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# Corporate Bond Trading on a Limit Order Book Exchange*

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## Abstract

We investigate the trading of corporate bonds (c-bonds) by an open limit order book (LOB) mechanism. To do so, we use the case of the Tel Aviv Stock Exchange (TASE) as a laboratory, in which both stocks and c-bonds are traded by an LOB mechanism. Contrary to the OTC market in the USA, the TASE c-bond market is liquid with narrow spreads and low price dispersion. The short-term traders (STT), who are the analog of the market makers in the LOB, have small trading rents and unconcentrated activity (a low Herfindahl index). In the cross-section of bonds, the low concentration is related to low spreads, low price dispersion, and small STT rents. The non-STT [including retail investors (RIs), whose participation is significant] competes with the STT on quotation and tends to tighter quotes. RIs' activity contributes to narrower spreads.

**JEL classification:** G12, G14

**Keywords:** Corporate bonds, Trading costs, Retail investors, Short-term investors, Bid–ask spreads, Liquidity

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## 1. Introduction

Corporate bonds (hereafter c-bonds) are mostly traded worldwide in over-the-counter (OTC) markets while stocks are mostly traded by an open limit order book (LOB) on exchanges. The c-bond OTC market in the USA is illiquid (see Table I, which summarizes empirical findings regarding the c-bond market and municipal bond market in the USA). For example, Harris (2015) estimates c-bond customer costs as roughly 0.5%.[1] This figure is much higher than the volume-weighted average of the half-quoted spread for US stocks, which is less than 0.02%.[2] This is quite puzzling because c-bonds should be more liquid than stocks due to their lower price variability, which makes liquidity provision less risky, and the lower degree of information asymmetry (Biais and Green, 2007).

Several researchers claim that the OTC mechanism is problematic and should be replaced by an LOB. For example, Harris, Kyle, and Sirri (2015) suggest a reform in the spirit of the NASDAQ reform from the 1990s that requires the dealers to post their customers' limit orders. In this context, O'Hara, Wang, and Zhou (2016, hereafter OWZ, 2016) cite Rick Ketchum, CEO, and chairman of FINRA, who says "It strikes me as odd that we've spent enormous energy in equity markets to measure and save pennies or just basis points on execution quality, while in the fixed income market it's more a question of nickels, quarters and dollars."[3] Biais and Green (2007) find that until the 1940s bond trading was quite active on the NYSE and the trading costs of retail investors (RIs) were lower than today, and conclude that the bond market in the USA may have reached an inefficient equilibrium of OTC dominance. The reason is that if one market is liquid and a second market is potentially more efficient but currently illiquid, it is not optimal for each trader individually to deviate from the equilibrium and move to the currently less liquid market.[4]

This paper investigates the case of the Tel Aviv Stock Exchange (hereafter TASE), where c-bonds and government bonds have been traded from its beginning (in 1953) by the same method on the exchange with no competing exchanges, dark pools, etc. Our sample period is 2014 and we investigate 402 c-bonds denominated in New Israeli Shekels (NIS), of 143 firms, with a minimum market value of at least 100 million NIS (~\$28 M) each.[5] The market cap of these bonds was 95.3% of the TASE c-bond market cap. The Israeli c-bond market is quite small (~\$80 billion at the end of 2014) and isolated (foreign holdings of 0.9%—see Section 2.2). Thus, one would expect it to be illiquid. Nevertheless, we find it to be a lively market with many transactions per bond-day, very little off-exchange trading and low spreads: the average transaction half spread (THS) is 0.078%. This figure is much lower than the comparable figures in the USA, especially for "retail size" transactions (Table I). In the following, we provide theoretical arguments and empirical evidence supporting our claim that the difference in characteristics between the Israeli LOB market and the US OTC market is due to the trading mechanism. While we cannot formally compare

1 Gunduz *et al.* (2017) find a mean bid-ask spread of 1.2% in the German corporate bond market. Biais and Declerck (2013) find lower effective spreads in Europe than in the US but their c-bond sample includes only large market-cap bonds. For evidence on the Norwegian bond market see Odegaard (2017).

2 Based on CRSP data of monthly bid and ask prices of stocks during 2014 (share codes 10 or 11).

3 FINRA (Financial Industry Regulatory Authority) is a private entity that acts as a self-regulatory organization.

4 See Duffie (2012).

5 During 2014 \$1 was equal on average to 3.58 NIS (Bank of Israel data).

**Table I.** Summary of empirical findings regarding the American markets for corporate bonds and municipal bonds

The table reports key findings from papers that investigate the corporate bond market and the municipal bond market in the USA. The points drawn from the papers are those that are most relevant to our paper. Detailed explanations about the methodologies employed by the papers can be found in Harris (2015).

| Paper | Sample | Sample period | Findings |
|---|---|---|---|
| Schultz (2001) | c-bonds (a sample of insurance companies' trades) | 1/1995–4/1997 | • Average trading costs (one way): 0.135%<br>• The cost decreases with trade size |
| Bessembinder, Maxwell, and Venkataraman (2006) | c-bonds (a sample of insurance companies' trades) | Pre-TRACE period (1/2002–6/2002) and post-TRACE period (7/2002–12/2002) | • Transaction costs decrease with trade size.<br>• TRACE decreases transaction costs.<br>• The AS (information) component of the spread is not significantly different from zero. |
| Harris and Piwowar (2006) | Municipal bonds | 11/1999 –10/2000 | Transaction costs (one way) decrease with trade size. For example, 1.34% (0.24%) for \$5 K (\$1 M) transactions |
| Edwards, Harris, and Piwowar (2007) | c-bonds | 1/2003–1/2005 | • Transaction costs (one way) decrease with trade size. For example, after the introduction of TRACE: 0.86% (0.15%) for \$5 K (\$1 M) transactions of bonds rated "A" and above.<br>• Costs dropped after the introduction of TRACE.<br>• Costs decrease for better credit rating, larger issue size, and closer time to maturity.<br>• 1.2% of Dollar volume arises from transactions <\$100 K |
| Goldstein, Hotchkiss, and Sirri (2007) | BBB-rated c-bonds that have an original issue size between \$10 million and \$1 billion | 7/2002–2/2004 | • Markup: transactions <\$10 K: 2.37%, >\$1,000 K: 0.56% (Table VI, Panel A)<br>• Transaction costs decrease with trade size.<br>• TRACE decreases transaction costs |
| Green, Hollifield, and Schurhoff (2007) | Municipal bonds | 5/2000–1/2004 | • Markup: \$0–100 K: 2.30%, \$100–500 K: 1.10%, >\$500 K: 0.16%<br>• Dealer's bargaining power is decreasing in transaction size. |
| Chen and Zhong (2016) | c-bond trades | 11/2008–3/2011 | • The spreads of bonds that are also traded on the NYSE are lower by 0.10% than the spreads of OTC—only bonds. |

(continued)

**Table I.** Continued

| Paper | Sample | Sample period | Findings |
|---|---|---|---|
| Harris (2015) | c-bond trades | 12/2014–4/2015 | • The mean half quoted spread for trades with two-sided quotes standing for at least 2 s is 0.435% (0.439% for customer trades) (Table XIV in their paper).<br>• The mean HES for customer trades is greater for retail-size trades (under $100,000) (0.772%) than for institutional-size trades (0.421%).<br>• There are many instances of trade-through (trading outside the spreads). |
| Hendershott and Madhavan (2015) | c-bonds regular ("voice") versus MarketAxess ("electronic") transactions | 1/2010–4/2011 | • Trading cost: Investment grade voice (electronic) 0–100 K $0.88% (0.22%), 100 K–1M $0.47% (0.14%), 1–5 M $0.15% (0.11%), >5 M $0.11% (0.10%)<br>• Cost (one way) is calculated using a benchmark such as the last trade in that bond in the inter-dealer market. |
| O'Hara, Wang, and Zhou (2016) | c-bond trades by US insurance companies | 2002–2011 | • Less active investors pay on average 0.49% more for buys and receive 1.78% less for sales than more active investors.<br>• The differences decrease, but remain significant, after the introduction of TRACE.<br>• The differences are larger for small size transactions.<br>• The top dealer does on average 70% of the annual volume and the average Herfindahl–Hirschman measure is 0.61.<br>• More concentration worsens execution quality differentials between trades for active and less active investors.<br>• Many small trades coming from institutions. |
| Randall (2015) | c-bond trades | From the start of TRACE in 2002 to 12/2010 | • Dealer markups are larger when dealers' inventory costs are higher.<br>• Mean dispersion of prices within a bond-minute at the end of 2010: for customer–dealer trades ~0.24% and for inter-dealer trades ~0.04% (Figure 5 in their paper). |
| Hendershott et al. (2016) | c-bond trades by US insurance companies | 1/2001–6/2014 | Execution costs are higher for smaller insurers and insurers with smaller networks. |

the Israeli LOB market to the American OTC market, it should be noted that the difference in size between the markets works against our findings. We find that the spreads of the related stocks are larger than the bond spreads and that the TASE stock spreads are larger than in the US stock market. These two facts support the notion that the spread difference between the bond markets of TASE and the USA is due to the difference in mechanism and it is not a "country effect."

