
</tr>
</tbody>
</table>

**Proposition 2** (Properties of the Specialization Equilibrium). Suppose dealers \( i \) and \( j \) are dealers specializing in liquidity and buy-and-hold investors, respectively: \( i > j \). Dealers of liquidity investors have a larger number of buyers and sellers: \( \mu_b^i > \mu_b^j \) and \( \mu_s^i > \mu_s^j \) but fewer owners and a smaller supply of bonds in circulation: \( \mu_o^i < \mu_o^j \) and \( s_i < s_j \). Buyers of dealer \( i \) face narrower round-trip transaction cost: \( \hat{\phi}_i(k) < \hat{\phi}_j(k) \) for all \( k \) but slower execution speed: \( \lambda \mu_{s,N,j}^i > \lambda \mu_{s,N,j}^j \). Customers of dealer \( i \) buy and sell at more favorable prices: \( p_{i,ask} > p_{j,ask} \) and \( p_{i,bid} < p_{j,bid} \).

The endogenous dealer specialization works as follows. Clients face a tradeoff between expected round-trip transaction costs and liquidity immediacy. Some dealers offer better liquidity immediacy but charge wide bid-ask spreads. Others offer narrow bid-ask spreads but have slow execution speeds. Buyers who expect to sell quickly (i.e., high \( k \) buyers) care more about round-trip transaction costs. They consequently prefer the dealer with narrow bid-ask spreads, despite the slow liquidity immediacy. Buy-and-hold investors, in contrast, worry less about bid-ask spreads and thus choose the dealer with fast liquidity immediacy. Thus, investors with heterogeneous liquidity needs endogenously sort across different dealers.

The specialization, in turn, generates heterogeneity in dealers’ client size, bid-ask spreads, and liquidity immediacy. Buy-and-hold investors trade infrequently and generate little turnover for their dealers. Their dealers, as a result, have fewer clients and rely more on the inter-dealer market for their liquidity provision service (that is, a greater proportion of its intermediation chains are CDDC chains, not CDC). But, since the inter-dealer market is more efficient, these dealers offer better execution speed, thus attracting any buyer. To restore equilibrium, prices adjust so that the dealer offering better liquidity immediacy also charges wide bid-ask spreads.

Bid-ask spreads, as a result, serve as a sorting device. Dealers offering narrow bid-ask spreads specialize in buyers who turn around and sell quickly, have frequent turnover among its clients, and thus have a large buyer and
seller customer base. The large client base, in turn, supports the narrow bid-ask spreads they charge. Dealers charging wide bid-ask spreads instead specialize in buy-and-hold investors: They have slow turnover among its clients, fewer buyers and sellers, but more end-owners. Figure 8 illustrates the properties.

Proposition 2 also shows that liquidity investors trade at more favorable prices. As buyers, they buy cheaply, and as sellers, they sell at a high price. Figure 9 shows these results.

An Endogenous Core-Periphery Network

We measure dealers’ network centrality by their volume of inter-dealer trades, $M_{N_i}$, given in (7). In the literature, two common ways to measure centrality are (1) the number of counterparties a dealer has and (2) the number of counterparties weighted by the trade volume. Since, in our environment, the number of links is identical across dealers, our measure is equivalent to (2). We define dealer $i$ as more central (i.e., core) than dealer $j$ if dealer $i$ intermediates larger volumes of inter-dealer trades ($M_{N_i}$) than dealer $j$.

Definition 1. Dealers $i$ and $j$ are defined as relatively core versus peripheral if $M_{N_i} > M_{N_j}$.

Proposition 3 gives the main insight of our paper. The endogenous heterogeneity in dealers’ client base generates dealer heterogeneity on the inter-dealer market. At one end, dealer 1 is the most peripheral dealer; at the other end, dealer 3 is the most central dealer. The large customer base of core dealers supports core dealers’ superior liquidity provision on the inter-dealer market (in terms of transaction volumes and transaction speeds). The large customer base of core dealers itself endogenously arises from the characteristics of clients that self-select with core dealers (namely, investors with frequent trading needs). The mechanism works in reverse for peripheral dealers. Figure 5 demonstrates the result.

Proposition 3 (An Endogenous Core-Periphery Network). The dealers that attract more liquidity investors intermediate more CDC chains, $M_i > M_j$. They also intermediate more inter-dealer trades, $M_{N_i} > M_{N_j}$, and thus form the core.

Thus, dealers vary by dimensions that existing work so far assumes. Dealers differ by their (a) network centrality (exogenous in fixed network models e.g., Babus and Kondor (2014)), (b) size measured by the size of their client base (assumed, for example, in Zhong (2014) and Atkeson, Eisfeld, and Weill (2014), and (c) matching technology (assumed in Neklyudov (2014)).
Core dealers charge clients narrow bid-ask spreads but have slow liquidity immediacy. Peripheral dealers, in contrast, offer liquidity immediacy but charge clients wide bid-ask spreads. Li and Schürhoff (2014) also conclude that investors face a tradeoff between transaction costs and liquidity immediacy. Our results on core vs. peripheral dealers’ bid-ask spreads are consistent with Neklyudov, Hollifield, and Spatt (2014), but not with Li and Schürhoff (2014), who document that core dealers charge clients wide bid-ask spreads.\footnote{We compute bid-ask spreads differently than Li and Schürhoff (2014) and Neklyudov, Hollifield, and Spatt (2014). They compute as follows. For CDDC chain, for example, the bid-ask spreads clients face are defined as the transaction price at the DC end of the chain (i.e. the price a client buys at) minus the price at the CD end of the chain (i.e. the price a client sells at) normalized by the mid-point in Neklyudov, Hollifield, and Spatt (2014) and by the price at the CD leg in Li and Schürhoff (2014). Li and Schürhoff (2014) regresses this bid-ask spreads on the centrality of the first dealer. Motivated by how clients in our model choose dealers, we instead take the perspective of a client of a particular dealer. We, first, take all chains $j$ such that $\{j : CD_i D_i C\}$, i.e. the buyer is a client of a dealer $i$ regardless of where dealer $i$ finds the bond (other dealers, core vs peripheral, or its own clients). Averaging the price at the $D_i C$ leg—across chains in this set—gives the expected price a buyer of dealer $i$ expects to buy at, again regardless of where the bond is coming from. Second, we do the same on the $CD$ leg: average the price at the $CD_i$ leg across chains $j$ such that $\{j : CD_j D_j C\}$. The average gives the expected sell price for a seller-client of dealer $i$. Our measure of the bid-ask spread is the difference, normalized by the midpoint. The difference in computations matters only for chains longer than CDC.
A dealer’s execution speed is unobservable in Li and Schürhoff (2014) and Neklyudov, Hollifield, and Spatt (2014) because their data reveal only transactions, not the order flows dealers receive. That is, the numerator in \( \frac{2\lambda \mu_s \mu_i^b}{\mu_i^d} \) is observable, not the denominator. Thus, the empirical counterparts to our model’s execution speed so far do not exist.\(^{12}\)

