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 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 a clientele effect. Customers with heterogeneous liquidity needs endogenously sort themselves with different dealers. Dealers that attract a clientele of liquidity investors have a larger customer base, support a greater fraction of inter-dealer transactions, and form the core. Dealers that instead cater to buy-and-hold investors form the periphery. Customers’ welfare and asset liquidity increase with dealer interconnectedness, but a partially fragmented dealer market yields the largest profits to dealers.

The network of over-the-counter transactions between dealers exhibits a core-periphery structure. Few highly interconnected dealers account for most of the transactions among dealers as well as directly with clients. These dealers form the core, while a large number of sparsely connected dealers trade infrequently and form the periphery. Core dealers place assets more readily and provide greater liquidity; the opposite holds for 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 exogenous heterogeneity among dealers. Atkeson, Eisfeldt, and Weill (2014) and Zhong (2014), for example, assume that dealers that form the core are exogenously large in size. Others, such as Kondor and Babus (2013), take
the network structure as given. Thus, we are yet to explain, first, how core dealers become large in the first place, second, how they are able to maintain their size and market share, and, third, why core dealers co-exist with peripheral dealers and do not necessarily take them over.\textsuperscript{1}

We build a search-based model of endogenous network formation that explains (1) the relative size of core and peripheral dealers and (2) the intermediation chain among dealers. We show that a core-periphery structure emerges from a clientele effect. Customers endogenously sort themselves with different dealers depending on their liquidity needs. Dealers that attract a clientele of liquidity investors have a larger customer base, support a greater fraction of inter-dealer transactions, and form the core. Dealers that instead cater to buy-and-hold investors form the periphery.

We show these results 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 assume dealers are ex-ante identical, but customers have heterogeneous 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 allow a fully connected dealer market, but the strength of the trading relationships between pairs of dealers is endogenous.

In this environment, a clientele equilibrium exists with the following properties. Compared to peripheral dealers, core dealers have a larger customer base, intermediate larger volumes of transactions directly between customers, and charge customers narrower bid-ask spreads. Core dealers also provide greater liquidity (by trading volume and transaction speed) to other dealers in the inter-dealer market. For the liquidity they provide, core dealers charge other dealers larger bid-ask spreads. Peripheral dealers, in contrast to core dealers, rely heavily on the inter-dealer market to supplement their liquidity provision to customers. Bonds, as a result, go through longer intermediation chains with peripheral dealers than with core dealers. Using the inter-dealer market, peripheral dealers, however, provide clients the same liquidity immediacy as core dealers.

We also compare customers’ welfare and dealer profits across three network structures with varying degree of interconnectedness: (1) a fragmented environment with no inter-dealer trades, (2) the above clientele equilibrium, and (3) a concentrated environment with just one dealer. We show that as

\textsuperscript{1}Farboodi (2014) provides a network model specific to the interbank loan market.
dealer interconnectedness increases, asset liquidity increases. Bonds are distributed more efficiently across customers and are held more by customers with the greatest utility for them. Customers’ welfare, in turn, increases with better asset allocation and is the highest in the concentrated environment.

The core-periphery structure, in contrast, yields the largest profits to dealers. If the dealer market is too fragmented, the total number of transactions and, hence, dealer profits are too small. If the dealer market is instead too concentrated, the average intermediation chain is too short. Lengthening the intermediation chain (through an increase in fragmentation) allows dealers to collectively extract larger fractions of the trading surplus and tilt the surplus in their favor against customers. A mid-point between the two extremes of complete fragmentation and concentration (such as the core-periphery structure) yields the largest profits to dealers. This also explains why it is not necessarily optimal for core dealers to drive peripheral dealers out of business by attracting their clients with sets of menus (e.g., one to liquidity investors and another to buy-and-hold investors).

Our model also explains the observed network persistence. In Hugonnier, Lester, and Weill (2014)’s environment, transactions among agents resemble a core-periphery structure. Investors in the middle of an intermediation chain form the core. In their model, however, market participants switch between different valuations, implying that a dealer that is a core dealer one period can randomly become a peripheral dealer the next period and vice versa. In reality, networks and trading patterns are highly persistent (see Li and Schürhoff (2014)). In our model, dealer networks are persistent as long as the distribution of customers’ liquidity needs is persistent. Liquidity investors of our model could be, for example, investment funds that track indices and trade frequently; buy-and-hold investors could be pension funds. Our results imply that dealer networks are persistent because the distribution of liquidity demands in the economy are persistent.

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 to other dealers. Section 3 compares network structures with varying degree of market fragmentation. Section 4 concludes.

2For example, Goldman Sachs, one of the core dealers in a variety of asset markets, does not turn into a small asset management firm one year and go back to being Goldman Sachs the next year.


1 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 $\delta$.

The economy is populated by two sets of agents, investors and dealers. The set of all dealers is denoted by $D$. A flow of investors enter the economy as buyers, contact a dealer, and, upon buying a bond through a dealer, become inactive bond owners. Bond owners get 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 a disutility from holding the bond. Upon selling the bond, the investor exits the economy.

Buyers entering the economy are heterogeneous in the intensity with which they receive the liquidity shock. Denoting buyers’ switching rates by $k$, 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 $\hat{f}(k)dk$.

A buyer of type $k$ chooses dealer $i$ with probability $\nu_i(k)$ according to

$$
\nu_i(k) = \begin{cases} 
1 & V_i^b(k) > \max_{j \neq i} V_j^b(k) \\
[0, 1] & \text{if } V_i^b(k) = \max_{j \neq i} V_j^b(k) \\
0 & V_i^b(k) < \min_{j \neq i} V_j^b(k), 
\end{cases}
$$

where $V_i^b(k)$ is the expected utility of a $k$-type buyer who is a customer of dealer $i$, and $\sum_{i \in D} \nu_i(k) = 1$. 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.