The spread difference is consistent with Duffie, Gârleanu, and Pedersen (2005; hereafter DGP, 2005) and Yin (2005), who highlight that the OTC mechanism is inherently uncompetitive because of the lack of pre-trade transparency. The intuition is that, even if there are many dealers, they have high bargaining power and therefore do not fully compete on the price. Each of them marks up the price, knowing that the customers will incur some costs if they shop further and cannot practically search the entire market for the best deal. While the uncompetitiveness of the US OTC market is reflected in price dispersion and a negative relation between a transaction's size and its spreads, we find a very weak relation between a transaction's size and its spread and negligible price dispersion within bond-minute in the TASE LOB market.[6]

To further investigate the characteristics of the LOB, we use a unique and proprietary database of the TASE that includes transaction records with trader identification. The database does not include the trader's classification (e.g., retail, institutional, etc.). We identify RIs as "low-volume" investors with less than 2 million NIS (~$559,000) in all TASE securities (excluding options). These low-volume investors are almost certainly RI. The second group that we identify is short-term traders (STT). We define a STT as a non-retail trader that on average flips between buying and selling within a trading day. These STT are the analog for the dealers in the OTC market. Their trading rents in their "making" transactions are 0.030% before trading fees (at least 0.005%). This is consistent with a competitive market where the liquidity providers earn very low rents.

Next, we investigate characteristics of the LOB that enhance competition and efficiency. The first aspect we refer to is competition among the liquidity providers (the STT). The LOB encourages competition between many STT in each bond. This is because trading can be done using automated trading systems that monitor many securities simultaneously. This is in contrast with the search-based structure of the OTC, which gives advantage to the few prominent dealers that are the natural first choice of the customers. Indeed, we find that although the TASE is much smaller than the US market, many STTs are active in the market and in each bond. The average (median) of the c-bond's Herfindahl–Hirschman Index (HHI) is 0.162 (0.126). This is in contrast to OWZ (2016), who find that although there are more than 400 dealer firms in the American market in many bonds there are only one to two active dealers per year. As a result, they find an average dealer-HHI of 0.61, which represents a situation between duopoly and monopoly. We link the competition among the STT to market liquidity and show that the c-bond's HHI is positively related (after controlling for relevant exogenous variables) to spread measures, consistent with the assertion that competition among the liquidity providers reduces spread.[7]

An additional form of competition is among the different investor types. LOB, as opposed to OTC, enables all traders to trade with each other and compete on quotation. Indeed, we find that a substantial part of the liquidity provision is made by non-STT, and

6 The price dispersion is the standard deviation of prices divided by average price.

7 The causality is likely to be from the *HHI* to illiquidity and not the other way around. The reason is that large spreads attract more STT and therefore lead to less concentration and lower *HHI*.

that the spreads in their "making" transactions are lower than the spreads in the transactions of STT. These findings are in line with Barclay *et al.* (1999) and Weston (2000), who find that the NASDAQ reform of the 1990s that enabled competing with the dealers by posting limit orders resulted in narrower spreads.

An additional aspect of investor participation in LOB trading is RI participation. In the US c-bond OTC market, retail participation is negligible.[8] The LOB is more welcoming to RI because the centralized structure of the market and the pre-trade transparency make it accessible to non-professional traders. Indeed, we find that at the TASE 8.8% of the NIS double-sided volume arises from RI and that RI participation contributes to the liquidity. First, we find that contrary to other non-STT, in the transactions where RI acts as "takers" (73% of their NIS volume), they impose no adverse selection (AS) on the "maker" side. Reducing the AS potential allows for tighter spreads.[9] Next, we examine the effect of retail participation on c-bond liquidity. We perform a simultaneous equations analysis, taking advantage of the fact that RI tends to invest in the non-CPI-linked c-bonds. In this analysis, we estimate that an increase of 1% in retail participation (say from 8% to 9%) is related to a decrease of about 8.1% in the bond's HQS, for example from 0.10% to 0.0919%.

To sum up, our paper provides clear empirical evidence that c-bonds can be successfully traded by an LOB and that characteristics of the LOB contribute to market liquidity. Thus, we support the views expressed in Harris (2015), and Harris, Kyle, and Sirri (2015), among others, that c-bond markets should move in the direction of a centralized open LOB.

The rest of the paper is organized as follows. Section 2 describes the market and the data. Section 3 describes the liquidity in the TASE c-bond market. Section 4 compares the LOB to the OTC and summarizes the empirical predictions following these differences. Section 5 reports price dispersion and trading rents in the TASE c-bond market. Section 6 analyzes the competition between STT. Section 7 analyzes the contribution of non-STT (including RI) to liquidity. Section 8 concludes.

## 2. Market Description and Data

### 2.1 The TASE market

The TASE is the only exchange in Israel.[10] The mechanism for all the securities on the TASE is continuous LOB trading, with opening and closing auction trading sessions.[11]

8 From Table 2 in Edwards, Harris, and Piwowar (2007) one can calculate that 1.2% of the dollar trading volume arises from transactions smaller than $100,000. Since there are many institutional transactions in this size category (see OWZ, 2016) the fraction of RI trading is probably much lower than 1.2%. Because of tax advantages, the holdings of individuals are higher in municipal bonds than in corporate bonds. They hold directly (indirectly) 50% (25%) of the market cap of municipal bonds. See Aguilar (2013).

9 See, for example, Proposition 5 in Glosten and Milgrom (1985), who show that the bid-ask spread is smaller as there are more "uninformed orders".

10 The Tel Aviv Stock Exchange is not an accurate translation of the Hebrew name, which uses the term "securities" rather than "stock" and is therefore more general.

11 The opening stage of the trade in c-bonds (stocks) takes place between 9:30 and 9:31 (9:45 and 9:46), the exact time for each security being arbitrary. The pre-opening stage, where orders are posted, starts at 9:00 am. The closing call auction stage takes place on Sunday (Monday to Thursday), between 16:24 and 16:25 (17:24 and 17:25), the exact time for each security again being arbitrary. Very illiquid securities are traded by daily auctions only.

In all stages, the limit orders are executed by price and time priority, and there are no hidden limit orders.[12] A minimum amount of 10,000 (2000) NIS, for c-bonds (stocks) applies for orders placed during the continuous stage.

In 2014 there were 26 exchange members at the TASE. These members are banks and brokerage firms through which traders can submit orders for all the securities that are traded on the TASE. The exchange members provide their clients with online access to the exchange without any human intervention: the clients can see the status of the order book online and submit orders, which are transmitted immediately to the exchange. All the traders can observe the three best bids and offers on each side of the market in all securities.[13] The identity of the member firms and traders submitting orders is unknown to the market participants. The tick size at the TASE is a function of each security's market price. For most of the c-bonds it is around 0.01%. The trading fees (including clearing fees) for each side of the transaction that the TASE charged its members were 0.0032% of the NIS transaction volume, subject to a minimal fee per transaction of 1.40 NIS ($0.39).[14] At the end of December 2014, the aggregate market value of the securities on the TASE was about $470 billion: stocks and warrants—$201 billion, c-bonds—$80 billion, government bonds—$161 billion, exchange traded notes (ETNs—substitutes for ETFs)—$26 billion.[15]

The participants in the Israeli market are quite similar to those in other developed markets. At the end of December 2014, out of the total c-bonds that were traded on the TASE, 24.6% were held by long-term savings, 24.2% by mutual funds, 18.2% by insurance companies and banks, 6.5% by ETNs, and 0.9% by foreign investors.[16] The rest (25.6%) were divided between other trader groups: individuals, nonprofit organizations, short-term trading firms, and hedge funds.[17] We do not have information about each of these sub-group's holdings.

## 2.2 The history of c-bond trading on the exchange

The first institution for securities' trading was established in Tel Aviv in 1935.[18] In 1953 this institution became the TASE. Back then, the market was very small and all the

12 Hidden orders were introduced in October 2014, but according to the TASE they were rarely used. The TASE also allows "fill or kill" and "immediate or kill" orders, but they are rarely used.

13 Since November 2014, the traders can observe the five best bids and offers.

14 We do not have formal information about the fees the exchange members charge their clients. According to www.hon.co.il (in Hebrew) the fees of discount brokers for individual c-bond trading were ~0.09% in January 2015. To the best of our knowledge the fees of the institutional investors can be very close to the fees the TASE charges its members.

15 See TASE annual review, http://www.tase.co.il/Eng/Statistics/QuarterlyandAnnualReviews/Pages/annualquarterlyreviews.aspx In addition, various types of options (on indices, stocks and exchange rates) are traded on the exchange.

16 See Tables 12 and 23 in the Bank of Israel statistics, http://www.boi.org.il/.

17 The Federal Reserve publishes the US financial accounts, which include the holdings of corporate and foreign bonds in the US (i.e., the Fed's flow of funds). At the end of December 2014, out of the total corporate and foreign bonds in the US, 10.5% were held by long-term savings, 17% by mutual funds, 28.1% by insurance companies and banks, 1.8% by ETFs and 26.7% by foreign investors.

18 It was a daily gathering of about 10 bankers and brokers who traded a few stocks and a few c-bonds for about an hour for their own accounts and on behalf of their clients. See the TASE publication (in Hebrew) http://www.tase.co.il/resources/pdf/newsjournal/05-11_nl32_nov2005_70-year.pdf. We also rely on information from the Israeli newspaper "Calcalist" available at http://www.cal

securities were traded by a daily auction.[19] Because the market was small, the TASE offered an operationally efficient solution (daily auctions) and there was no room for an OTC market, which requires considerable human resources.[20] As the market expanded, market participants became used to the fact that all instruments were traded on the exchange and that the liquidity was there, so an OTC market was not able to attract the initial liquidity. An additional explanation is that until 2005 the institutional investors (e.g., long-term savings and mutual funds) were mostly the banks, which were the potential dealers for an OTC market. Therefore, dealer activity could have exposed the banks to conflict of interest and potentially to claims of illegal activity.