**Key Ingredients** The endogenous dealer heterogeneity relies on three key ingredients. The first key ingredient is search frictions (\( \lambda < \infty \)) together with an imperfectly competitive dealer market. Absent trading frictions (\( \lambda \to \infty \)), the dealer heterogeneity and, hence, the core-periphery structure do not arise.

The second key ingredient is the assumption that intermediation chains involving multiple dealers are more efficient than chains involving just one dealer. This assumption is necessary: clients have to somehow benefit from inter-dealer intermediation chains for them to prefer a dealer who relies relatively more on intermediation chains. Otherwise, dealer heterogeneity does not emerge. Clients would either all pool with one dealer (consequently, only a monopoly dealer exists) or choose all dealers with the same probability (that is, only the symmetric equilibrium exists). Our specification is one way to capture a benefit of inter-dealer intermediation chains. The main insight of our paper—that clients with heterogenous liquidity needs endogenously sort across different dealers, and the specialization in turn supports dealer heterogeneity—does not depend on the specific benefit we model. Other model implications and interpretations can, however, be specific to the particular assumed benefit.

The third and final ingredient is dealer segmentation: a client can only sell through the dealer she initially chooses. If clients can later sell through any dealer, specialization will not necessarily arise. The dealer segmentation captures a fixed cost of building a client-dealer relationship that the client and any averages computed using both CDC and longer chains. Since CDC comprise a majority of all chains, our results should be comparable to the results of Li and Schürhoff (2014) and Neklyudov, Hollifield, and Spatt (2014).

\(^{12}\)Proxying liquidity immediacy with days bonds sit in a dealer inventory, Li and Schürhoff (2014), nevertheless, conclude that core dealers offer better liquidity immediacy to clients. We do not model dealer inventory explicitly. If we proxy dealer inventory with the measure of client-sellers \( \mu^a \) (see our discussion on dealer inventory in Section 4), bonds leave a dealer’s inventory with intensity \( \frac{\lambda \mu_s \mu_i^b}{\mu_i^d} = \lambda \mu_i^b \), that is, a period of \( \frac{1}{\lambda \mu_i^b} \), in expectation. Since \( \lambda \mu_i^b \) is smaller for a core dealer, bonds sit longer in a core dealer’s inventory, consistent with Li and Schürhoff (2014). However, it still not obvious that the typical length bonds sit in a dealer’s inventory captures liquidity immediacy clients face. To compare liquidity immediacy across dealers, one has to assess dealers’ rate of either pre-arranging or taking bonds onto to their inventory relative to the volume of client order flows.
then needs to recoup over multiple trades. Presumably, such costs exist due to agency and contracting frictions, in the absence of which, clients would freely choose new dealers. Thus, although we do not model it explicitly, our results suggest that the core-periphery phenomenon is inherently due to contracting frictions between OTC counterparties.\(^{13}\)

The extent of all three ingredients increases the extent of dealer heterogeneity and, hence, the core-periphery structure. For example, as matching frictions increase, the extent of the core-periphery structure also increases.

### Prices and Liquidity on the Inter-Dealer Market

**Proposition 4** (Prices and Liquidity Provision on the Inter-Dealer Market). Suppose dealer \(i\) is a core dealer, while dealer \(j\) is peripheral. A dealer faces lower prices from a core dealer than from a peripheral dealer: \(P_{i_{\text{buy}}} < P_{j_{\text{buy}}}\) and \(P_{i_{\text{sell}}} < P_{j_{\text{sell}}}\). Core dealers charge other dealers wider bid-ask spreads than peripheral dealers: \(\Phi_i > \Phi_j\). Core dealers buy and sell more than peripheral dealers: \(2\lambda_{i_d}^s \mu_i^b > 2\lambda_{j_d}^s \mu_j^b\) and \(2\lambda_{i_d}^b \mu_i^s > 2\lambda_{j_d}^b \mu_j^s\). Core dealers provide greater liquidity immediacy: \(\frac{1}{2\lambda_{i_d}^b} < \frac{1}{2\lambda_{j_d}^b}\) and \(\frac{1}{2\lambda_{i_d}^s} < \frac{1}{2\lambda_{j_d}^s}\).

Core dealers, supported by the volume their liquidity clients generate, supply liquidity to other dealers. First, they transact greater volumes.\(^{14}\) The number of bonds an arbitrary dealer \(d\) sells on the inter-dealer market is \(2\lambda_{i_d}^s \left(\mu_i^b + \mu_i^s\right)\), where \(i\) is a core dealer and \(j\) is a peripheral dealer. Since a core dealer \(i\) has a larger number of buyers and sellers, a larger proportion of dealer \(d\)'s trades is with a core dealer. It is analogous for buy-side trades.

