Exchanges for government bonds?

Evidence during COVID-19*

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Abstract

We leverage the unique institutional feature that the Israeli government bond market operates on an exchange rather than over-the-counter to analyze whether and why having an exchange affects market liquidity during a crisis. We document how the liquidity crisis in March 2020 affected the Israeli government bond market, and conduct difference-in-differences analyses, comparing bid-ask spreads in exchange markets, such as the Israeli government bond market, with markets lacking an exchange. Our findings support the idea that having an exchange enhances market liquidity. A counterfactual analysis using trade data from the Israeli exchange suggests that this is due to the ability of investors to readily provide liquidity to one another and the efficient netting of trade flows on an exchange.

JEL: D4, G1, G12 , G14

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*The views presented are those of the authors and not necessarily of the Bank of Israel.

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1 Introduction

Treasury markets in most developed economies, especially the U.S., are highly liquid markets and known to be a safe haven. This view changed, at least temporarily, in March 2020 when these markets became illiquid (e.g., Logan (2020)). Central banks around the world stepped in to restore market functioning and a policy debate began on whether Treasury markets should be centralized. One proposal is to let all trades be centrally cleared and allow investors to trade with one another, as on an exchange.[1] Unfortunately, it is difficult to provide evidence for or against this reform, because Treasuries around the world trade on decentralized over-the-counter (OTC) markets. This means that we do not observe what would happen if these markets operated on an exchange.

This paper exploits the fact that there is an exception—the Israeli Treasury market, which is on an exchange—to study whether and why having an exchange enhances liquidity during a crisis. After documenting the severity of the liquidity crisis in the Israeli Treasury market, we examine the extent to which having an exchange can foster liquidity and analyze why this may be the case.

We begin our analysis in Section 2 by highlighting the unique characteristics of the Israeli government bond market compared to typical government bond markets. These markets are usually decentralized, with most trades conducted bilaterally between counterparties or on electronic platforms that do not centrally clear trades. In some cases, a smaller portion of trades occurs on a separate exchange via a limit order book, as seen in the U.S. for on-the-run inter-dealer trades and in South Korea, where a government bond exchange is accessible to all traders. In contrast, over 99% of trades in Israel take place on the Tel Aviv Stock Exchange (TASE), with only a small fraction of large block trades executed off-exchange.

Building on this institutional context, we combine a novel dataset of prices and trade

[1]Proposals that move towards full central clearing have already been voted for. For instance, on September 14, 2022, the Securities and Exchange Commission proposed that all trades made on automated and anonymous inter-dealer broker platforms should go through clearinghouses. Earlier it had proposed to force market participants trading more than $25 billion a month in Treasuries to register as dealers (see `https://www.ft.com/content/cffbcc3c-2c06-42c3-92e3-839a1e9ff5e8`, accessed on 02/20/2023).

flows, detailed in Section 3. Specifically, we gather daily bid-ask spreads (hereafter, spreads) for fixed-rate nominal government bonds in Israel from the TASE and for comparison countries, including both large and small developed economies: Germany, Greece, Ireland, Japan, Mexico, Portugal, South Korea, the U.K., and the U.S., from Bloomberg. Additionally, we obtain spreads from the South Korean stock exchange, the U.S. futures market from the Chicago Mercantile Exchange, and for large cap stock market indices of all countries in our sample from Bloomberg. We supplement this data with trade-flow information from TASE, which provides detailed insights into each transaction, including the type of trader (e.g., dealer-bank, mutual fund), the quantity traded, the security involved, and the transaction price.

In Section 4, we begin our empirical analysis by documenting the severity of the liquidity crisis in the Israeli Treasury market during March 2020 as a foundation for analyzing how liquidity responded to the crisis. We highlight significant bond sell-offs driven by institutional investors, with Israeli mutual funds liquidating over 20% of their portfolios— more than the 12% sell-off seen in the U.S. (as reported by Ma et al. (2022)). Despite rising yields, market depth and spreads remained relatively stable.

In Section 5, we assess how an exchange impacts liquidity, measured by daily spreads, through a series of difference-in-differences analyses. The core approach is to examine how spreads responded in markets with and without exchanges following the World Health Organization's (WHO) declaration of COVID-19 as a global pandemic. As an initial step, we compare stock market spreads (on an exchange) with government bond spreads (traded OTC) using difference-in-differences for non-Israeli countries. Then, to better control for differing liquidity crisis effects on stocks and bonds, we perform a triple-difference analysis, comparing the difference in spreads between government bonds and stocks in Israel versus other countries. We control for country-date fixed effects to address concerns of differential shocks across countries. Finally, we analyze within-country markets in the U.S., Israel, and South Korea by leveraging differences between OTC and exchange trading, focusing on U.S. Treasury futures versus Treasuries, and OTC versus exchange traded bonds in Israel and

South Korea.

Our findings suggest that exchanges enhance liquidity during crises. The cross-country difference-in-differences analysis shows that government bond spreads in Israel increased on average by roughly 25% less than in countries where bonds trade primarily over-the-counter. Similarly, U.S. futures market spreads rose less than U.S. government bond spreads, and spreads for exchange-traded bonds in Israel and South Korea increased less than those traded off-exchange. Although some spread differences may be driven by unobservable factors, as indicated by the variation in estimated effects across the various markets we consider, the consistent pattern in our results offers suggestive evidence in favor of exchanges.