The c-bond market in Israel expanded dramatically in the 2000s following regulation changes that relaxed limitations on long-term c-bond investing by institutions. The aggregate market cap of c-bonds increased from $6 billion in 2003 to $73 billion in 2009. To sum up, the practice of c-bond trading on the exchange like stocks was instituted many years ago when market conditions were very different than they are today. Therefore, the exchange trading is not a result of current economic conditions.

## 2.3 Why are many of the bonds CPI-linked?

In Israel, many of the government bonds and the c-bonds are CPI-linked. Ben-Shachar Bronfeld and Cukierman (1971) state that until 1954 all government bonds were nominal and the high inflation of that time caused heavy losses to bond investors.[21] This led the government to issue CPI-linked bonds. In the period from 1980 to 1985, Israel experienced hyperinflation (e.g., the annual inflation in 1984 was 445%) and during that period almost all bonds (most of them were then governmental) were CPI-linked. Currently inflation is very low (it was –0.2% in 2014) but the memory of high inflation probably affects the prevalence of CPI-linked bonds.

## 2.4 The database and the sample of c-bonds

We use a unique and proprietary database of the TASE that includes transaction records in which both sides of the transaction are identified. The identification includes the identity of the exchange member and a code that identifies the trader within the member's list of traders. In addition, the database documents the transaction time, whether the transaction was "buyer initiated" or "seller initiated," and the trading stage at which the transaction was executed.

We focus on a sample of c-bonds which were traded on the TASE during 2014, the only requirements being a market value of at least 100 million NIS per bond (equivalent to ~$28 M) and denomination of the c-bond in NIS.[22] The sample consists of 402 c-bonds of 143 firms, which covered 95.3% (95.7%) of the market cap (NIS trading volume) of the 676 c-bonds traded on the TASE during 2014. Most of the c-bonds in the sample are CPI-

calist.co.il/markets/articles/0,7340,L-3687769,00.html and a magazine of the open University of Israel available at http://www.openu.ac.il/publications/magazine-07/download/Pages_23-27.pdf.

19 For example, in 1960 the daily dollar volume of **all** bonds – mostly governmental and a few corporate bonds – was $60,000 (Ben-Shachar, Bronfeld and Cukierman, 1971).

20 This explanation is provided by Saul Bronfeld, who served in several key positions in the Israeli capital market, including as vice president of the TASE, later as its CEO and eventually as chairman of the board, and has a deep knowledge of the history of the Israeli capital market.

21 The cumulative rate of inflation during 1952–1954 was 113%. Data for prior years is unavailable.

22 Two US dollar-linked c-bonds were excluded because of this condition.

linked (272 out of 402) and investment grade (according to the average rating of the credit rating agencies)[23]: At the end of 2014 (or the last trading day if the bond matured during 2014), 361 of the c-bonds in our sample were rated investment grade (BBB and above), 13 were rated speculative grade (below BBB), and 28 were not rated.[24]

Table II reports summary statistics of the c-bond sample. The average number of daily transactions is 61 with an average transaction size of about 32,000 NIS (about $9000). This transaction size is much lower than the transaction size in the US c-bond market. For example, the average transaction size in Edwards, Harris, and Piwowar (2007) is $0.75 M (see their Table I). The average of the c-bonds' NIS proportion outside the exchange is 6.76%. This means that most of the trading needs are fulfilled on the exchange.

## 2.5 Identification of RIs and STTs

The database does not include the trader's classification (institutional, retail, short-term, etc.). Therefore, we rely on technical information such as trading volume and trading frequency to classify investor types. We focus on two investor groups: STTs and RIs.

The STT provide liquidity to other investor types (institutional, retail) that trade for a longer horizon. In an OTC market, these are the dealers. We define the STT as traders that flip from buying to selling within a short period of time and are not identified as RI. For each trader in each c-bond of the sample that she traded, we calculate the number of switches from buying to selling or vice versa, and divide it by the number of trading days that the trader was active in the c-bond. A trader is classified as "short-term" if the value-weighted average of this ratio across the c-bonds that the trader traded is equal to or greater than 1 (see the formal definition in the Appendix).[25] As a robustness check, we also examine a cutoff of 0.5. All our main findings (reported in Tables VI–VII) remain qualitatively similar.

We find 280 STT that were active in our c-bond sample. Their mean (median) annual trading volume at the TASE is about 768 (88) million NIS. The low median implies that many of these traders are small trading firms or individual traders. However, most of the transactions and the trading volume of this group arise naturally from the large traders, as presented in Section 6.1.

We identify RI as "low-volume" investors with <2 million NIS (roughly $559,000 during the sample period) in all the securities that are traded on the TASE (excluding options). It is possible that there are RIs with higher trading volumes but non-RI with such low trading volumes are probably rare. Therefore, this definition can be viewed as restrictive. As a robustness check, we examine a cutoff of 3 million NIS, showing that our findings in Section 7 are not changed qualitatively.

We find 159,738 RI that were active in our c-bonds sample during 2014. Their activity is low and infrequent. The average (median) trading volume, in all TASE securities

23 Israel has two rating agencies: Maalot (a subsidiary of S&P) and Midroog (a subsidiary of Moody's). The rating in Israel is local, meaning that the firms are rated relative to other Israeli firms without taking into account the country risk.

24 The data on credit rating and the c-bond characteristics are from www.valuation.co.il. We thank Eran Ben-Horin for providing the data.

25 A ratio of 1 means that on each day the investor traded the security, a sale transaction was followed with a buy transaction (or vice versa), on average. Such trading frequency can naturally be interpreted as short-term trading, especially in c-bonds.

**Table II.** Summary statistics

The table reports the cross-section statistics of the corporate bond sample. The sample period is 2014 (245 trading days). The sample includes 402 corporate bonds with a market cap of >100 million NIS. Average return is the average daily return adjusted for coupon payments. Daily volume (Daily volume during the continuous stage) is the average daily NIS volume (the average daily NIS volume during the continuous stage) in NIS millions. Number of daily transactions (number of daily transactions during the continuous stage) is the average number of daily transactions (the average number of daily transactions during the continuous stage). Trading outside exchange (%) is the proportion of NIS trading outside the TASE relative to the total trading volume of the c-bond. Number of traders is the number of accounts that participated in at least one transaction of the corporate bond during 2014. See the Appendix for the definitions of the rest of the variables. "VW mean" is the value-weighted mean according to "Daily volume (in NIS millions)."

| | *N* | Mean | VW mean | Median | SD | Min | Max |
|---|---|---|---|---|---|---|---|
| Average return | 402 | 0.02% | 0.02% | 0.01% | 0.06% | −0.42% | 0.51% |
| STD | 402 | 0.48% | 0.47% | 0.29% | 0.45% | 0.02% | 3.11% |
| Daily volume (in NIS millions) | 402 | 1.95 | 4.86 | 0.98 | 2.70 | 0.03 | 25.41 |
| Daily volume during the continuous stage (in NIS millions) | 402 | 1.70 | 4.19 | 0.87 | 2.26 | 0.03 | 18.18 |
| Number of daily transactions | 402 | 60.99 | 121.81 | 47.79 | 56.45 | 0.96 | 363.74 |
| Number of daily transactions during the continuous stage | 402 | 41.80 | 90.90 | 24.87 | 47.48 | 0.79 | 332.29 |
| Trading outside exchange | 402 | 6.76% | 7.41% | 3.58% | 9.05% | 0.00% | 78.15% |
| SIZE (in NIS million) | 402 | 647.26 | 1,388.53 | 407.07 | 724.73 | 100.50 | 5,421.06 |
| FIRM_SIZE (in NIS million) | 402 | 5,159.85 | 7,893.93 | 2,456.94 | 5,988.70 | 79.77 | 26,868.87 |
| DURATION | 402 | 3.62 | 4.30 | 3.35 | 2.02 | 0.11 | 10.41 |
| RATING | 402 | 19.44 | 21.12 | 21.29 | 6.13 | 0.00 | 25.89 |
| PRICE | 402 | 1.15 | 1.19 | 1.14 | 0.16 | 0.33 | 1.51 |
| Turnover | 402 | 63.01% | 87.91% | 48.85% | 48.89% | 4.58% | 391.76% |
| Number of traders | 402 | 2,351.1 | 4,807.5 | 1,407.5 | 2,460.6 | 71.0 | 17,686.0 |
| PROP_RI | 402 | 8.98% | 8.56% | 7.53% | 6.16% | 0.54% | 30.82% |

**Table III.** Bid–ask spread measures

The table reports bid–ask spread measures. The c-bond sample is defined in Table II. The first line reports statistics of the transactions' THS. The second line reports statistics for the transactions' HQS. That is, for each transaction we provide its c-bond's HQS. "VW mean" is the value-weighted mean according to the NIS volume of the transaction. THS and HQS are defined in the Appendix.

| | *N* | Mean (%) | VW mean (%) | Median (%) | SD (%) | Min (%) | Max (%) |
|---|---|---|---|---|---|---|---|
| THS | 3,498,596 | 0.078 | 0.067 | 0.039 | 0.202 | 0.003 | 10.000 |
| HQS by transaction | 3,498,596 | 0.082 | 0.077 | 0.055 | 0.102 | 0.012 | 2.910 |

(excluding options), is 379,862 (232,485) NIS. The average (median) number of trading days at the TASE (out of the 245 possible trading days) is 6.16 (4.00).[26] These RIs are quite "long term." In only 10.2% of the cases do we find both buying and selling.