Second, core dealers provide greater liquidity immediacy to other dealers. Dealer \(d\) sells from dealer \(i\) and \(j\) with intensities \(\frac{2\lambda_{i_d}^s \mu_i^b}{\mu_i^s} = 2\lambda_{i_d}^b\) and \(\frac{2\lambda_{j_d}^s \mu_j^b}{\mu_j^s} = 2\lambda_{j_d}^b\), respectively. Since core dealers have a larger number of buyers and sellers, they provide faster transaction speeds on the inter-dealer market: \(\frac{1}{2\lambda_{i_d}^s} < \frac{1}{2\lambda_{j_d}^s}\). It is analogous for buy-side trades. This result on liquidity immediacy from dealers’ perspective is a novel prediction and has not been tested.\(^{15}\)

Peripheral dealers consume the liquidity core dealers supply and pass it on to their clients. They rely relatively more on the inter-dealer market and on long intermediation chains for their liquidity provision service to clients:

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\(^{13}\)The fact that the client segmentation is asymmetric—a buyer can choose over dealers, but a seller cannot—is immaterial.

\(^{14}\)This, of course, holds by construction because we define a dealer’s network centrality by its total inter-dealer volume.

\(^{15}\)As in the earlier discussion of liquidity immediacy from clients’ perspective, because order flows are unobservable (be it from clients or other dealers), empirical counterparts also do not exist.
CDDC chains comprise a relatively larger proportion of all their intermediations than CDC chains. This prediction of our model is consistent with Li and Schürhoff (2014) and Neklyudov, Hollifield, and Spatt (2014): They document long chains with peripheral dealers.

Bonds, as a result, cycle through the economy starting with core dealers’ clients, then the inter-dealer network, and eventually end with buy-and-hold investors who are concentrated with peripheral dealers. The cycle repeats when a buy-and-hold investor gets a liquidity shock and sells the bond. The sell order primarily gets absorbed, via the inter-dealer network, first by core dealers and their clients. Thus, core dealers serve as a central conduit in transmitting assets through the market from one end-customer to another.

For the liquidity they provide, core dealers charge other dealers wide bid-ask spreads. This result is a novel prediction and is yet to be tested. Recall that the opposite holds for dealer-customer transactions: core dealers charge clients narrow bid-ask spreads. Figure 10 shows these results.

3 Additional Results

3.1 Dealer Interconnectedness

In this section, we contrast environments with and without the inter-dealer market and show that dealer interconnectedness increases customers’ welfare, dealer profits, bond liquidity and bond prices. Without the inter-dealer market, dealers intermediate between only their own customers. We assume the supply of bonds circulating among customers of each dealer is identical at $s_i = S/3$. Table 2 shows the equilibrium cutoffs $\{k_1^*, k_2^*\}$. The environment without the inter-dealer market is similar to Vayanos and Wang (2007). Markets in their setting are the counterparts to dealers in our setting.

The clientele mechanism reverses in the absence of inter-dealer trades. In particular, buyers prefer the dealer with a larger mass of sellers because

\begin{itemize}
\item For a core dealer, in contrast, intermediations directly between customers constitute a relatively larger fraction of all the intermediations she is involved in.
\item Li and Schürhoff (2014) consider how dealers split the total round-trip spread from the CD to DC legs and find that dealers closer to the end-buyer extract a bigger fraction of the total spread. They, however, do not consider how core vs. peripheral dealers split the intermediation surplus. Neklyudov, Hollifield, and Spatt (2014) consider similar splits and conclude that core dealers take a narrower chunk of the total spread. In contrast, we characterize bid-ask spreads from dealers’ perspective to understand the liquidity service core vs. peripheral dealers provide other dealers. Thus, as shown in 26, we define bid-ask spreads from dealers’ perspective analogous to bid-ask spreads from clients’ perspective: the expected round-trip transaction cost a dealer faces from a core vs. peripheral dealer.
\item Note that Vayanos and Wang (2007) is a special case with $z(n) = z(n + 1) = 1$ and $N_i = \emptyset$ for all $i$.
\end{itemize}
it translates to a faster execution speed. To reach an equilibrium, bid-ask spreads are higher from the dealer with more sellers. Liquidity immediacy, not bid-ask spreads, serve as a sorting device: buyers with a high \( k \) prefer the larger dealer with superior liquidity immediacy and, in return, pay a higher bid-ask spread. The reverse holds for buy-and-hold investors.

With the inter-dealer market, in contrast, buyers prefer the dealer with a small client base because the dealer relies more on the inter-dealer market and thus offers faster execution speed. The dealer that cannot attract clients based on its liquidity immediacy (i.e. a core dealer) instead attracts clients by charging narrow bid-ask spreads. For the asymmetric equilibrium to exist, round trip transaction costs are lower from a core dealer, while the peripheral dealer charges wider bid-ask spreads for its superior liquidity immediacy. In contrast to the environment without the inter-dealer market, bid-ask spreads, not liquidity immediacy, serve as a sorting device. Buyers with different probabilities of having to reverse their positions choose dealers based on the expected round-trip transaction cost.

We define customers’ welfare as

\[
W_c \equiv \sum_{i \in N} \left[ \int_k^\bar{k} \hat{\mu}_i^b(k) V_i^b(k) dk + \int_k^\bar{k} \hat{\mu}_i^o(k) V_i^o(k) dk + \mu_i^s V_i^s \right].
\]

(27)

For dealer \( i \), the present value of the stream of flow profits is

\[
\pi_i \equiv \frac{1}{r} \int_k^\bar{k} \lambda \hat{\mu}_i^b(k) \mu_i^a (1 - 2z(1)) \left( V_i^o(k) - V_i^b(k) - V_i^s \right) dk
\]

\[
+ \frac{1}{r} \sum_{j \in N_i} \left( \int_k^\bar{k} \lambda \hat{\mu}_j^b(k) \mu_j^a \left( \frac{1 - 2z(2)}{2} \right) \left( V_j^o(k) - V_j^b(k) - V_j^s \right) dk \right)
\]

\[
+ \frac{1}{r} \sum_{j \in N_i} \left( \int_k^\bar{k} \lambda \hat{\mu}_j^b(k) \mu_j^a \left( \frac{1 - 2z(2)}{2} \right) \left( V_j^o(k) - V_j^b(k) - V_j^s \right) dk \right).
\]

(28)

The first term captures profits from intermediations directly between her customers (that is, CDC chains). The second and third terms are profits from buy and sell inter-dealer transactions, respectively (that is, CDDC chains). The total profit across dealers is

\[
\Pi \equiv \sum_{i \in N} \pi_i.
\]

(29)
The total welfare of all agents in the economy is then

\[ W_{\text{all}} \equiv W_c + \Pi. \]  

(30)

As Lemma 2 shows, the total welfare depends only on one endogenous variable: the aggregate mass of sellers \( \mu^s_N \).