We denote by $\mu_i^s$, $\mu_i^b$, and $\mu_i^o$ the total measure of sellers, buyers, and owners of dealer $i$, where

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

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 $[k, k + dk]$. 

Dealers and Intermediations

Dealers intermediate bond transactions. Dealer $i$ produces matches directly among her buyers and sellers according to

$$M^c_i \equiv \lambda \mu^s_i \mu^b_i,$$

where $\lambda$ is an exogenous efficiency of her matching ability. We assume dealers do not hold inventory. They instead buy a bond from one client and instantly sell to another client only after she is pre-arranged the match first.

A dealer also supplements her liquidity provision to customers by contacting dealers in her network. Dealer $i$’s network, denoted by $D_i$, is the set of dealers that dealer $i$ is connected to. We define two dealers $i$ and $j$ as connected if they share their sellers with each other. In particular, dealer $i$ has $\mu^s_i$ sellers of her own, but a link with dealer $j$ gives her access to all the sellers of dealer $j$, $\mu^s_j$. It is symmetric for dealer $j$. Dealer $i$ takes as inputs $(\mu^s_i + \sum_{j \in D_i} \mu^s_j)$ on the sell side and $\mu^b_j$ on the buy side and produces a total number of matches according to the matching technology $\lambda(\mu^s_i + \sum_{j \in D_i} \mu^s_j)\mu^b_i$. For later references, we denote the inter-dealer portion by $M^{b,I}_i \equiv \lambda(\sum_{j \in D_i} \mu^s_j)\mu^b_i$.

In addition, dealer $i$ also helps intermediate transactions in which other dealers in dealer $i$’s network use her sellers: $M^{s,I}_i \equiv \lambda \mu^s_i(\sum_{j \in D_i} \mu^b_j)$. Thus, the total number of transactions that dealer $i$ intermediates is $M_i \equiv M^c_i + M^{b,I}_i + M^{s,I}_i$.

What is search frictions in our environment? Customers can contact their dealers and put an order instantly; similarly, dealers can contact other dealers instantly. But, after receiving clients’ orders, dealers take time in producing the actual matches. This results in wait times for clients. Our specification is realistic. In practice, customers can easily call up and put an order through their dealers; similarly, dealers can call up other dealers they know. Immediate transactions, however, are not guaranteed.

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:

$$\int_k^\infty \hat{\mu}^c_i(k) dk + \mu^s_i = S_i.$$  \hspace{1cm} (2)
For market clearing, the number of bonds circulating across all dealers has to equal the total fixed supply of the bond, $S$:

$$
\sum_{i \in D} S_i = S. \tag{3}
$$

**Inter-dealer trades**

We impose that, in the steady state, a dealer cannot be a net buyer or a seller on the inter-dealer market. The total number of bonds dealer $i$ sells and buys on the inter-dealer market are $M^{s,t}_i = \lambda \mu^s_i (\sum_{j \in D_i} \mu^b_j)$ and $M^{b,t}_i = \lambda (\sum_{j \in D_i} \mu^s_j) \mu^b_i$, respectively. Equating the two ensures that she is neither a net buyer or a seller:

$$
\lambda \mu^s_i (\sum_{j \in D_i} \mu^b_j) = \lambda (\sum_{j \in D_i} \mu^s_j) \mu^b_i. \tag{4}
$$

**Transitions**

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

The flow $\hat{f}(k) \nu_i(k) dk$ 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 $\lambda (\mu^s_i + \sum_{j \in D_i} \mu^s_j)$. Thus, the population measure of $k$-type buyers is determined by

$$
\nu_i(k) \hat{f}(k) dk = k \hat{\mu}^b_i(k) dk + \lambda (\sum_{j \in \{i, D_i\}} \mu^s_j) \hat{\mu}^b_i(k) dk. \tag{5}
$$

Similarly, the population measure of $k$-type owners is given by

$$
\lambda (\sum_{j \in \{i, D_i\}} \mu^s_j) \hat{\mu}^b_i(k) = k \hat{\mu}^o_i(k). \tag{6}
$$

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

We assume that dealers facilitating a transaction and end-customers split the total gains from trade equally, and each gets $z_{i,j}$ fraction of the total surplus:

$$z_{i,j} = \begin{cases} 1/3 & \text{if } j = i \\ 1/4 & \text{if } j \in D_i. \end{cases} \quad (7)$$

Eq. (7) says that if an intermediation between end-customers requires an inter-dealer trade, four agents (the two dealers and two end customers) each get $z_{i,j} = 1/4$ fraction of the total surplus. If the intermediation is among customers of the same dealer, the three agents (a dealer and two end customers) each get $z_{i,i} = 1/3$ fraction of the total surplus.