## 3. Liquidity in the TASE LOB C-Bond Market

We estimate the liquidity of the LOB c-bond market using fundamental spread measures of liquidity (see detailed definitions in the Appendix). The first measure is the THS, which compares the transaction price to the mid-quote prevailing before the transaction. As can be seen from Table III, its average (value-weighted average) across the transactions is 0.078% (0.067%). These figures are much lower than the estimates in the US market, especially for transactions of less than $100,000 (Table I). The HQS of a c-bond is the average of DAILY_HQS, which is the average of the half-quoted bid–ask spread at six time points each trading day, on the hour from 11:00 to 16:00. The second line of Table III reports statistics for transactions' HQS. That is, for each transaction we provide its c-bond's HQS. The average (value-weighted average) is 0.082% (0.77%). These figures represent the average cost of an investor who trades a small quantity immediately after arriving at the market. The average of a transaction's HQS is larger than the average of the THS since transactions tend to occur where bid–ask spreads are relatively narrow.[27]

Since both stocks and c-bonds are traded on an LOB it is of interest to compare their liquidity. As noted at the beginning of the introduction, it is well-known that OTC c-bond markets are less liquid than stock markets, which is quite puzzling, because c-bonds should be more liquid than stocks due to their lower variability and the lower degree of information asymmetry (Biais and Green, 2007). We focus on a sub-sample of 102 firms from our c-bond sample that traded stocks on the TASE.[28] This sub-sample includes 102 stocks and

26 It is possible that a trader trades through different exchange members or through different accounts of a given exchange member. Casual observation suggests that RI tend to concentrate their trading activity in one account. In any case, however, an account that trades less than 2 million NIS per year is likely to be an account of a small RI.

27 On the other hand, large quantity orders "walk on the book", that is, are executed against different layers of the limit order book.

28 In Israel, there are firms with publicly traded bonds that have stocks that are not traded publicly. These firms are not included, of course, in our comparison sample.

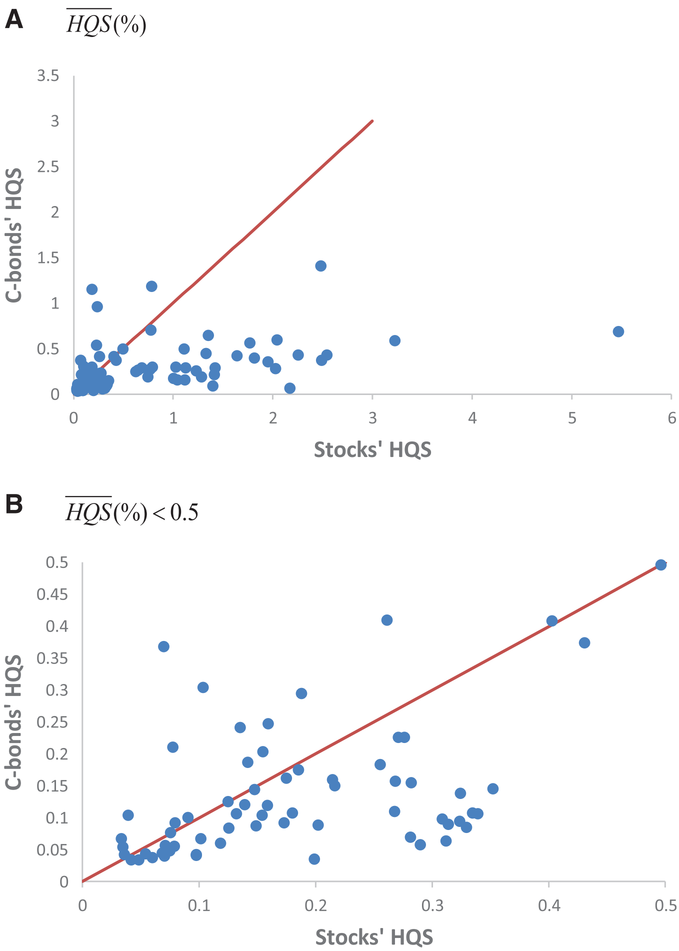


**Figure 1.** Bid–ask spreads of corporate bonds and stocks of the same firm.
*Notes*: The figure reports the half quoted bid–ask spread (HQS) for a sub-sample of firms that traded stocks on the TASE as well as corporate bonds. The sample is defined in Table II. HQS is defined in the Appendix. Corporate bonds of the same firm are averaged into a single observation. Panel **A** relates to the entire sub-sample. Panel **B** presents the firms for which the average HQS (of stocks and corporate bonds) is smaller than 0.5%.



346 c-bonds. The mean of the HQS of c-bonds (stocks) is 0.18% (0.65%) and for the half effective spread (HES—the security's average THS) the means are somewhat lower: 0.16% (0.55%). That is, both the HQS and the HES of the c-bonds are considerably lower than the comparable measures of the stocks.

To demonstrate this difference between c-bonds and stocks graphically, Figure 1 plots HQS at the firm level, averaging the c-bonds of the same firm into a single observation. Panel A of Figure 1 presents a scatter plot of the 102 pairs of HQS. In most cases (81 out of 102), the points are below the 45° line, indicating that the average HQS of a firm's c-bonds is lower than the corresponding HQS of the firm's stocks. The mean (median) HQS is

0.65% (0.27%) for stocks and 0.25% (0.16%) for c-bonds.[29] The $p$-value of a double-sided binomial test in this case is <0.0001 and the $t$-statistic for the series of difference between the numbers in each pair is 5.26. The difference in HES between c-bonds and stocks is qualitatively similar to the difference in HQS. To present a clearer picture, in Panel B of Figure 1 we focus on firms with an average HQS (of stocks and c-bonds) that is smaller than 0.5%.

In sum, at the TASE LOB market c-bonds are very liquid and more liquid than stocks. The fact the stocks' spreads are higher than c-bonds' spreads (and higher than US stocks' spreads—see Exhibit 3 in Avramovic and Mackintosh, 2013) supports the notion that the low c-bonds' spreads in the LOB are not due to an "Israeli effect."

## 4. A Comparison between LOB and OTC

The finding that the small Israeli LOB market is more liquid than the large US OTC c-bond market (and probably other OTC markets worldwide) is striking. In our opinion, this finding is due to the trading mechanism. Unfortunately, we cannot formally test this claim due to the lack of a counterfactual. Therefore, in this section, we summarize the differences between an LOB and OTC markets so that our empirical findings can be interpreted in light of these differences.

The first issue is the pre-trade transparency. The OTC markets have no pre-trade transparency (there are no binding bid–ask spreads) and the customers need to shop between the dealers and negotiate for the price.[30] In an open LOB market, there is pre-trade and post-trade transparency.

Yin (2005) compares two dealer markets that differ in their pre-trade transparency. In the non-transparent market, the customers pay the dealers a spread depending on the customers' searching costs. As noted in the "Introduction" section, the intuition is that, even if there are many dealers, they have high bargaining power and therefore do not fully compete on the price. Each of them marks up the price, knowing that: the customers may incur costs if they shop further; a dealer who wants to deviate from the equilibrium by approaching the potential customer with a better price cannot technically do so. The intuition of Yin (2005) is in line with the claim of Duffie, Gârleanu, and Pedersen (DGP, 2005) that "… a search economy is inherently uncompetitive".

The uncompetitiveness of the non-transparent market leads to:

1. Higher spreads.
2. Higher dealer profits.
3. A larger price dispersion between transactions on the same side (buy or sell) that occur at approximately the same time.
4. A negative relation between the transaction's size and its spread (assuming that search costs are negatively related to trade size).[31]

29 The results are qualitatively similar when we consider a sub-sample of non-dual-listed firms with stocks and c-bonds (it includes 84 firms). In 73 out of the 84 the average *HQS* of a firm's c-bonds are lower than the corresponding *HQS* of the firm's stocks.

30 In many OTC markets there is no post-trade transparency either. In the US c-bond market there is partial post-trade transparency – the transactions are reported with some delay.

31 This relation in the OTC market may arise from trading relations between dealers and customers. See the model and supportive empirical evidence in Bernhardt et al. (2005).

In addition to the difference in transparency between OTC and LOB, there are other differences that make the LOB more liquid.

A. Other things being equal, it is reasonable to assume a larger number of STT in the LOB because:

- The search-based structure of the OTC is advantageous for prominent dealers, who are the natural first choice of the customers. This is likely to wipe out smaller dealers from the market or force them to concentrate in small niches of assets or clients.
- In an LOB, trading can be done using automated trading systems that monitor many securities simultaneously, enabling cheap activity in many securities simultaneously.

A large number of STT competing in each security should further lower the spreads and STT rents.

B. An additional feature of an open LOB is enabling the customers to trade with each other. This should lower the spread paid by the customers and the price dispersion in the market because:

- If two customers trade with each other, their average spread is zero by definition.
- The competition from customers lowers STT spreads.
- Non-STT tend to post tighter quotes than STT because they need to trade anyway. They gain from trading and are willing to provide a better price.

Support for this prediction can be found in Barclay *et al.* (1999) and Weston (2000), who find that the NASDAQ reform of the 1990s resulted in narrower spreads.