**Lemma 2.** The total welfare is given by

\[ W_{\text{all}} = \frac{\delta}{T} S - \frac{x}{T} \mu^s_N. \]  

(31)

The first term is the present value of the stream of bond coupon flows. The welfare in a frictionless environment corresponds to this term because only investors that enjoy the full value of the coupon flow own the bond. Search frictions, however, create misallocations: investors (with total mass \( \mu^s_N \)) who dislike holding the bond \( x \) own the bond also. Thus, the second term represents the welfare loss from search frictions.

**Lemma 3** (The Effect of Interconnectedness). Customers’ welfare \( W_c \), the aggregate dealer profit \( \Pi \), and the total welfare \( W_{\text{all}} \) increase with dealer interconnectedness.

The presence of the inter-dealer market improves bond liquidity: it increases the aggregate volume of transactions, narrows bid-ask spreads, and speeds up transaction times. Greater liquidity, in turn, alleviates misallocations: a larger number of investors who enjoy the full value of the coupon flow (hence, fewer sellers) own the bond. The more efficient asset allocation increases customer welfare, while larger volumes of trade increase dealer profits. The total welfare, as a result, increases.

Second, since bonds are held proportionately more by investors with the greatest utility for them, bond prices increase and, in particular, approach the frictionless price. For the parameter values in Table 1, the measure of buyers is greater than the total bond supply; consequently, buyers are the marginal investors in the bond. In a frictionless environment \( (\lambda \to \infty) \), the bond price is the present value of buyers’ valuation of the bond, \( p = \frac{\delta}{T} \). With frictions, low-valuation investors also hold the bond, leading to discounted bond prices relative to the frictionless price. Thus, the more efficient allocation of bonds and the increase in bond prices imply that bond prices approach the frictionless price.

Third, the dispersion of prices and liquidity across dealers decreases: dealers become more similar to one another. Fourth, we proxy dealers’ inventory
balance by the ratio of their sellers to buyers. Without the inter-dealer market, the ratio differs across dealers and is higher for dealers that cater to buy-and-hold investors. With the inter-dealer market, as Lemma 4 shows, the ratio is identical across dealers; thus, dealers achieve what looks like a full inventory risk-sharing.

**Lemma 4.** In the presence of the inter-dealer market, the inventory balance is identical across dealers:

$$\frac{\mu_s^i}{\mu_b^i} = \frac{\mu_s^N}{\mu_b^N}. \quad (32)$$

### 4 Assumptions

In this section, we discuss our assumptions and how relaxing them might affect our results. In Section 2, we discussed the assumptions that our main results rely on. Relaxing below assumptions would make the environment more realistic but would not affect our main insights.

We assume a fully connected dealer network and that dealers do not choose who to connect to. Implicitly, we are assuming a zero cost of both initially connecting and maintaining the connection. We could relax this by assuming that dealers have to pay for an access to other dealers’ clients. If dealers charge a cost per client, then we expect our results to remain the same. But if dealers charge a fixed amount regardless of the client size, dealers would pay only for an access to core dealers’ clients. Our basic mechanism would go through, and the core-periphery structure maybe even more pronounced.

Although important, we leave for future work showing pairwise and group stability properties of the dealer networks in our model.

We take the aggregate number of dealers as fixed and do not model dealer entry and exit. We could model dealer entry as follows. Dealers have an outside opportunity. Dealers enter until the marginal dealer is indifferent between its outside opportunity and the profit it expects to make as one of the dealers in the economy. Nevertheless, endogenizing dealer entry would not change our main insight on dealer specialization.

For tractability, we assume that dealers do not hold inventory and that bonds sit on the balance sheet of client-sellers. Even though empirical studies try to infer the proportion of intermediations that are pre-arranged versus held in inventory, dealer inventories are not directly observable, and the importance of modeling it is not obvious.

In our model, intermediation chains involve at most two dealers. Although longer chains are observed in practice, our environment captures the
majority of transactions. Li & Schurhoff (2014) document that just CDC and CDDC trades comprise 90% of all transactions, and the average intermediation chain involves just one dealer. Nevertheless, we mention two ways to allow for longer intermediations. First, in our matching function specification, for a dealer to be involved in a chain, one of the end-customers has to be the dealer’s own client. If, instead, a dealer can produce matches among clients of other dealers, intermediation chains can be longer than just two dealers. The second way is to allow dealers to hold inventory. In both ways, the longest chain in the model can be as long as the aggregate number of dealers in the model.

We assume a full information structure. In particular, dealers know client types, and clients know both their own and other dealers’ client structure. The latter seems reasonable since clients can figure out whether a dealer-brokerage firm is a large or small market player and, hence, a relatively core versus peripheral dealer. Regarding dealers’ information about client types, Vayanos and Wang (2007) show that the clientele effect still emerges in the presence of asymmetric information about buyers’ type. Thus, we predict that our main insight on dealer specialization would hold in the presence of asymmetric information.

We abstract from adverse selection problems. We observe the hierarchal core-periphery structure and intermediation chains in markets where adverse selection problems are small. Currency and municipal bonds markets are an example. Thus, asymmetric information cannot be a first order in explaining the core-periphery structure.

5 Conclusion

The network structure of over-the-counter markets exhibits a core-periphery structure: few dealers are highly interconnected with a large number of dealers, while a large of number of small dealers are sparsely connected. We build a search-based model of dealer network formation and show that the core-periphery structure emerges from dealer specialization. Dealers that attract a clientele of liquidity investors have a larger customer base, support a greater fraction of inter-dealer transactions, and, thus, form the core. Dealers that instead cater to buy-and-hold investors form the periphery.
A Proofs

Proof of Proposition 1. We prove existence for the case of two dealers, indexed 1 and 2. In particular, we show that \( \hat{V}_2^b(k^*) - \hat{V}_1^b(k^*) < 0 \) at \( k^* = \bar{k} \) and \( \hat{V}_2^b(k^*) - \hat{V}_1^b(k^*) > 0 \) at \( k^* = \tilde{k} \), which will imply that there exists \( k^* \in (\bar{k}, \tilde{k}) \) such that \( \hat{V}_2^b(k^*) - \hat{V}_1^b(k^*) = 0 \).