Figure 1 depicts characterization of prices. Let us first denote by $V_i^s$, $V_i^b(k)$, and $V_i^o(k)$ 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

$$\hat{p}_{i,j}^{\text{bid}}(k) = (1 - z_{i,j})V_i^s + z_{i,j}(V_j^o(k) - V_j^b(k)) \quad (8)$$

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:

$$\hat{p}_{i,j}^{I}(k) = (1 - 2z_{i,j})V_i^s + 2z_{i,j}(V_j^o(k) - V_j^b(k)). \quad (9)$$

After purchasing the bond from dealer $i$, dealer $j$ sells to his buyer at the ask price

$$\hat{p}_{i,j}^{\text{ask}}(k) = z_{i,j}V_i^s + (1 - z_{i,j})(V_j^o(k) - V_j^b(k)). \quad (10)$$

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

Figure 1: Prices

<table>
<thead>
<tr>
<th>$V_i^s$</th>
<th>$\hat{p}_{i,j}^{\text{bid}}(k)$</th>
<th>$\hat{p}_{i,j}^{I}(k)$</th>
<th>$\hat{p}_{i,j}^{\text{ask}}(k)$</th>
<th>$V_j^o(k) - V_j^b(k)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>end-seller's reservation value</td>
<td>$z_{i,j}$</td>
<td>$z_{i,j}$</td>
<td>$z_{i,j}$</td>
<td>$z_{i,j}$</td>
</tr>
</tbody>
</table>
Value Functions

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

\[
rV^b_i(k) = k \left( \delta + V^o_i(k) - V^b_i(k) \right) + \sum_{j \in \{i, D_i\}} \lambda \mu^b_j \left( V^o_i(k) - V^b_i(k) - \hat{p}^{ask}_{j,i}(k) \right).
\] (11)

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 \( j \in D_i \), 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

\[
rV^o_i(k) = \delta + k \left( V_i^s - V^o_i(k) \right). \] (12)

The expected utility of a seller who is a customer of dealer \( i \) is given by

\[
rV^s_i = \delta - x + \sum_{j \in \{i, D_i\}} \left( \int_{\tilde{K}} \lambda \hat{p}^{bid}_{i,j}(k) \left( \hat{p}^{bid}_{i,j}(k) - V^s_i \right) \right). \] (13)

**Definition.** A steady state equilibrium is expected utilities \( \{V^o_i(k), V^b_i(k), V^s_i\}_{i \in D} \), population measures \( \{\mu^o_i(k), \mu^b_i(k), \mu^s_i\}_{i \in D} \), distribution of bond supply across dealers \( \{S_i\}_{i \in D} \), prices \( \{\hat{p}^{bid}_{i,j}(k), \hat{p}^{ask}_{i,j}(k), \hat{p}^{I}_{i,j}(k)\}_{i,j \in D} \), and entry decisions \( \{\nu_i(k)\}_{i \in D} \) such that

1. Value functions solve investors’ optimization problems (11)–(13).

2. Population measures and the distribution of bonds across dealers solve inflow-outflow equations (5)–(6), the market clearing conditions (2)–(3), and inter-dealer transactions equations (4).

3. Prices arise from bilateral bargaining (8)–(10).

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

2 Results

2.1 Clientele Equilibrium

In this section, we numerically derive results using the parameter values in Table 1. We consider the simplest setting, an economy with three dealers
\(D = \{1, 2, 3\}\), and each dealer is connected to every other dealer: \(D_i = \{j \in D : j \neq i\}\) for all \(i\), (i.e., a complete network). All results described in this section and in Section 3 are shown in tables in Appendix D.

**Result 1.** There exists a symmetric equilibrium where each \(k\)-type buyer chooses all dealers with equal probability.

In the symmetric equilibrium, all dealers are identical. We instead focus on the asymmetric equilibrium of Result 2. Also, without loss of generality, we focus on the case where dealer 1 endogenously attracts clients with greatest liquidity need, dealer 2 attracts clients with intermediate liquidity needs, and dealer attracts 3 the slowest buyers (that is, the most buy-and-hold investors). Other asymmetric equilibria have identical properties but just indices on the dealers reversed.

**Result 2.** There exists a clientele equilibrium. It is characterized by cutoffs \(\{k_1^*, k_2^*\}\), where \(k < k_1^* < k_3^* < \bar{k}\), buyers with \(k > k_3^*\) choose dealer 1, buyers with \(k \in [k_1^*, k_2^*]\) choose dealer 2, and buyers with \(k < k_3^*\) choose dealer 3. At the cutoff \(k = k_1^*\), buyers are indifferent between dealers 2 and 3, and at the cutoff \(k = k_2^*\), buyers are indifferent between dealers 1 and 2.

Table 2 shows the numerical values of the equilibrium cutoffs \(\{k_1^*, k_2^*\}\), and Figure 2 illustrates the result.

![Figure 2: Cutoffs \(\{k_1^*, k_2^*\}\)](image_url)

Anticipating our result from a later section, we will refer to dealer 1 as a core dealer, and to dealers 2 and 3 as peripheral dealers. Result 3, illustrated in Figure 9 and Table 3, highlights properties of the clientele equilibrium.

**Result 3.** The clientele equilibrium has the following properties:

1. Dealers that attract a clientele of more liquidity investors have a larger number of buyers and sellers: \(\mu_1^b > \mu_2^b > \mu_3^b\) and \(\mu_1^s > \mu_2^s > \mu_3^s\).

2. Dealers that attract more buy-and-hold investors have a larger supply of bonds in circulation among customers: \(S_1 < S_2 < S_3\).
2.2 Prices and Liquidity Provided to Customers

Our model features a continuum of prices depending on the type of end customers and the dealers that are involved. In the following sections, we consider aggregated prices. Appendix A explains in detail the intuition behind how we aggregate prices.

Prices

Consider prices, first, from an end-buyer’s perspective. For transactions that involve an inter-dealer intermediation chain, the price an average buyer of dealer $i$ expects to buy at is:

$$P_{\text{ask},I}^i \equiv E_{\text{b},i}^b \left[ \frac{1}{\sum_{j \in D_i} \mu_j^b} \sum_{j \in D_i} \mu_j^b \hat{p}_{\text{ask},j,i}^b(k) \right],$$

(14)

where the expression inside the expectations operator is the price $k$-type buyer expects to pay, and $E_{\text{b},i}^b$ is the expectation under the distribution of $k$ in the population of buyers of dealer $i$.