C. An additional issue is investor composition. It is likely that investors' asset selection depends on their trading costs. Therefore, investors with high searching costs (e.g., RI) may refrain from trading in the OTC and may prefer to invest in substitutes that are traded in an LOB. Assuming information asymmetry (unlike DGP, 2005; Yin 2005), if investors with high searching costs have less information about the asset, then their inclusion in the market lowers the AS and contributes to spread narrowing.[32]

## 5. Price Dispersion and Trading Rents in the LOB C-Bond Market

### 5.1 The Relation between the Transaction's Size and Its Spread

In the US c-bond market, the smaller the quantity the higher the transaction costs (see Schultz, 2001; Edwards, Harris, and Piwowar, 2007; Harris and Piwowar, 2006 among others in Table I). Biais and Green (2007) suggest that this relation is due to the weaker bargaining power of small traders.[33] The evidence at the TASE is consistent with the American evidence, but on a much smaller scale. We divide the transactions of each c-bond into quintiles according to their NIS trading volume and then group the transactions of each quintile

32 The comparison of the degree of information asymmetry in the two market types is not straightforward. On one hand, the fact that the dealers in the OTC market know the identity of their counterparties can mitigate the information asymmetry that they face (see the model of Benveniste, Marcus and Wilhelm, 1992, in the context of a system with specialists and the empirical support in Battalio, Ellul and Jennings, 2007). On the other hand, in the OTC market, an informed trader can act roughly simultaneously against several dealers, increasing their information disadvantage (see Pagano and Röell, 1992).

33 See the theoretical models of DGP (2005) and Bernhardt et al. (2005).

**Table IV.** Relation between transaction size and transaction spread

The table reports the relation between the transaction size and its spread. The c-bond sample is defined in Table II. See the Appendix for the definitions of all variables.

All transactions

| Quintile | *N* | Average transaction NIS volume | Average THS (%) |
|---|---|---|---|
| 1 | 699,723 | 4,508 | 0.082 |
| 2 | 699,628 | 12,487 | 0.086 |
| 3 | 699,881 | 20,243 | 0.081 |
| 4 | 699,810 | 33,159 | 0.075 |
| 5 | 699,585 | 130,250 | 0.066 |

(roughly 700,000 transactions in each quintile). The results are reported in Table IV. The magnitude of the difference, however, is quite small: 0.016% between the lowest and the top quintile (0.082% versus 0.066%). A simple explanation for this difference is that the smaller the quantity the less the pay-off from efforts to minimize trading costs. To demonstrate this, look at the average deal volume in the lowest quintile, which is roughly $1,250. With this amount, saving 0.016% for example (the difference between the lowest and top quintile) means only $0.2. To sum up, we find very small differences in THS according to deal volume. This difference, consistent with prediction 4 in Section 4, is much smaller than in the USA (Table I).

## 5.2 Price Dispersion

A c-bond may be traded at different prices within a very short time period. This price dispersion is measured by the standard deviation of prices within each minute, divided by the mean of those prices for customer–dealer and inter-dealer trades. Randall (2015) uses price dispersion to measure price competitiveness in the US market. At the end of 2010 the mean dispersion for inter-dealer (customer–dealer) trades is around 0.04% (0.24%), consistent with inefficiency of the customer–dealer transactions. To compare the price dispersion in the LOB c-bond market, we calculate this measure and Table V reports the results. Consistent with prediction 3, the dispersion at the TASE is much lower than in the US market. The average price dispersion in the overall sample is 0.02%. This is also the figure for transactions between STT and non-STT (the analog for dealer–customer transactions in the USA). The price dispersion of transactions on the same side is even smaller. We filter bond-minutes with transactions of STT as makers and non-STT as takers and the STT either buy or sell in these transactions. The average dispersion in this case is 0.015%.

## 5.3 Trading Rents of STTs

An economy with search costs is inherently uncompetitive (DGP, 2005). Therefore, we expect STT profits in an LOB to be lower than dealer profits in the OTC. In about 56% of their NIS volume the STT act as "makers." We measure their trading profits in these transactions using the realized half spread (RHS) (see Section 2.2.3 in Foucault, Pagano, and Roell, 2013), which is the THS minus the AS component.[34] The RHS is usually measured

34 See the appendix for the definitions of the variables.

**Table V.** Price dispersion

The table reports price dispersion. Within each c-bond minute, if there are two transactions or more, we calculate the standard deviation of the prices and divide it by the average price. The price dispersion is calculated on the entire sample, on a sub-sample of transactions between STT and non-STT and on a sub-sample of transactions of STT with non-STT where the STT transact on the same side. The c-bond sample is defined in Table II. See the Appendix for the definitions of the variables.

| | *N* | Mean (%) | Median (%) | SD (%) | Min (%) | Max (%) |
|---|---|---|---|---|---|---|
| All transactions | 857,655 | 0.022 | 0.006 | 0.061 | 0.000 | 3.537 |
| Transactions of STT versus non-STT | 404,280 | 0.019 | 0.006 | 0.056 | 0.000 | 3.987 |
| Same-side transactions of STT versus non-STT | 364,810 | 0.015 | 0.005 | 0.050 | 0.000 | 3.987 |

**Table VI.** Rents of STTs

The table reports the rents of STTs. Trading rents of STT are the RHS in their "making" and the minus of the RHS in their "taking" transactions. Standard errors are double clustered by c-bond and date. The c-bond sample is defined in Table II. See the Appendix for the definitions of the variables.

| | | Equally weighted | | | Value weighted | | |
|---|---|---|---|---|---|---|---|
| STT as | *N* | THS (%) | RHS (%) | AS (%) | THS (%) | RHS (%) | AS (%) |
| Makers | 1,559,455 | 0.087 | 0.039 | 0.048 | 0.071 | 0.030 | 0.041 |
| | | (18.99) | (10.57) | (9.65) | (19.82) | (10.73) | (10.44) |
| Takers | 954,438 | 0.072 | 0.015 | 0.087 | 0.057 | 0.007 | 0.065 |
| | | (17.91) | (2.72) | (10.33) | (17.97) | (1.66) | (10.99) |

using the mid-quote a short time after the transaction. We tried several mid-quote horizons (30 min, 60 min, 120 min, 240 min, and 24 h).[35] The 30/60/120/240 min horizons seem too short relative to the closing price, because the price reversal following the transaction is not completed within these horizons. That is, we find predictable price changes beyond these horizons. We do not, however, find predictable price changes from the closing price to the 24-h mid-quote, indicating that the time interval from the closing to 24 h only adds noise. Therefore, we focus on the closing price as the benchmark price for the transactions. This is consistent with the high frequency traders' profit estimation in Van Kervel and Menkveld (2016) and the estimations of NYSE specialists' revenues in Comerton-Forde et al. (2010).

Table VI reports the average of these measures using the transactions in which the STT are "makers" and "takers." The first line reports these measures in the case that the STT are "makers." The value-weighted averages of THS, RHS, and AS are 0.071%, 0.030%, and 0.041%, respectively. All these measures are positive and highly statistically different

35 In the 30/60/120/240 minute horizons we used the closing price if the horizon ended after the closing.

from zero.[36] The second line presents the spread measures in the cases where the STT are "takers." In these transactions, the value-weighted RHS is 0.007% (the *t*-statistic is 1.66), indicating a small (though insignificant) loss in these cases.

The average trading profits of STT in both "maker" and "taker" transactions is 0.013% (RHS as makers minus RHS as takers; transactions are value weighted). This small number does not include the trading fees paid to exchange members. The TASE charges exchange members about 0.005% for the transactions of STT.[37] It is reasonable to assume that the STT pay the exchange members at least this figure as trading fees. This leaves a very small amount to cover monitoring costs and compensate STT for the risk. Therefore, if there are rents beyond that, they are negligible. This is consistent with a competitive market where the liquidity providers earn very low rents.

Consistent with prediction 2, the STT rents on the LOB are much smaller than the dealer rents in the USA. This difference is especially large when the comparison is to small/medium size transactions in the USA (Table I). For comparison, Goldstein, Hotchkiss, and Sirri (2007) estimate that one-side markups for BBB-rated c-bonds are 1.18% (0.28%) for transactions smaller than \$10,000 (larger than \$100,000) and Green, Hollifield, and Schurhoff (2007) estimate (see their Table VII) one-side markups of 1.15% (0.08%) in the municipal bond markets for transactions smaller than \$100,000 (larger than \$500,000).[38]

## 6. Competition between STTs

### 6.1 STT Activity and Concentration

As discussed in Section 4, LOB–STT activity is likely to be less concentrated than OTC-dealer activity. The reason is that the search-based structure of the OTC gives advantage to prominent dealers, who are the natural first choice of the customers. Indeed, we find that although the TASE c-bond market is small its STT activity is very unconcentrated. The top 10 STT account for 50% of the aggregate STT trading volume. The corresponding figure in Hendershott *et al.* (2016), who investigate a database of aggregate c-bond trading by insurance companies in the USA, is 75%. In contrast, at the TASE, 75% of STT activity is done by the top 27 STT. Therefore, STT activity at the TASE is less concentrated than the dealer activity in the US c-bond market. To estimate market concentration, we use the common measure of the HHI, calculated as:

$$\mathrm{HHI} = \sum_{i=1}^{n} S_i^2,$$

where $S_i$ is the NIS market share of STT$_i$. The HHI ranges from $1/n$ to 1 (monopoly) and it may be interpreted as the reciprocal of the "equivalent" number of equal share traders. We find that the HHI of the c-bond market is 0.0382. This implies a very unconcentrated market with an "equivalent" number of equal-share STT of $1/0.0382 = 26$.[39]

36 All the *t*-statistics are above 10 (standard errors double clustered by c-bond and date).

37 We calculate this figure applying the 0.0032% fee and the minimum of 1.40 NIS per transaction.

38 See Table 6 in Goldstein, Hotchkiss, and Sirri (2007) and Table 7 in Green, Hollifield and Schurhoff (2007). Both papers report the round-trip markups. To compare to our findings, we report their one-side markup in the text.