Solving (17) for \( \hat{V}_i^o(k) \), we get

\[
\hat{V}_i^o(k) = \frac{\delta + kV_i^s}{k + r}
\]

(33)

If we set \( k^* = \tilde{k} \), then \( \mu_1^b = 0 \) and \( \mu_2^b = 0 \). Using (33) and (16), and solving for \( V_1^b(k) \) and \( V_2^b(k) \), we get

\[
\hat{V}_1^b(k) = \frac{\lambda \mu_1^s (z - rV_1^s)}{(k + r)(k + r + z\lambda \mu_1^s)}
\]

\[
\hat{V}_2^b(k) = \frac{\lambda \mu_1^s (2zI) (\frac{\delta + V_1^s}{k + r} - V_1^s)}{(k + r)(k + r + z\lambda \mu_1^s)}
\]

Taking the difference \( \hat{V}_2^b(k) - \hat{V}_1^b(k) \) and multiplying by \( \frac{k + r}{\lambda \mu_1^s} \), the sign of \( \hat{V}_2^b(k) - \hat{V}_1^b(k) \) depends on

\[
- \frac{z(\delta - rV_1^s)}{k + r + z\lambda \mu_1^s} + \frac{(2zI)(\delta - (k + r)V_1^s + kV_2^s)}{k + r + (2zI) \lambda \mu_1^s}
= - \frac{z(\delta - rV_1^s)}{k + r + z\lambda \mu_1^s} + \frac{(2zI)(\delta - rV_1^s)}{k + r + (2zI) \lambda \mu_1^s} + \frac{(2zI)(V_2^s - V_1^s)}{k + r + (2zI) \lambda \mu_1^s}
\]

(34)

(35)

To determine the sign of (34), we first show that \( \delta - rV_1^s > 0 \) and \( \delta - rV_2^s > 0 \). Using (18), and solving for \( V_1^s \) and \( V_2^s \), we get:

\[
rV_1^s = \delta - x + \frac{z\lambda \mu_1^b}{(k + r + z\lambda(\mu_1^b + \mu_1^s))} \]

(36)

\[
rV_2^s = \delta - x + \frac{(2zI) \lambda \mu_1^s (r + z\lambda \mu_1^b)}{(r + (2zI) \lambda \mu_1^s)(k + r + z(\mu_1^b + \mu_1^s))}
\]

(37)

Thus, \( rV_1^s = \delta - x(1 - \frac{z\lambda \mu_1^b}{k + r + z\lambda(\mu_1^b + \mu_1^s)}) \), and, hence, \( \delta - rV_1^s > 0 \). Analogously, \( \delta - rV_2^s > 0 \).

The term \( \frac{z(\delta - rV_1^s)}{k + r + z\lambda \mu_1^s} \) is then an increasing function of \( z \); thus, \( \frac{(2zI)(\delta - rV_1^s)}{k + r + (2zI) \lambda \mu_1^s} > \frac{z(\delta - rV_1^s)}{k + r + z\lambda \mu_1^s} \), and the first two terms (34) together are positive. It remains to show that \( V_2^s - V_1^s > 0 \). The sign of \( V_2^s - V_1^s \) depends on the difference of the last terms in (36) and (37):
Since, $2z_I - z > 0$, we have $V_2^b - V_1^b > 0$, and consequently $V_2^b(k) - V_1^b(k) > 0$. Thus, as we expand the client base of dealer 1 (hence, shrink the client base of dealer 2) by $k^* \to \bar{k}$, buyers strictly prefer to change their dealer from dealer 1 to dealer 2.

By an analogous argument, if we set $k^* \to k$ and expand the client base of dealer 2, while shrinking the client base of dealer 1 to zero, every buyer wants to switch out of dealer 2 and go with dealer 1: $V_2^b(k) - V_1^b(k) < 0$.

Thus, the function $V_2^b(k^*) - V_1^b(k^*)$ is negative at $k^* = \bar{k}$ and positive at $k^* = \bar{k}$. Since it is a continuous function of $k^*$, there exists $k^*$ such that $V_2^b(k^*) = V_1^b(k^*)$. For any given cutoff, the system of equations has a unique solution. \hfill \square

**Proof of Lemma** ??: From buyers’ inflow-outflow equation (11),

$$\hat{\mu}^b_i(k) = \frac{\hat{f}(k)\nu_i(k)}{k + \lambda(\mu^s_i + 2 \sum_{j \in N_i} \mu^s_j)}$$ (38)

From owners’ inflow-outflow equation (12) and (38),

$$\hat{\mu}^o_i(k) = \frac{\lambda\hat{\mu}^b_i(k)\left(\mu^s_i + 2 \sum_{j \in N_i} \mu^s_j\right)}{k} = \frac{\hat{f}(k)\nu_i(k)\lambda\left(\mu^s_i + 2 \sum_{j \in N_i} \mu^s_j\right)}{k\left(k + \lambda\left(\mu^s_i + 2 \sum_{j \in N_i} \mu^s_j\right)\right)}$$

Using the market clearing condition (8), the measure of sellers of dealer $i, \mu^s_i,
is determined by:

\[
\int_{\hat{k}}^{k} \frac{\hat{f}(k)\nu'(k)\lambda (\mu_i^s + 2 \sum_{j \in N_i} \mu_j^s)}{k (k + \lambda (\mu_i^s + 2 \sum_{j \in N_i} \mu_j^s))} dk + \mu_i^s = s_i
\]

Summing across dealers and replacing \( \sum_{j \in N_i} \mu_j^s = \mu_N^s - \mu_i^s \), we get

\[
\sum_{i \in N} \left( \int_{\hat{k}}^{k} \frac{\nu_i(k)\hat{f}(k)\lambda (-\mu_i^s + 2\mu_N^s)}{k (k + \lambda (-\mu_i^s + 2\mu_N^s))} dk \right) + \mu_N^s = S. \tag{39}
\]