For transactions in which a dealer intermediates directly between her customers, an average buyer of dealer $i$ buys at:

$$P_{\text{ask},c}^i = E_{\text{b},i}^b[\hat{p}_{\text{ask},i,i}^b(k)],$$

(15)

where $\hat{p}_{\text{ask},i,i}^b(k)$ is given by (10) for $j = i$.

Now consider prices from an end-seller’s perspective. For transactions that involve an inter-dealer intermediation chain, the price a seller of dealer $i$ expects to sell at is the weighted average price across dealers in dealer $i$’s network:

$$P_{\text{bid},I}^i \equiv \frac{1}{\sum_{j \in D_i} \mu_j^b} \sum_{j \in D_i} \mu_j^b E_{\text{b},j}^b[\hat{p}_{\text{bid},j,i}^b(k)],$$

(16)

where $E_{\text{b},j}^b[\hat{p}_{\text{bid},j,i}^b(k)]$, inside the summation, is in turn the weighted average price across buyers of each $j$ dealer.

For transactions in which dealer $i$ directly matches among her customers, the seller expects to sell at:

$$P_{\text{bid},c}^i = E_{\text{b},i}^b[\hat{p}_{\text{bid},i}^b(k)],$$

(17)

Result 4. Customers face lower prices from core dealers than from peripheral dealers: $P_{\text{ask},I}^1 < P_{\text{ask},I}^2 < P_{\text{ask},I}^3$, $P_{\text{ask},c}^1 < P_{\text{ask},c}^2 < P_{\text{ask},c}^3$, $P_{\text{bid},I}^1 < P_{\text{bid},I}^2 < P_{\text{bid},I}^3$.

$^3$For example, for some function $f(k)$, $E_i^b[f(k)] = \int_\mathbb{K} \frac{\mu_i^b(k)}{p_i^b} f(k) dk$. 

10
Result (4), illustrated in Figure 10 and Table 4, compares prices across dealers. Customers of core dealers buy at a lower (hence, better) price than customers of peripheral dealers. Customers of dealer 3 pay the highest price. In contrast, sellers of peripheral dealers sell at a high (hence, better) price, while sellers of core dealers sell at the lowest price. This is true for both direct transactions and the transactions that involve an inter-dealer chain.

**Liquidity**

We now compare core and peripheral dealers’ liquidity provision to customers in terms of (1) bid-ask spreads, (2) trading volume, and (3) transaction times.

For a client of dealer $i$, we define the expected round-trip transaction cost as the expected ask price minus the expected bid price normalized by the mid-point:

$$\omega_i^L = \frac{P_{\text{ask},i}^L - P_{\text{bid},i}^L}{0.5(P_{\text{ask},i}^L + P_{\text{bid},i}^L)}.$$  \hspace{1cm} (18)

Bid-ask spreads for transactions in which a dealer directly intermediates between her own customers is, similarly:

$$\omega_i^c = \frac{P_{\text{ask},c,i} - P_{\text{bid},c,i}}{0.5(P_{\text{ask},c,i} + P_{\text{bid},c,i})}.$$ \hspace{1cm} (19)

The equivalent of a search friction in our environment is the time a dealer takes to place a bond with a client. A buyer purchases a bond through her dealer with intensity $M_i = \lambda \sum_{i \in D} \mu_i$, where $M_i$ is the total number of bonds dealer $i$ places with buyers. A buyer’s wait time is then $\tau_b^i \equiv 1/(\lambda \sum_{i \in D} \mu_i)$. A seller’s wait time is, similarly, $\tau_s^i \equiv 1/(\lambda \sum_{i \in D} \mu_i)$.

**Result 5. A comparison of liquidity provision:**

1. Core dealers charge narrower bid ask spreads: $\omega_1^c < \omega_2^c < \omega_3^c$ and $\omega_1^L < \omega_2^L < \omega_3^L$.

2. Core dealers intermediate more transactions: $M_1^c > M_2^c > M_3^c$, $M_1^b,I > M_2^b,I > M_3^b,I$, and $M_1^s,I > M_2^s,I > M_3^s,I$.

3. Transaction times are identical across core and peripheral dealers: $\tau_b^i = 1/(\lambda \sum_{i \in D} \mu_i)$ and $\tau_s^i = 1/(\lambda \sum_{i \in D} \mu_i)$ for all $i \in D$. 


Result 5 is illustrated in Figure 10 and Table 4. It shows that, compared to peripheral dealers, core dealers charge clients narrower bid-ask spreads for both direct and indirect transactions. Core dealers also intermediate larger volumes of transactions overall for customers as well as directly between her customers.

Core and peripheral dealers, however, provide identical transaction speeds to their clients. The intuition is as follows. A core dealer has a large customer base of her own. She supplements her own pool with a small number of clients of peripheral dealers she is connected to. A peripheral dealer, in contrast, has a small customer base of her own, but has access to the large pool of clients of a core dealer she is connected to. As a result, in the presence of inter-dealer trades, core and peripheral dealers provide the same liquidity immediacy to their clients.

2.3 Prices and Liquidity in the Inter-Dealer Market

Prices

Since our economy is populated by only three dealers, we can analyze liquidity and prices that core and peripheral dealers provide to peripheral dealers only.