39 The Horizontal Merger Guidelines of the U.S. Department of Justice and the Federal Trade Commission generally classify markets into three types: Unconcentrated Markets (*HHI* below

**Table VII.** Concentration of short-term trading

The table reports the market share of STTs and their concentration in the cross-section of c-bonds. The c-bond sample is defined in Table II. The table relates to transactions of STT versus non-STT. Number of STT is the number of STT that traded in the c-bond during the sample period. HHI is the Herfindahl–Hirschman index. 1/HHI is the reciprocal of the Herfindahl–Hirschman index. Proportion of largest trader out of STT volume in the corporate bond/Proportion of three largest traders out of STT volume in the corporate bond/Proportion of five largest traders out of STT volume in the corporate bond are the NIS volume of the largest STT/three largest STT/five largest STT in the corporate bond divided by the total NIS volume of all STT (in their transactions versus non-STT) in the corporate bond, respectively. Proportion of largest trader out of the corporate bond volume/Proportion of three largest traders out of the corporate bond volume/Proportion of five largest traders out of the corporate bond volume are the NIS volume of the largest STT/three largest STT/five largest STT in the corporate bond divided by the corporate bond's NIS volume, respectively. "VW mean" is the value-weighted mean according to the c-bonds annual NIS volume. See the Appendix for the definitions of the rest of the variables.

| Variable | *N* | Mean | VW mean | Median | STD |
|---|---|---|---|---|---|
| Number of STT | 402 | 32.11 | 49.64 | 30.00 | 18.06 |
| HHI | 402 | 0.162 | 0.112 | 0.126 | 0.122 |
| 1/HHI | 402 | 8.14 | 10.32 | 7.92 | 3.48 |
| Proportion of largest trader out of STT volume in the corporate bond | 402 | 27.76% | 22.07% | 24.15% | 0.14 |
| Proportion of three largest traders out of STT volume in the corporate bond | 402 | 54.77% | 45.89% | 51.42% | 0.16 |
| Proportion of five largest traders out of STT volume in the corporate bond | 402 | 70.04% | 60.95% | 68.81% | 0.14 |
| Proportion of largest trader out of the corporate bond volume | 402 | 7.23% | 7.10% | 6.47% | 0.04 |
| Proportion of three largest traders out of the corporate bond volume | 402 | 14.70% | 14.81% | 14.40% | 0.05 |
| Proportion of five largest traders out of the corporate bond volume | 402 | 19.13% | 19.75% | 19.21% | 0.07 |

What about the concentration in the individual c-bonds? Since LOB trading can be done using automated trading systems that monitor many securities simultaneously, the monitoring costs per security are small. That is, an LOB enables a presence of STT in many bonds, even though the activity in each of the bonds can be small. Indeed, looking at the 20 largest STT (which account for two-thirds of the total NIS volume of the STT) we find that each of them is active in 171 bonds on average, with an average daily transaction volume of about $18,000 per bond. Hence, although the Israeli market is small, we expect to find less concentration of STT activity relative to US dealer concentration at the individual bond level as well (and not only at the aggregate market level).

0.15), Moderately Concentrated Markets (*HHI* between 0.15 and 0.25) and Highly Concentrated Markets (*HHI* above 0.25).

Table VII reports statistics on the number and concentration of STT in the cross-section of c-bonds. The mean (median) HHI is 0.162 (0.126). Consistent with our predictions, dealer concentration in the US c-bond market is much higher. For comparison, OWZ (2016) find that the mean HHI of dealer activity is 0.61 and the median is 0.54. These figures indicate a highly concentrated market—roughly a duopoly. Moreover, at the TASE, for the median c-bond, the market share of the top STT is 24.15% and for the top three STT it is 51.42%. These figures are much smaller than the corresponding figures in OWZ (2016) who find that the median market share of the top dealer (three top dealers) is 69% (100%).

### 6.2 The Relation between Liquidity and STT Concentration

As discussed in Section 4, the LOB mechanism leads to less concentrated short-term trading than in an OTC. We report consistent evidence for this in Section 6.1. It is, therefore, reasonable to assume that the low concentration of STT contributes to spread narrowing. In this sub-section we show supportive evidence for this hypothesis.

Table VIII presents regressions of liquidity measures on c-bond characteristics with and without HHI. The illiquidity measures are LOG_HES, the log of the average THS of non-STT in their "taking" transactions, LOG_THS_NST, and price dispersion per c-bond, DISPER. We run cross-sectional regressions clustered by firm. As control variables, we use c-bond characteristics which are supposed to be exogenous determinates of liquidity. These variables, which are defined in the Appendix, are commonly used to explain transaction costs in the US c-bond market, and include the c-bond's size, average duration, average credit rating, age, average closing price, and the standard deviation of the c-bond daily returns.[40] We also control for the firm's size. Harris and Piwowar (2006) find that in the US municipal bond market transaction costs are positively related to the c-bond duration and negatively related to credit rating. The negative relation between c-bond transaction costs and credit rating is confirmed by Edwards, Harris, and Piwowar (2007) with respect to the US c-bond market. They also find that the inverse of the bond's price is positively related to its transaction costs.[41] Hendershott *et al.* (2016) find a positive relation between bond age and execution costs.

Our results are reported in regressions (1), (2), (4), (5), (7), and (8). For each of the dependent variables, HHI is significantly positively related to the illiquidity measure. That is, more concentration of STT is related to less liquidity and higher price dispersion. The causality is likely to be from STT concentration to illiquidity and dispersion and not the other way around, since large spreads attract more STT and therefore lead to less concentration (i.e., lower HHI). This analysis and its finding are consistent with OWZ (2016), who find a positive relation between bond dealers' HHI and transaction price differences between institutional clients. One may argue that the causality is in the opposite direction because STT are attracted to high volume c-bonds (that have low spreads). Therefore, as a robustness check, in regressions (3), (6), and (9) we add LOG_VOL (the log of the c-bond's

40 It is possible that liquidity affects the c-bond's standard deviation and size, but the effect is likely to be small.

41 The reason is that the c-bond price captures credit issues which are not reflected accurately in the credit rating. In our sample, bond prices range from 0.33 NIS to 1.51 NIS and they are indeed positively related to the bonds' ratings.

**Table VIII.** The relation between STTs' concentration and liquidity

The table presents the coefficients of the cross-section regressions of the relation between liquidity measures and STTs' concentration. The c-bond sample is defined in Table II. In regressions (1)–(3), the dependent variable is LOG_ HES. In regressions (4)–(6), the dependent variable is LOG_THS_NST, the log of the average THS of non-STT in their "taking" transactions. In regressions (7)–(9), the dependent variable is DISPER. Standard errors are clustered by firm. See the Appendix for the definitions of the variables.

| | LOG_HES | | | LOG_THS_NST | | | DISPER | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Intercept | 13.538 | 9.512 | 9.251 | 12.163 | 8.381 | 8.134 | 0.229 | 0.173 | 0.169 |
| | (14.31) | (12.67) | (14.91) | (13.28) | (11.94) | (13.62) | (6.18) | (5.88) | (6.08) |
| LOG_STD | 0.022 | 0.108 | 0.190 | 0.096 | 0.178 | 0.256 | 0.009 | 0.010 | 0.011 |
| | (0.31) | (2.05) | (4.19) | (1.65) | (3.86) | (5.04) | (3.54) | (3.95) | (4.18) |
| LOG_SIZE | −0.625 | −0.534 | −0.193 | −0.576 | −0.491 | −0.167 | −0.006 | −0.004 | 0.001 |
| | (−14.48) | (−14.32) | (−4.46) | (−15.14) | (−14.76) | (−4.22) | (−5.09) | (−3.64) | (0.31) |
| LOG_FIRM_SIZE | −0.147 | −0.080 | −0.073 | −0.125 | −0.062 | −0.055 | −0.002 | −0.001 | −0.001 |
| | (−3.73) | (−3.06) | (−3.24) | (−3.26) | (−2.53) | (−2.51) | (−1.11) | (−0.54) | (−0.46) |
| DURATION | 0.138 | 0.144 | 0.130 | 0.118 | 0.123 | 0.110 | 0.002 | 0.002 | 0.002 |
| | (6.08) | (10.33) | (12.24) | (5.89) | (9.48) | (9.16) | (0.00) | (3.15) | (2.92) |
| RATING | −0.062 | −0.061 | −0.055 | −0.058 | −0.057 | −0.051 | −0.002 | −0.002 | −0.002 |
| | (−4.24) | (−5.40) | (−6.30) | (−4.39) | (−5.60) | (−5.92) | (−3.16) | (−3.29) | (−3.36) |
| RATING_DUMMY | 0.752 | 1.147 | 0.933 | 0.697 | 1.068 | 0.864 | 0.033 | 0.039 | 0.036 |
| | (2.25) | (4.80) | (5.18) | (2.27) | (4.87) | (4.82) | (1.83) | (2.32) | (2.24) |
| PRICE | −0.043 | −0.052 | 0.193 | 0.001 | −0.008 | 0.226 | −0.026 | −0.026 | −0.022 |
| | (−0.17) | (−0.28) | (1.04) | (0.01) | (−0.04) | (1.49) | (−2.53) | (−2.75) | (−2.66) |
| AGE_1.5 | −0.338 | −0.261 | −0.105 | −0.478 | −0.406 | −0.257 | −0.015 | −0.014 | −0.012 |
| | (−3.36) | (−3.74) | (−1.82) | (−5.01) | (−6.31) | (−4.69) | (−3.51) | (−3.99) | (−3.35) |
| HHI | | 2.787 | 1.869 | | 2.618 | 1.745 | | 0.039 | 0.025 |
| | | (9.94) | (7.07) | | (9.94) | (6.50) | | (2.42) | (1.54) |
| LOG_VOL | | | −0.349 | | | −0.332 | | | −0.005 |
| | | | (−9.20) | | | (−8.56) | | | (−3.16) |
| $R^2$ | 0.7248 | 0.8160 | 0.8643 | 0.7071 | 0.7981 | 0.8474 | 0.5848 | 0.6096 | 0.6242 |
| $N$ | 402 | 402 | 402 | 402 | 402 | 402 | 402 | 402 | 402 |

annual NIS volume) to the explanatory variables and the HHI's coefficients remain positive and significant [except in regression (9)].[42]