From the inter-dealer constraints \( \mu_i^s \mu_N^b = \mu_i^b \mu_N^s \),

\[
\mu_i^s \sum_{i \in N} \left( \int_{\hat{k}}^{k} \frac{\hat{f}(k)\nu'(k)\lambda}{k + \lambda (-\mu_i^s + 2\mu_N^s)} dk \right) = \mu_N^s \int_{\hat{k}}^{k} \frac{\hat{f}(k)\nu'(k)\lambda}{k + \lambda (-\mu_i^s + 2\mu_N^s)} \tag{40}
\]

Consider an environment with two dealers \( i \) and \( j \). Writing \( \mu_j^s = \mu_N^s - \mu_i^s \), (39) and (40) boil down to two equations and two unknowns, \( \mu_i^s \) and \( \mu_N^s \). Using the Implicit Function Theorem, \( \frac{\partial \mu_N^s(k^*)}{\partial k} \) evaluated at \( k^* = \hat{k} \) (that is, \( \mu_i^s = 0 \)) is

\[
\frac{\partial \mu_N^s(k^*)}{\partial k^*} = \frac{f \lambda \mu_N^s (2(\hat{k} - k)\lambda \mu_N^s + k(S - \mu_N^s)(\hat{k} + \lambda \mu_N^s))}{k(2\lambda \mu_N^s) \left[ \lambda + (k + \lambda \mu_N^s)(k + \lambda \mu_N^s) \right] \left[ -(S - \mu_N^s) \right]} - \frac{f \lambda \mu_N^s (2(\hat{k} - k)\lambda \mu_N^s + k(S - \mu_N^s)(\hat{k} + \lambda \mu_N^s))}{k(2\lambda \mu_N^s) \left[ \lambda + (k + \lambda \mu_N^s)(k + \lambda \mu_N^s) \right] \left[ -(S - \mu_N^s) \right]}
\]

The numerator is positive, while the denominator is negative; hence, \( \frac{\partial \mu_N^s(k^*)}{\partial k^*} < 0 \). This implies that as we go from an environment with just one dealer \( (k^* = k) \) to an environment with two dealers \( (k < k^* < \hat{k}) \) (that is, as \( k^* \) increases), the misallocation—captured by \( \mu_N^s \)—decreases. Social welfare, as a result, increases. Thus, increasing the aggregate number of dealers increases social welfare. \( \square \)

**Proof of Lemma 4.** The inter-dealer constraints are

\[
\mu_i^s \mu_N^b = \mu_N^b \mu_i^s.
\]

Substituting in \( \mu_N^b = \mu_i^b \) and \( \mu_N^s = \mu_i^s \), we get

\[
\mu_i^s \left( \mu_N^b - \mu_i^b \right) = (\mu_N^s - \mu_i^s) \mu_i^b.
\]

From this, we get (32). \( \square \)
Proof of Lemma 2. Integrating the value functions over the respective client masses yields:

\[ r \int_k^{\bar{r}} V_i^a(k) \hat{\mu}_i^a(k) dk = \delta \int_k^{\bar{r}} \hat{\mu}_i^a(k) dk + k \int_k^{\bar{r}} (V_i^a - V_i^o(k)) \hat{\mu}_i^o(k) dk. \]

\[ r \int_k^{\bar{r}} V_i^b(k) \hat{\mu}_i^b(k) = \int_k^{\bar{r}} k (0 - V_i^b(k)) \hat{\mu}_i^b(k) dk \]

\[ + \int_k^{\bar{r}} \sum_{j \in N} \lambda \mu_j^b (z_{ij} \rho_{ij}) (V_i^o(k) - V_i^b(k) - V_j^a) \hat{\mu}_i^b(k) dk. \]

\[ rV_i^a \mu_i^a = (\delta - x) \mu_i^a + \sum_{j \in N} \left( \int_k^{\bar{r}} \lambda \mu_i^a \hat{\mu}_j^b (z_{ij} \rho_{ij}) (V_i^a(k) - V_j^b(k) - V_i^a) \right). \]

Adding these up, plus the new entrants expected utility \( \int_k^{\bar{r}} V_i^b(k) \hat{f}(k) \nu_i(k) dk \) and dealer profits \( r \pi_i \), we get

\[ r(W_i^c + \pi_i) = \delta \int_k^{\bar{r}} \hat{\mu}_i^a(k) dk + \int_k^{\bar{r}} k (V_i^a - V_i^o(k)) \hat{\mu}_i^o(k) dk \]

\[ + \int_k^{\bar{r}} k (0 - V_i^b(k)) \hat{\mu}_i^b(k) dk \]

\[ + \int_k^{\bar{r}} \sum_{j \in N} \lambda \mu_j^b (z_{ij} \rho_{ij}) (V_i^o(k) - V_i^b(k) - V_j^a) \hat{\mu}_i^b(k) dk \]

\[ + (\delta - x) \mu_i^a + \sum_{j \in N} \left( \int_k^{\bar{r}} \lambda \mu_i^a \hat{\mu}_j^b (z_{ij} \rho_{ij}) (V_i^a(k) - V_j^b(k) - V_i^a) \right) \]

\[ + \int_k^{\bar{r}} V_i^b(k) \hat{f}(k) \nu_i(k) dk \]

\[ + \int_k^{\bar{r}} \lambda \hat{\mu}_i^b(k) \mu_i^a (1 - 2z) (V_i^o(k) - V_i^b(k) - V_i^a) dk \]

\[ + \sum_{j \in N_j} \left( \int_k^{\bar{r}} \lambda \hat{\mu}_i^b(k) \mu_j^a \left( \frac{1 - 2z_j}{2} \rho_{ij} \right) (V_i^o(k) - V_j^b(k) - V_j^a) dk \right) \]

\[ + \sum_{j \in N_j} \left( \int_k^{\bar{r}} \lambda \hat{\mu}_i^b(k) \mu_i^a \left( \frac{1 - 2z_j}{2} \rho_{ij} \right) (V_j^o(k) - V_j^b(k) - V_j^a) dk \right). \]