Denote by $j = c$ a core dealer and $j = p$ a peripheral dealer. Dealer $i$ buys from dealer $j \in \{c, p\}$ at price $\hat{p}^I_{j,i}(k)$, defined in (9), if her client is a $k$-type buyer. The weighted average price across all her buyers is

$$P^I_{j,i} = E^b_i[\hat{p}^I_{j,i}(k)].$$

Similarly, a dealer sells to dealer $j \in \{c, p\}$ at price $\hat{p}^I_{i,j}(k)$ if the other dealer’s client is a $k$-type buyer. The weighted average price across buyers of the other dealer is

$$P^I_{i,j} = E^b_j[\hat{p}^I_{i,j}(k)].$$

Result 6. On the inter-dealer market, dealer $i$ faces lower prices from a core than a peripheral dealer: $P^I_{c,i} < P^I_{p,i}$ and $P^I_{i,c} < P^I_{i,p}$.

Thus, on a buy-side of a trade, a dealer gets a lower (hence, better) price from a core dealer, but, on a sell-side, a dealer gets a higher (hence, worse) price from a core dealer. This result can been seen in Figure 11 and Table 5.
Liquidity

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

\[ \omega_{i,j} = \frac{P_{j,i}^I - P_{i,j}^I}{0.5P_{j,i}^I + 0.5P_{i,j}^I}. \]

Result 7. Liquidity provision in the interdealer market.

1. On the interdealer market, core dealers charge wider bid-ask spreads:
   \[ \omega_{i,c}^I < \omega_{i,p}^I. \]

2. Dealer \( i \) buys and sells more from core dealers than from peripheral dealers: \( \lambda \mu_i^b \mu_c > \lambda \mu_i^p \mu_p^b \) and \( \lambda \mu_i^b \mu_c^s < \lambda \mu_i^p \mu_p^s \).

3. Core dealers provide greater liquidity immediacy: \( 1/(\lambda \mu_c^b) < 1/(\lambda \mu_p^b) \) and \( 1/(\lambda \mu_c^s) < 1/(\lambda \mu_p^s) \).

Result 7 is illustrated in Figure 11 and Table 5. It shows that, core dealers charge wider bid-ask spreads for inter-dealer transactions. Recall that the opposite holds for customer transactions: core dealers charge customers narrower bid-ask spreads.

The total number of bonds dealer \( i \) sells and buys on the inter-dealer market are \( \lambda \mu_i^s (\mu_c^b + \mu_p^b) \) and \( \lambda \mu_i^b (\mu_c^s + \mu_p^s) \), respectively, where \( c = 1 \) is a core dealer and \( p = 2 \) is a peripheral dealer. Since core dealers have a larger number of buyers and sellers (Result 3), core dealers intermediate larger fractions of buy and sell transactions for other dealers compared to peripheral dealers. Thus, on the inter-dealer market, dealers rely more on core dealers than on other peripheral dealers.

How long do core and peripheral dealers take to fill orders for other dealers? For dealer \( i \), the probability of selling through dealer \( j \in \{c, p\} \) is \( \frac{\lambda \mu_i^b \mu_j^b}{\mu_j^b} = \lambda \mu_j^b, \) and the probability of buying is \( \frac{\lambda \mu_i^b \mu_j^s}{\mu_j^s} = \lambda \mu_j^s. \) Since core dealers have a larger number buyers and sellers, they provide greater liquidity immediacy (i.e. faster transaction times) in the inter-dealer market: \( 1/(\lambda \mu_c^b) < 1/(\lambda \mu_p^b) \) and \( 1/(\lambda \mu_c^s) < 1/(\lambda \mu_p^s). \) Thus, the large customer base of core dealers enables them to intermediate large volumes of interdealer transactions.

Because of the greater liquidity provided by core dealers in the interdealer market, peripheral dealers rely more on the inter-dealer market than on their own customer base when filling customer orders. For a core dealer, in contrast, intermediations directly between customers constitute the largest fraction of all the intermediations she is involved in.
3 A Comparison of Dealer Networks

In this section, we compare liquidity, customer welfare, and dealer profits across different network structures with varying market fragmentation (conversely, concentration). In particular, we compare the clientele equilibrium of Section 2 to two alternative environments.

The first is an environment without the inter-dealer market. We call this completely fragmented environment ($frag$): dealers do not trade with one another, but only intermediate directly between customers. We assume the supply of bonds circulating among customers of each dealer is identical at $S_i = 1$. This environment is similar to Vayanos and Wang (2007), but markets in their setting map into dealers in our setting, and we also have more than two dealers.

Table 2 shows the equilibrium cutoffs $\{k_1^*, k_2^*\}$. Similar to the intuition from Vayanos and Wang (2007), core dealers provide greater liquidity to clients (in terms of transaction times and bid-ask spreads) than peripheral dealers. In return for the greater liquidity they provide, core dealers charge higher prices.

The second alternative environment is the exact opposite of the fragmented setting: dealers are merged into one dealer. The supply of bonds circulating with customers of this dealer is simply the total supply of bonds in the economy $S = 3$. We call this setting completely concentrated ($conc$).