## 7. Non-STTs also Provide Liquidity

In OTC markets, traders must interact with dealers and cannot compete with them on providing liquidity.[43] In an open LOB every trader can potentially trade with anyone else. In our sample, more than half (53.4%) of the NIS trading volume is between non-STT. Therefore, the competition on liquidity provision is not only among STT. It is intensified by the participation of other traders, who also compete on liquidity provision.

We present evidence on liquidity provision by non-STT. First, non-STT act in many cases (47.78% of their NIS trading volume) as "makers" by posting limit orders. In addition, we find that when acting as "makers" the non-STT post narrower spreads than the STT. To demonstrate this, for each c-bond we calculate the difference between the transaction's THS in the case that the "maker" side is a non-STT and the transaction's THS where the "maker" side is an STT. The average difference between these measures is −0.042% and it is statistically significant, with a *t*-statistic of −9.14 (standard errors clustered by firm).

The OTC market is not designed to attract RI. The decentralized structure of the market, the lack of pre-trade transparency, and the fact that the prices are based on bargaining are not appropriate for non-professional traders. The empirical evidence in the USA (Table I) indicates larger trading costs for smaller quantities and for less active traders. Indeed, the participation of RI in the USA is negligible (see footnote 8). We find much higher retail participation in the TASE c-bond market. In our c-bond sample RI participation is 8.84% of the double-sided NIS trading volume, as opposed to the popular belief that RI are not interested in c-bonds.[44] Naturally, the trading mechanism enables RI to trade with low trading costs and this is probably one of the main reasons for retail participation being higher than in the USA.

We show that retail participation contributes to market liquidity. The intuition is that RI are uninformed and therefore do not impose AS costs for trading with them. Indeed, Peress and Schmidt (2016) find that news that distracts the attention of RI (not related to the economy; such as the verdict in the O.J. Simpson trial) adversely affects stock liquidity. This is because RI contribute to liquidity by serving both as noise traders and as liquidity providers. We present evidence that in the TASE c-bond market RI contribute to the liquidity of c-bonds in the same manner: RI act also as "makers" and with lower spreads than others and as "takers" RI impose less AS costs than others. We also measure the contribution of RI to the market liquidity using simultaneous equations analysis.

42 As a robustness check, we also include *NON_LINKED* (a dummy variable for the bond being not index linked) in the regressions of Table 8. The results remain similar.

43 McAllister reports in tabbforum.com that 52% of the volume in dealer-client institutional-sized ($1M or greater) transactions in the US are crossable, meaning that customers bought and sold the same security in matching sizes on the same day. Hypothetically these transactions could occur between customers. See http://tabbforum.com/opinions/how-trace-data-demystifies-corporate-bond-liquidity.

44 In a sub-sample of firms with both stocks and c-bonds the retail trading volume is 6.53% in stocks and 8.56% in c-bonds.

In 26.84% of their transactions RI act as "makers." The THS in these cases are much lower than in the cases where the STT are makers, and about 5% lower than in the cases where the makers are not STT but not RI. In 73.16% of their transactions RI act as "takers." In these cases, they impose practically no AS costs on the "maker" side of the transaction. To see this, we measure the AS of RI as detailed in Section 5.1. The average (weighted average) of AS across transactions is 0.004% (−0.002%), and are not statistically different than zero. This is opposed to the AS of non-RI as takers (an average of 0.0815% across transactions).

To further explore the effect of retail participation on liquidity and more specifically on the spread measures HQS and HES, we use a simultaneous equations approach and assume the following structural form equations.

$$\widetilde{\mathrm{Log\_HQS}}_j = \alpha_0 + \alpha_1 \cdot \widetilde{\mathrm{PROP\_RI}}_j + \sum_{i=3}^{10} \alpha_i \cdot \widetilde{X}_{ij} + \widetilde{\varepsilon}_{\mathrm{HQS}_j}, \tag{1}$$

$$\widetilde{\mathrm{PROP\_RI}}_j = \beta_0 + \beta_1 \cdot \widetilde{\mathrm{Log\_HQS}}_j + \beta_2 \cdot \widetilde{\mathrm{NON\_LINKED}}_j + \sum_{i=3}^{10} \beta_i \cdot \widetilde{X}_{ij} + \widetilde{\varepsilon}_{\mathrm{RT}_j}, \tag{2}$$

where $X_{3j}$, $X_{10j}$ are the following control variables as in Table VIII: LOG_STD, LOG_SIZE, LOG_FIRM_SIZE, DURATION, RATING, RATING_DUMMY, PRICE, and AGE_1.5.

We assume that whether the c-bond is CPI-linked directly affects the proportion of RI in the c-bond, and that c-bond liquidity is not affected directly, but through its effect on other variables (like STD and RI).[45] Since the number of exogenous variables that do not appear in Equation (1) (NON-LINKED) equals the number of endogenous variables that appear in Equation (1) (PROP_RI), the coefficients of Equation (1) have an exact identification. We estimate the equations using two-stage least-squares (TSLS) estimation.

Table IX presents an estimation of Equation (1), which has an exact identification. Regressions (1) and (3) include the first-stage estimation and regressions (2) and (4) include the second-stage estimation of the TSLS. In regression (2) [regression (4)], the dependent variable is LOG_HQS (LOG_HES). The estimated values of the coefficients of PROP_RI in regressions (1) and (2) are −0.085 and −0.064, and they are statistically significant, with *t*-stat. of −5.84 and −4.83, respectively (standard errors clustered by firm).[46] The economic interpretation of this value is that a 1% increase in PROP_RI (say from 8% to 9%) is related to a decrease of about 8.1% in the bond's HQS ($e^{-0.085} - 1 \approx -0.081$), say from 0.10% to 0.0919%. The results of LOG_HES as a dependent variable are qualitatively similar: a 1% increase in PROP_RI (say from 8% to 9%) is related to a decrease of about 6.2% in the bond's HES.

We cannot empirically examine a situation of no retail trading because in our sample all c-bonds have retail participation. Even after bond issuance there is some retail trading

45 The *HES* (*HQS*) of CPI-linked c-bonds is similar to the *HES* (*HQS*) of non-CPI linked c-bonds: 0.078% (0.083%) vs. 0.078% (0.080%), respectively.

46 Stock, Wright and Yogo (2002) report critical values of an F-test for testing the null hypothesis that the instrument variable (IV) used in TSLS estimation is not weak. They conclude: "Evidently the first-stage F-statistic must be large, typically exceeding 10 for TSLS inference to be reliable". On our TSLS estimation, the F-statistic of the first-stage estimation is 22.42 (see regressions (1) and (3) in Table 9), suggesting that the instrumental variable *NON_LINKED* is not weak.

**Table IX.** Bond spreads and retail participation: simultaneous equations

The table reports the coefficients of cross-section regressions. The regressions provide an estimation of Equation (1) of the simultaneous Equations (1) and (2). The system of equations is estimated using TSLS, and only Equation (1) has an exact identification. Regressions (1) and (3) include the first-stage estimation and regressions (2) and (4) include the second-stage estimation of the TSLS. The sample is defined in Table II. In regression (2) the dependent variable is LOG_HQS, the log of HQS. In regression (4), the dependent variable is LOG_HES, the log of HES. See the Appendix for the definitions of the variables. Standard errors are clustered by firm.