Simplifying it and replacing \( \hat{\mu}_i^b(k) \) and \( \hat{\mu}_i^o(k) \) with \( \hat{\mu}_i^b(k) = \frac{\hat{f}(k) \nu_i(k)}{k + \lambda \hat{\mu}_i^N} \) and
Adding the second term in the first row, the first term in the second row and the very last term, we get:

\[
r(W^c_i + \pi_i) = \delta \int_{k}^{\hat{k}} \frac{\hat{f}(k)\nu_i(k)\lambda \mu_i^N}{k(k + \lambda \mu_i^N)} \, dk + \int_{k}^{\hat{k}} (V^o_i(k) - V^o_i(k)) \frac{\hat{f}(k)\nu_i(k)\lambda \mu_i^N}{k(k + \lambda \mu_i^N)} \, dk.
\]

\[
+ \int_{k}^{\hat{k}} k(0 - V^b_i(k)) \frac{\hat{f}(k)\nu_i(k)}{k + \lambda \mu_i^N} \, dk
\]

\[
+ \int_{k}^{\hat{k}} \lambda \mu_i^N (V^o_i(k) - V^b_i(k) - V^o_i(k)) \, \hat{\mu}_i^b(k) \, dk
\]

\[
+ \int_{k}^{\hat{k}} \sum_{j \in N_i} \lambda \mu_j^s (\frac{\rho_{ij}}{2}) (V^o_i(k) - V^b_i(k) - V^o_i(k)) \, \hat{\mu}_i^b(k) \, dk
\]

\[
+ (\delta - x) \mu_i^s + \sum_{j \in N_i} \left( \int_{k}^{\hat{k}} \lambda \mu_i^s \hat{\mu}_i^b(k) (\frac{\rho_{ij}}{2}) (V^o_i(k) - V^b_i(k) - V^o_i(k)) \right)
\]

\[
+ \int_{k}^{\hat{k}} V^b_i(k) \hat{f}(k)\nu_i(k) \, dk.
\]

Adding the second term in the first row, the first term in the second row and the very last term, we get:

\[
r(W^c_i + \pi_i) = \delta \int_{k}^{\hat{k}} \frac{\hat{f}(k)\nu_i(k)\lambda \mu_i^N}{k(k + \lambda \mu_i^N)} \, dk - \lambda \mu_i^N \int_{k}^{\hat{k}} (V^o_i(k) - V^b_i(k) - V^o_i(k)) \, \hat{\mu}_i^b(k) \, dk.
\]

\[
+ \lambda \mu_i^s \int_{k}^{\hat{k}} (V^o_i(k) - V^b_i(k) - V^o_i(k)) \frac{\hat{f}(k)\nu_i(k)}{k + \lambda \mu_i^N} \, dk
\]

\[
+ \int_{k}^{\hat{k}} \sum_{j \in N_i} \lambda \mu_j^s (\frac{\rho_{ij}}{2}) (V^o_i(k) - V^b_i(k) - V^o_i(k)) \, \hat{\mu}_i^b(k) \, dk
\]

\[
+ (\delta - x) \mu_i^s + \sum_{j \in N_i} \left( \int_{k}^{\hat{k}} \lambda \mu_i^s \hat{\mu}_i^b(k) (\frac{\rho_{ij}}{2}) (V^o_i(k) - V^b_i(k) - V^o_i(k)) \right).
\]

Summing across all dealers \( i \in N \) and using the fact \( \mu_i^b = \mu_i^s \frac{\rho_{iN}}{\rho_N^s} \), all the expressions involving \( V^o \)'s cancel. We are left with:

\[
\sum_{i \in N} \left( \delta \int_{k}^{\hat{k}} \frac{\hat{f}(k)\nu_i(k)\lambda \mu_i^N}{k(k + \lambda \mu_i^N)} \, dk + (\delta - x) \mu_i^s \right)
\]

\[
= \sum_{i \in N} (\delta(s_i - \mu_i^s) + (\delta - x) \mu_i^s)
\]

\[
= \delta S - x \mu_N^s,
\]

where the second equality comes from the market clearing condition.
Figure 6: The Observed Network Structure in Municipal Bond Market
The figure shows the network structure of inter-dealer transactions of municipal bonds as documented in Li and Schürhoff (2014). Nodes are dealers. The top plot shows just the most active dealers; the bottom plot shows the entire dealer market.
Figure 7: The Observed Network Structure in ABS, CDO, CMBS Markets
The figure shows the network structure of inter-dealer transactions of asset-backed securities (ABS), collateralized debt obligations (CDOs), and mortgage backed securities (CMBS) as documented in Hollifield, Neklyudov, Spatt (2014). Nodes are dealers. The size of the nodes represent dealer sizes by number of transactions.

C Model Figures

Figure 8: Clientele Equilibrium Properties
The figures plot the number of owners, buyers, and sellers and bond supply as functions of dealer centrality (in x-axis). Dealer centrality is measured by the total number of inter-dealer transactions that a dealer intermediates, $M_{Ni}$. See Section 2 for more detail.
Figure 9: Liquidity and Prices Customers Face
The figures plot liquidity and prices clients face as functions of dealer centrality (in x-axis). Network centrality is measured by the total number of inter-dealer trades that a dealer intermediates, $M_{Ni}$. See Section ?? for more detail.