![Figure 3: Comparing Network Structures](image)

3.1 Prices and Liquidity

To study the bid-ask spread and prices in the entire economy across different network structures, we consider a weighted average price and liquidity customers face across dealers. We first take the weighted average across the two types of transactions, weighted by the volume of each type of transaction:\(^4\)

\(^4\)Recall that only the clientele environment has the two types of transactions. In the other two environments, prices from transactions intermediated directly between clients are the only relevant prices.
Then, the weighted average price and bid-ask spread across dealers are:

$$\bar{P}_{\text{ask}} = \frac{M_i^{s,I} P_{i}^{\text{ask},I} + M_i^{c} P_{i}^{\text{ask},c}}{M_i^{s,I} + M_i^{c}}$$

$$\bar{P}_{\text{bid}} = \frac{M_i^{s,I} P_{i}^{\text{bid},I} + M_i^{c} P_{i}^{\text{bid},c}}{M_i^{s,I} + M_i^{c}}$$

$$\bar{\omega}_i = \frac{M_i^{s,I} \omega_i^{I} + M_i^{c} \omega_i^{c}}{M_i^{s,I} + M_i^{c}}$$

As dealers become more interconnected, prices 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, $p = \frac{\bar{P}}{r}$. Prices are the most discounted in the completely fragmented environment and increase and approach the frictionless price as dealers become more interconnected. Prices are the closest to the frictionless price in the concentrated environment.

As dealers become more interconnected, asset liquidity generally improves. The aggregate volume of trade and transaction speeds improve in the presence of inter-dealer trades. They, however, are identical between the clientele environment and the fully concentrated environment. The bid-ask spread customers face is the widest in the core-periphery structure and narrows if the network structure becomes either more fragmented or more concentrated. The bid-ask spread is the narrowest in the concentrated environment.

The cross-sectional dispersion of prices and liquidity measures across core and peripheral dealers is the greatest in the fragmented environment. With dealer interconnectedness, the dispersion decreases, and dealers become more similar to one another.

Above results are shown in Figure 12 and Table 4.
3.2 Profits and Welfare

This section analyzes how fragmentation affects customers’ welfare and dealer profits. We define the total welfare of customers as

\[ W_c = \sum_{i \in D} \left( \int \hat{\mu}_i^b(k) V_i^b(k) dk + \int \hat{\mu}_i^o(k) V_i^o(k) dk + \mu_i^s V_i^s \right). \]

Dealer \( i \)'s profit from inter-dealer transactions is

\[ \pi_i^I = \sum_{j \in D_i} \left( \int \hat{\mu}_i^b(k) \mu_j^s z_{j,i} \left( V_i^o(k) - V_j^b(k) - V_j^s \right) dk \right) + \sum_{j \in D_i} \left( \int \hat{\mu}_i^b(k) \mu_i^s z_{i,j} \left( V_j^o(k) - V_j^b(k) - V_i^s \right) dk \right), \]

where the first and second terms are profits from buy- and sell-transactions for clients, respectively. Dealer \( i \)'s profit from intermediations directly between his customers is

\[ \pi_i^C = \int \hat{\mu}_i^b(k) \mu_i^s z_{i,i} \left( V_i^o(k) - V_i^b(k) - V_i^s \right) dk. \]

Dealer \( i \)'s total profit from both types of transactions is

\[ \pi_i = \pi_i^I + \pi_i^C. \]

The total welfare of all agents in the economy is then

\[ W_{all} = W_c + \sum_{i \in D} \pi_i. \]

Below results are shown in Figure 13 and Table 6.

Result 8. Customers’ welfare increases with dealer interconnectedness: \( W_c^{\text{conc}} > W_c^{\text{clnt}} > W_c^{\text{frag}} \).

Customers’ welfare increases with the dealer interconnectedness and is the highest in the concentrated network structure. The intuition is as follows. The inefficiency in this environment is that investors with a low-valuation for the bond are stuck with the bond. As the dealer interconnectedness increases, liquidity increases. Assets, as a result, are allocated more efficiently and are held more by investors with the greatest utility for them. The better allocation of assets increases customer welfare.
**Result 9.** The total dealer profit is the highest in the core-periphery network structure and is the lowest in the concentrated setting: \[ \sum_{i \in D} \pi_{clnt}^i > \sum_{i \in D} \pi_{frag}^i > \sum_{i \in D} \pi_{conc}^i. \]

Two opposing forces determine dealer profits. On the one hand, as the interconnectedness increases, dealers intermediate a greater number of transactions and make larger profits. On the other hand, as the interconnectedness increases, the average intermediation chain requires fewer dealers. As a result, dealers of an average chain collectively capture a smaller fraction of the total gains from trade. To see why, if a chain involves two dealers, the two dealers together capture half of the surplus, but if a chain involves one dealer, the dealer gets just one third of the total gains from trade. Thus, a greater interconnectedness puts a downward pressure on the overall dealer profits because the per transaction profit is lower. Dealer profits are the highest in the core-periphery structure—in between the two extremes of complete fragmentation and complete concentration.

**Result 10.** The total welfare increases with dealer interconnectedness and is the highest in the concentrated setting: \[ W_{conc}^{all} > W_{clnt}^{all} > W_{frag}^{all}. \]

For our parameter values, the total welfare is determined primarily by customers’ welfare. Since customers’ welfare improves with dealer interconnectedness, so does the total welfare in the economy.

## 4 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 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 a clientele effect. Customers with heterogeneous liquidity needs endogenously sort themselves with different dealers. Dealers that attract a clientele of liquidity investors have a larger customer base, support a greater fraction of inter-dealer transactions, and form the core. Dealers that instead cater to buy-and-hold investors form the periphery. Customers’ welfare and asset liquidity increase with dealer interconnectedness, but a partially fragmented dealer market yields the largest profits to dealers.
A Aggregating Prices

For intermediations directly between clients, Figure 4 illustrates expected prices that clients of dealer $i$ face.

Figure 4: Prices
The figure illustrates prices from transactions in which a dealer intermediates directly between her customers. $\Delta^b_i(k)$ denotes the reservation value of the $k$-type buyer of dealer $i$.