| | PROP_RI (1) | LOG_HQS (2) | PROP_RI (3) | LOG_HES (4) |
|---|---|---|---|---|
| Intercept | 7.311 | 16.312 | 7.311 | 14.803 |
| | (1.02) | (14.61) | (1.02) | (14.81) |
| PROP_RI | | −0.085 | | −0.064 |
| | | (−5.84) | | (−4.83) |
| LOG_STD | −0.029 | 0.067 | −0.029 | 0.027 |
| | (−0.05) | (0.74) | (−0.05) | (0.40) |
| LOG_SIZE | −0.496 | −0.740 | −0.496 | −0.677 |
| | (−1.32) | (−13.53) | (−1.32) | (−15.33) |
| LOG_FIRM_SIZE | 1.336 | −0.043 | 1.336 | −0.052 |
| | (4.33) | (−0.94) | (4.33) | (−1.25) |
| DURATION | 0.275 | 0.168 | 0.275 | 0.151 |
| | (1.50) | (6.42) | (1.50) | (7.00) |
| RATING | −0.047 | −0.051 | −0.047 | −0.052 |
| | (−0.41) | (−2.84) | (−0.41) | (−3.48) |
| RATING_DUMMY | −5.405 | 0.117 | −5.405 | 0.173 |
| | (−2.25) | (0.29) | (−2.25) | (0.51) |
| PRICE | −11.672 | −1.412 | −11.672 | −1.247 |
| | (−5.14) | (−3.43) | (−5.14) | (−3.44) |
| AGE_1.5 | −2.143 | −0.511 | −2.143 | −0.453 |
| | (−2.38) | (−4.18) | (−2.38) | (−4.45) |
| NON_LINKED | 4.759 | | 4.759 | |
| | (7.55) | | (7.55) | |
| $R^2$ | 0.3404 | 0.6750 | 0.3404 | 0.6913 |
| $N$ | 402 | 402 | 402 | 402 |
| F_STAT | 22.42 | 58.85 | 22.42 | 82.79 |
| Prob.>$F$ | <0.001 | <0.001 | <0.001 | <0.001 |

(though smaller in volume than in other months). Therefore, to get a rough idea of this hypothetical situation we take the point estimate from the simultaneous equations analysis and calculate an estimate for an average of HES for a hypothetical "zero retail trading" situation. This estimate is 0.135%, which is higher than the current average of 0.078%. It should be treated as a rough estimate since it is not clear that the coefficient value is relevant for such a large change from the current situation. Taking this estimate on its face value it seems that RI contribute a lot to market liquidity but even without their presence the bid–ask spread is still reasonably low.

## 8. Conclusion

We investigate c-bond trading by an LOB mechanism. To do so, we use as a laboratory the case of the TASE, where both stocks and c-bonds are traded by an LOB mechanism. This is in contrast to the common practice worldwide of c-bonds being mostly traded in OTC markets.

We find high liquidity in the TASE LOB, which is reflected in low spreads (average THS and HQS are around 0.08%)—lower than the comparable figures in the US OTC c-bond markets and lower than comparable figures for the related stocks in the TASE. These finding are consistent with DGP (2005) and Yin (2005), who highlight that the OTC mechanism is inherently uncompetitive because of the lack of pre-trade transparency. Consistent with this prediction we find, contrary to the US OTC market, negligible price dispersion in bond-minute and a very weak negative relation between a transaction's size and its spread.

Our database, which includes trader identification, enables us to identify RIs and STT, who are the analog for the dealers in the OTC market. Consistent with the notion of competitive trading in an LOB, we find very low trading rents for STT (around 0.013%). We also find many active liquidity providers (STT) (in the market as a whole and in each bond), and the average of the c-bond's HHI is 0.162. We link STT competition to market liquidity, consistent with the assertion that competition among the liquidity providers reduces spread.

In relating to retail participation, we show that 8.8% of the trading volume arises from RI and that as "takers" they impose no AS on the "making" side (as opposed to other non-STT)—which enables narrower spreads. In a simultaneous equation analysis, we show that RI presence decreases the spreads.

The comparison to the US c-bond market is striking. Although the size of the TASE c-bond market is only 1% of American market ($80 billion versus $7,840 billion) and it is quite isolated (foreign holdings of 0.9%) it has much lower trading costs, especially for RI.[47] Our paper provides clear empirical support for the notion that c-bonds can be traded successfully in an LOB. Therefore, it supports the views expressed in Harris (2015), and Harris, Kyle, and Sirri (2015), among others, that c-bond markets should move in the direction of a centralized open LOB. The direct effects of such a change are expected to be a reduction of trading costs and enabling RI and small institutions fair and cheap access to the market. The change may also have the indirect effect of reducing the cost of capital of firms (in line with Amihud and Mendelson, 1986).

47 See www.sifma.org for the aggregate market cap of US c-bonds in 2014.

**Appendix.**

| Variable | Definition |
|---|---|
| RI | Retail investors. Defined as "low-volume" investors with less than 2 million NIS (~\$559,000) in all TASE securities (excluding options). |
| STT | Short-term traders. Defined as traders that flip from buying to selling within a short period of time and are not identified as RI. For each trader in each c-bond of the sample that she traded, we calculate the number of switches from buying to selling or vice versa and divide it by the number of trading days that the trader was active in the c-bond. Then, we calculate the value-weighted average of this ratio across the c-bonds that the trader traded, and classify the trader as "short-term" in the case that this measure is equal to or >1 (a ratio of 1 means that on each day the investor traded the security, a sale transaction was followed with a buy transaction, or vice versa, on average). Formally, trader $j$ is considered a STT if $$\frac{1}{\sum_{i=1}^{n} \text{trader\_vol}_i} \cdot \sum_{i=1}^{n} \left( \text{trader\_vol}_i \cdot \frac{\text{sign\_switches}_i}{\text{ntd}_i} \right) \geq 1,$$ where $n$ is the number of c-bonds that the trader traded during the sample period, $\text{trader\_vol}_i$ is the trader's NIS trading volume in c-bond $i$, $\text{sign\_switches}_i$ is the number of times the trader switched positions in c-bond $i$ during the sample period, and $\text{ntd}_i$ is the number of trading days of the trader in c-bond $i$. |
| Non-STT | Investors who are not identified as STT. |
| HQS | The half quoted bid–ask spread of a security. An hourly observation of half the difference between the ask price and the bid price, divided by the mid-quote is calculated at six time points each trading day, on the hour from 11:00 to 16:00. Formally, the hourly observation is $\frac{\text{Ask}_{i,j,t} - \text{Bid}_{i,j,t}}{2 \cdot \text{Mid}_{i,j,t}}$, where $\text{Mid}_{i,j,t} = (\text{Ask}_{i,j,t} + \text{Bid}_{i,j,t})/2$, $\text{Ask}_{i,j,t}$ and $\text{Bid}_{i,j,t}$ are ask and bid quotes prevailing on day $i$ for security $j$ at hour $t$. This hourly observation is winsorized if the value is >10% or if there is no valid bid–ask spread (0.043% of the sample). HQS of security $j$ is the average of its observation (within days and then across days). |
| THS | The transaction half spread is the HES of a transaction. It is measured as the absolute value of the difference between the transaction price and the mid-quote prior to the transaction, divided by the mid-quote. Formally, it is $\frac{\lvert \text{Price}_{i,j,t} - \text{Mid}_{i,j,t} \rvert}{\text{Mid}_{i,j,t}}$, where $\text{Price}_{i,j,t}$ is the transaction price on day $i$ for security $j$ at transaction $t$. The observations are winsorized to 10% in the rare cases where the bid or ask is missing or they are >10% (0.019% of the sample). |
| HES | The half effective spread of a security. It is the average of THS over all the transactions of the security in the continuous stage. |
| AS | The adverse selection component of a transaction. For each transaction, it is calculated as $d \cdot (\text{Close}_{i,j,t}/\text{Mid}_{i,j,t} - 1)$, where $\text{Close}_{i,j,t}$ is the closing price on day $i$ for c-bond $j$ at transaction $t$ and $d$ is an indicator that equals 1 (minus one) in the case that the transaction is buyer (seller) initiated. |
| RHS | The realized half spread. It is the difference between the THS and the AS. |
| HHI | The Herfindahl–Hirschman Index of the STT activity in a c-bond. It is calculated as $\text{HHI} = \sum_{i=1}^{n} S_i^2$ where $S_i$ is the NIS market share of $\text{STT}_i$. The HHI ranges from $1/n$ to 1 (monopoly). It may be interpreted as the reciprocal of the "equivalent" number of equal share traders. |
| STD | The standard deviation of the c-bond's daily returns adjusted for coupon payments. |

(continued)

**Appendix.** Continued

| Variable | Definition |
|---|---|
| LOG_STD | The log of the STD. |
| LOG_SIZE | The log of the c-bond's size, calculated as the average of the market capitalization (in NIS) at the beginning and end of the sample period for each security. |
| LOG_FIRM_SIZE | The log of the market value of the firm's tradable securities. |
| DURATION | The average duration (in years) of the c-bond during the sample period. |
| RATING | The average credit rating according to the two Israeli rating agencies during the sample period. A c-bond gets a credit rating if at least one of the agencies rates it. This variable equals 0 if the bond has no rating. Otherwise it ranges from 1 ("D") to 26 ("AAA"). |
| DUMMY_RATING | A dummy variable that equals 0 if the c-bond has no credit rating from the two Israeli rating agencies and 1 otherwise. Using this dummy variable allows the inclusion of all the c-bonds (including c-bonds without credit rating) without affecting inferences on the slope coefficient. See, for example, Pontiff and Woodgate (2008). |
| NON_LINKED | A dummy variable that equals 0 if the c-bond is CPI-linked and 1 otherwise. |
| PRICE | The average closing price of the c-bond. |
| AGE_1.5 | The average of a dummy variable that equals 1 if the bond was issued in the last 18 months and 0 otherwise. |
| LOG_VOL | The log of the annual c-bond NIS trading volume during the continuous stage. |
| PROP_RI | The percentage of the NIS trading volume of RI in the c-bond relative to the total double-sided NIS volume of the c-bond (of the transactions during the continuous stage). |
| DISPER | Price dispersion. It is the standard deviation of prices within each minute, divided by the mean of those prices. |

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