Figure 10: Liquidity and Prices Dealers Face from Other Dealers
The figures plot liquidity (transaction times and bid-ask spreads) and prices that dealer $d$ faces from core versus peripheral dealer $i$. The x-axis is network centrality of dealer $i$, measured by the total number of inter-dealer transactions, $M_{Ni}$. See Section 2 for more detail.
### D Tables

#### Table 1: Parameter Values
This table gives the parameter values chosen for the numerical analysis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Notation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond coupon blow</td>
<td>$\delta$</td>
<td>1</td>
</tr>
<tr>
<td>Disutility of holding the bond</td>
<td>$x$</td>
<td>0.5</td>
</tr>
<tr>
<td>Support of customer distribution</td>
<td>$[k, \bar{k}]$</td>
<td>[1, 5]</td>
</tr>
<tr>
<td>Dealers’ matching efficiency</td>
<td>$\lambda$</td>
<td>100</td>
</tr>
<tr>
<td>Supply of bonds</td>
<td>$S$</td>
<td>0.3</td>
</tr>
<tr>
<td>Risk-free rate</td>
<td>$r$</td>
<td>0.04</td>
</tr>
<tr>
<td>Customer bargaining power, $n=1$</td>
<td>$z(1)$</td>
<td>$\frac{1}{2}$</td>
</tr>
<tr>
<td>Customer bargaining power, $n=2$</td>
<td>$z(2)$</td>
<td>$\frac{1}{3}$</td>
</tr>
</tbody>
</table>

#### Table 2: The Equilibrium Cutoffs

<table>
<thead>
<tr>
<th>Fragmented Clientele</th>
<th>$k^*_1$</th>
<th>$k^*_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.55717</td>
<td>1.89443</td>
</tr>
<tr>
<td></td>
<td>2.59545</td>
<td>3.1563</td>
</tr>
</tbody>
</table>

#### Table 3: Equilibrium Properties

<table>
<thead>
<tr>
<th>Variable</th>
<th>Notation</th>
<th>No Inter-dealer, 3 dealers</th>
<th>With Inter-Dealer, 3 dealers</th>
<th>One dealer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond supply</td>
<td>$s_i$</td>
<td>0.1000</td>
<td>0.1000</td>
<td>0.1000</td>
</tr>
<tr>
<td>Num. of owners</td>
<td>$\mu^o_i$</td>
<td>0.0741</td>
<td>0.0731</td>
<td>0.0722</td>
</tr>
<tr>
<td>Total across dealers</td>
<td>$\mu^o_K$</td>
<td>0.2193</td>
<td>0.2193</td>
<td>0.2193</td>
</tr>
<tr>
<td>Num. of sellers</td>
<td>$\mu^s_i$</td>
<td>0.0259</td>
<td>0.0269</td>
<td>0.0278</td>
</tr>
<tr>
<td>Total across dealers</td>
<td>$\mu^s_K$</td>
<td>0.0807</td>
<td>0.0807</td>
<td>0.0807</td>
</tr>
<tr>
<td>Num. of buyers</td>
<td>$\mu^b_i$</td>
<td>0.0356</td>
<td>0.0543</td>
<td>0.0931</td>
</tr>
<tr>
<td>Total across dealers</td>
<td>$\mu^b_K$</td>
<td>0.1831</td>
<td>0.1831</td>
<td>0.1831</td>
</tr>
<tr>
<td>Seller to buyer ratio</td>
<td>$\mu^s_i/\mu^b_i$</td>
<td>0.7277</td>
<td>0.4958</td>
<td>0.2988</td>
</tr>
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</table>

#### Table 4: Prices and Liquidity Provision to Clients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Notation</th>
<th>No Inter-dealer, 3 dealers</th>
<th>With Inter-Dealer, 3 dealers</th>
<th>One dealer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client-to-Dealer Trades</td>
<td>$M_i$</td>
<td>0.0925</td>
<td>0.1464</td>
<td>0.2588</td>
</tr>
<tr>
<td>Dealer-to-Dealer Trades</td>
<td>$M_N$</td>
<td>0.2405</td>
<td>0.2635</td>
<td>0.2835</td>
</tr>
<tr>
<td>Total transactions</td>
<td>$M_i + M_N$</td>
<td>0.0925</td>
<td>0.1464</td>
<td>0.2588</td>
</tr>
<tr>
<td>Total across dealers</td>
<td>$\sum(M_i + M_N)$</td>
<td>0.4977</td>
<td>0.4977</td>
<td>0.4977</td>
</tr>
<tr>
<td>Bid-ask spread (%)</td>
<td>$\phi_i$</td>
<td>0.5358</td>
<td>0.3659</td>
<td>0.2219</td>
</tr>
</tbody>
</table>
Table 5: Inter-Dealer Prices

<table>
<thead>
<tr>
<th>Variable</th>
<th>Notation</th>
<th>From Peripheral</th>
<th>From Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price at which dealer (d) buys</td>
<td>(P^\text{buy}_i)</td>
<td>19.2700</td>
<td>19.2703</td>
</tr>
<tr>
<td>Price at which dealer (d) sells</td>
<td>(P^\text{sell}_i)</td>
<td>19.2544</td>
<td>19.2433</td>
</tr>
<tr>
<td>Bid-ask spread (%)</td>
<td>(\Phi_i)</td>
<td>0.0810</td>
<td>0.1404</td>
</tr>
</tbody>
</table>

Table 6: Customer Welfare and Dealer Profits

<table>
<thead>
<tr>
<th>Variable</th>
<th>Notation</th>
<th>No Inter-dealer, 3 dealers</th>
<th>With Inter-Dealer, 3 dealers</th>
<th>One dealer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peri. (1)</td>
<td>Peri. (2)</td>
<td>Core (3)</td>
<td>Peri. (1)</td>
<td>Peri. (2)</td>
</tr>
<tr>
<td>Customer welfare</td>
<td>(W_{ci})</td>
<td>1.97188 1.93935 1.90987</td>
<td>2.98178 2.05259 1.39492</td>
<td>6.45983</td>
</tr>
<tr>
<td>Total across dealers</td>
<td>(W^c)</td>
<td>5.82109</td>
<td>6.62929</td>
<td></td>
</tr>
<tr>
<td>Dealer profit</td>
<td>(\pi_i)</td>
<td>0.20384 0.22387 0.24254</td>
<td>0.11829 0.11660 0.11776</td>
<td>0.52210</td>
</tr>
<tr>
<td>Total across dealers</td>
<td>(\Pi)</td>
<td>0.67024</td>
<td>0.35264</td>
<td></td>
</tr>
<tr>
<td>Total welfare</td>
<td>(W_{all})</td>
<td>6.49133</td>
<td>6.98193</td>
<td>6.98193</td>
</tr>
</tbody>
</table>

References


Shen, Ji, Bin Wei, and Hongjun Yan, 2015, Financial Intermediation Chains in a Search Market, *SSRN Electronic Journal*.


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