For transactions that instead involve an inter-dealer chain, Figure 5 illustrates the price that different dealers’ average buyer expects to pay. In particular, substituting the definition of $\hat{p}_{i,j}^{ask,I}(k)$, given in (10), into the definition of $P_{i,1}^{ask,I}$, given in (14), and simplifying, $P_{i,1}^{ask,I}$ can be expressed as

$$P_{i,1}^{ask,I} = z_i \bar{V}_{j \in D_i} + (1 - z_i) E_i^{\text{b}} \left[ \Delta_i(k) \right],$$

where $\Delta_i(k) = V_i^a(k) - V_i^b(k)$ denotes the reservation value of a $k$-type buyer of dealer $i$, and

$$\bar{V}_{j \in D_i} \equiv \frac{1}{\mu_i} \sum_{j \in D_i} \mu_j V_j^s.$$

In (20), $\bar{V}_{j \in D_i}$ is the average reservation value of sellers in dealer $i$’s network. Thus, an average buyer of dealer $i$ expects to buy at a price that lies between the average reservation value of sellers in dealer $i$’s network and the reservation value of the average buyer.

Figure 5: Prices from an End-Buyer’s Perspective
The figure illustrates the price that different dealers’ average end-buyer expects to pay for transactions that involve an inter-dealer chain.

Similarly, Figure 6 illustrates the prices different dealers’ end-sellers face from transac-
tions that involve inter-dealer chain. Substituting $\hat{p}_{i,j}^{bid}(k)$, given in (8), into the definition of $p_{i,i}^{bid,I}$, given in (16), $p_{i,i}^{bid,I}$ can be expressed as

$$p_{i,i}^{bid,I} = (1 - z_I) V_i^s + z_I \sum_{j \in D_i} \Delta_j^b,$$

where

$$\sum_{j \in D_i} \Delta_j^b = \frac{1}{\mu_{i,j}^b} \sum_{j \in D_i} \mu_{i,j}^b E_{j}^{b_i}[\Delta_j^b(k)].$$

(21)

Figure 6: Prices from an End-Seller’s Perspective

The figure illustrates prices from an end-seller’s perspective (i.e. bid prices) for transactions that involve an inter-dealer chain.
B Observed Network Structures

Figure 7: 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 8: 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 9: 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, $M_I(i)$. See Section 2.1 for more detail.
Figure 10: Liquidity and Prices Customers Face

The figures plot liquidity and prices clients face as functions of dealer centrality (in x-axis). Dealer centrality is measured by the total number of inter-dealer transactions that a dealer intermediates, \( M_i \). Figures in the top row show results for transactions in which a dealer intermediates directly between one’s clients. The bottom row shows results for transactions that involve an inter-dealer chain. See Section 2.2 for more detail.

- **Number of Transactions**
  - X-axis: Dealer centrality
  - Y-axis: Number of transactions

- **Expected Prices**
  - X-axis: Dealer centrality
  - Y-axis: Expected prices

- **Bid–Ask Spread**
  - X-axis: Dealer centrality
  - Y-axis: Bid–Ask spread
Figure 11: Liquidity and Prices Dealers Face from Other Dealers
The figures plot liquidity (by transaction times and bid-ask spreads) and prices that dealer $i$ faces from core versus peripheral dealer $j$. The x-axis is dealer centrality of dealer $j$, measured by the total number of inter-dealer transactions, $M_I(j)$. See Section 2.3 for more detail.

Figure 12: Asset Liquidity and Prices Across Network Structures
The figures plot asset liquidity (by volume and bid-ask spreads) and prices in the economy across three different network structures (in the order of increasing concentration): (1) fragmented environment without any inter-dealer trades, (2) clientele equilibrium, and (3) completely concentrated environment with just one dealer. See Section 3 for more detail.
Figure 13: Customer Welfare, Dealer Profits, and Total Welfare Across Network Structures

The figures plot customer welfare, dealer profits, and total welfare across three different network structures (in the order of increasing concentration): (1) fragmented environment without any inter-dealer trades, (2) clientele equilibrium, and (3) completely concentrated environment with just one dealer. See Section 3 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>δ</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, ¯k]</td>
<td>[1,5]</td>
</tr>
<tr>
<td>Dealers’ matching efficiency</td>
<td>λ</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>
</tbody>
</table>

Table 2: The Equilibrium Cutoffs

<table>
<thead>
<tr>
<th></th>
<th>Fragmented</th>
<th>Clientele</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k_1^*$</td>
<td>1.55717</td>
<td>1.89443</td>
</tr>
<tr>
<td>$k_2^*$</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>Fragmented</th>
<th>Core</th>
<th>Peripheral</th>
<th>Peripher</th>
<th>Concentrated</th>
<th>Core</th>
<th>Peripheral</th>
<th>Peripher</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>
<td>0.0749</td>
<td>0.0938</td>
<td>0.1312</td>
<td>0.3000</td>
<td>0.2586</td>
</tr>
<tr>
<td>Num. of owners</td>
<td>$\mu_{oi}$</td>
<td>0.0719</td>
<td>0.0731</td>
<td>0.0744</td>
<td>0.0587</td>
<td>0.0802</td>
<td>0.1197</td>
<td>0.2586</td>
<td>0.0414</td>
</tr>
<tr>
<td>Total across dealers</td>
<td>$\sum \mu_t$</td>
<td>0.2194</td>
<td>0.2586</td>
<td>0.2586</td>
<td>0.0162</td>
<td>0.0137</td>
<td>0.0116</td>
<td>0.0414</td>
<td>0.0414</td>
</tr>
<tr>
<td>Num. of sellers</td>
<td>$\mu_{si}$</td>
<td>0.0281</td>
<td>0.0269</td>
<td>0.0256</td>
<td>0.0563</td>
<td>0.0474</td>
<td>0.0401</td>
<td>0.1438</td>
<td>0.1438</td>
</tr>
<tr>
<td>Total across dealers</td>
<td>$\sum \mu_t$</td>
<td>0.0806</td>
<td>0.1830</td>
<td>0.1830</td>
<td>0.1380</td>
<td>0.1438</td>
<td>0.1438</td>
<td>0.1438</td>
<td>0.1438</td>
</tr>
<tr>
<td>Buyers to sellers ratio</td>
<td>$\mu_{bi}/\mu_{si}$</td>
<td>3.2726</td>
<td>2.0301</td>
<td>1.4202</td>
<td>3.4697</td>
<td>3.4697</td>
<td>3.4697</td>
<td>3.4697</td>
<td>3.4697</td>
</tr>
</tbody>
</table>

Table 4: Prices and Liquidity Provided to Clients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Notation</th>
<th>Fragmented</th>
<th>Core</th>
<th>Peripheral</th>
<th>Peripher</th>
<th>Concentrated</th>
<th>Core</th>
<th>Peripheral</th>
<th>Peripher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer transactions</td>
<td>$M_i^c$</td>
<td>0.2585</td>
<td>0.1472</td>
<td>0.0931</td>
<td>0.0913</td>
<td>0.0649</td>
<td>0.0463</td>
<td>0.2585</td>
<td>0.1472</td>
</tr>
<tr>
<td>Inter-dealer transactions</td>
<td>$M_i^{b,I} + M_i^{s,I}$</td>
<td>0.2839</td>
<td>0.2635</td>
<td>0.2396</td>
<td>0.3752</td>
<td>0.3284</td>
<td>0.2860</td>
<td>0.2585</td>
<td>0.1472</td>
</tr>
<tr>
<td>Total transactions</td>
<td>$M_i$</td>
<td>0.2585</td>
<td>0.1472</td>
<td>0.0931</td>
<td>0.0913</td>
<td>0.0649</td>
<td>0.0463</td>
<td>0.3752</td>
<td>0.3284</td>
</tr>
<tr>
<td>Total across dealers</td>
<td>$\sum M_i$</td>
<td>0.4987</td>
<td>0.5960</td>
<td>0.5960</td>
<td>0.2592</td>
<td>0.2592</td>
<td>0.2592</td>
<td>0.4987</td>
<td>0.5960</td>
</tr>
</tbody>
</table>

Prices Clients Face from Transactions Intermediated Directly Between Clients

| Bid price $P^{bid,c}_{i,j}$ | 17.5213 | 17.2922 | 17.0513 | 19.0286 | 19.0361 | 19.0464 | 19.3993 |
| Ask price $P^{ask,c}_{i,j}$ | 17.5431 | 17.3270 | 17.1008 | 19.0440 | 19.0579 | 19.0771 | 19.4184 |
| Bid-ask spread (%) $\omega_{i,j}^{c}$ | 0.1240 | 0.2011 | 0.2900 | 0.0810 | 0.1145 | 0.1611 | 0.0986 |

Prices Clients Face from Transactions Involving an Inter-Dealer Chain

| Bid-ask spread (%) $\omega_{i,j}^{I}$ | -14.6589 | 3.0495 | 19.1330 | -14.6589 | 3.0495 | 19.1330 | -14.6589 |

Table 5: Inter-Dealer Prices

<table>
<thead>
<tr>
<th>Variable</th>
<th>Notation</th>
<th>From Core ($j = c$)</th>
<th>From Peripheral ($j = p$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price at which dealer $i$ buys</td>
<td>$P_{i,j}^c$</td>
<td>19.0605</td>
<td>19.0611</td>
</tr>
<tr>
<td>Price at which dealer $i$ sells</td>
<td>$P_{i,j}^s$</td>
<td>19.0376</td>
<td>19.0477</td>
</tr>
<tr>
<td>Bid-ask spread (%)</td>
<td>$\omega_{i,j}^c$</td>
<td>0.1204</td>
<td>0.0701</td>
</tr>
</tbody>
</table>

26
Table 6: Customers’ Welfare and Dealer Profits

<table>
<thead>
<tr>
<th>Variable</th>
<th>Notation</th>
<th>Fragmented</th>
<th></th>
<th>Clientele</th>
<th></th>
<th>Concentrated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Core Peripheral Peripheral</td>
<td>Core Peripheral Peripheral</td>
<td>Core Peripheral Peripheral</td>
<td>Core Peripheral Peripheral</td>
<td></td>
</tr>
<tr>
<td>Customer welfare</td>
<td>$W^c_i$</td>
<td>1.75769</td>
<td>1.73951</td>
<td>1.72249</td>
<td>1.42884</td>
<td>1.79375</td>
</tr>
<tr>
<td>Total across dealers</td>
<td>$W^c$</td>
<td>5.21970</td>
<td></td>
<td></td>
<td></td>
<td>5.74175</td>
</tr>
<tr>
<td>Dealer profit</td>
<td>$\pi_i$</td>
<td>0.00562</td>
<td>0.00512</td>
<td>0.00461</td>
<td>0.00580</td>
<td>0.00572</td>
</tr>
<tr>
<td>Total across dealers</td>
<td>$\sum \pi_i$</td>
<td>0.01535</td>
<td></td>
<td></td>
<td></td>
<td>0.01736</td>
</tr>
<tr>
<td>Total welfare</td>
<td>$W_{all}$</td>
<td>5.23505</td>
<td></td>
<td></td>
<td></td>
<td>5.75911</td>
</tr>
</tbody>
</table>
References