In Section 6 we explore two key reasons why an exchange can promote liquidity. First, on an exchange everyone can trade with everyone. This is called all-to-all-trading, and implies that customers can provide liquidity to one another if dealers cannot or do not want to. Second, market-wide central clearing enables instant netting of settlement obligations involving the same securities, reducing the number of securities that need to be delivered. This process lowers settlement risks and frees up balance sheet resources.

To highlight the importance of all-to-all trading, we document that significant customer-to-customer trading persisted on the Israeli exchange throughout the crisis, with these trades even surpassing dealer-to-customer transactions at times. Notably, around 50% of the total amount investors sold was purchased by other investors, including hedge funds and algorithmic trading firms, indicating that non-market makers stepped in to provide liquidity. We then link customer-to-customer trading to market liquidity, hypothesizing that all-to-all trading on an exchange enhances liquidity by facilitating these transactions. We demonstrate that higher customer-to-customer trading activity is negatively correlated with bid-ask spreads, even after controlling for confounding factors such as dealer-trading activity and security-and day-specific demand and supply shocks.

To underline the benefits of efficient netting, we conduct a counterfactual analysis estimating the total settlement obligations dealers in Israel would have needed to absorb onto their balance sheets if there had been no exchange—meaning no all-to-all trading and no central clearing for all trades. This analysis complements Fleming and Keane (2021), who quantify the reduction in U.S. banks' gross settlement obligations under market-wide central netting compared to the current system without all-to-all trading, and only inter-dealer trades being centrally cleared. Our findings indicate that the Israeli netting rules decreased settlement obligations by 65%–81% relative to the U.S. rules—an effect of roughly similar magnitude to that found by Fleming and Keane (2021).

Moreover, since we observe a market with all-to-all trading, we can approximate what fraction of the total effect on settlement obligations comes from the impact of removing all-to-all trading, because customers who trade with other customers need to re-route their trades and trade with dealers. Our findings indicate that eliminating all-to-all trading is an important driver of the increase in settlement obligations. The substantial increase in balance sheet usage, along with recent findings by Duffie et al. (2023) showing that liquidity in the Treasury market is highly sensitive to dealers' balance sheet capacity—sharply declining once they reach around 50% of their capacity—suggests that, without an exchange, Israeli banks might have exceeded this threshold, potentially causing severe illiquidity.

Taken together, our findings have direct policy implications in shaping the ongoing policy discussion in the U.S. and other countries regarding whether to reform government bond markets (e.g., Benos et al. (2022)). Concretely, our findings support advocates of the reform who argue that central clearing can reduce dealer balance sheet constraints and allow investors to provide liquidity to one another (e.g., Duffie (2020); Liang and Parkinson (2020)).

Related literature. Our main contribution is to leverage the fact that the Israeli government bond market operates on an exchange to examine the extent to which having an exchange, rather than OTC trading, can enhance government bond market liquidity during a crisis and explain why. This adds to four strands of the literature.

First, we contribute to a growing empirical literature that studies whether to centralize OTC markets (e.g., Barklay et al. (2006); Hendershott and Madhavan (2015); Loon and Zhong (2016); Fleming et al. (2017); Biais and Green (2019); Benos et al. (2020); Thorsten

(2021); O'Hara and Zhou (2021); De Roure et al. (2022); Allen and Wittwer (2023)).[2] Most of these papers analyze hybrid markets, in which a significant number of trades are executed bilaterally and another fraction on electronic platforms that match buyers to sellers. This market structure differs from an exchange market in that there is no all-to-all trading or central clearing for the majority of trades.

In contrast, we leverage the unique institutional feature of the Israeli bond market. This is similar to Abudy and Wohl (2018) and Plante (2017), who focus on corporate bond trading in regular times, as well as Abudy and Shust (2023), which is closer to our study. Inspired by our project, Abudy and Shust (2023) document that bid-ask spreads and trade volume rose during March 2020 in the Israeli corporate bond market. Our analysis focuses on government bonds and differs in key dimensions. We conduct a careful empirical analysis that extends beyond the Israeli market to control for unobservable country-specific factors that might drive pricing and trade behavior, including central bank interventions. Further, we bring in transaction data from the TASE to analyze why liquidity remained stable. This helps us establish a direct link between the market's design and liquidity.

Second, we complement studies that analyze different aspects of having an exchange. Most focus on eliminating counterparty risk by having a central counterparty (CCP) clearing markets for risky assets (e.g., Loon and Zhong (2014); Menkveld et al. (2015); Bernstein et al. (2019); Mancini et al. (2016); McSherry et al. (2017); for an overview of this literature, see Menkveld and Vuillemey (2021)). We focus on trading safe assets to understand the role of all-to-all trading and order-flow netting. As such, we add to the few studies that analyze netting (e.g., Bernstein et al. (2019) for stocks and Fleming and Keane (2021) for U.S. government bonds), and customer-to-customer trading (e.g. Mattmann (2021) for U.S. corporate bonds and Chaboud et al. (2022) for U.S. government bonds). Of these papers, Fleming and Keane (2021) is the closest to ours. They observe trade-level data on the U.S. government bond market and make predictions regarding what would happen if dealers could

[2]An extensive theoritical literature studies the fragmentation or centralization of financial markets (e.g., Glosten (1994); Budish et al. (2019); Glode and Opp (2019); Chen and Duffie (2020); Rostek and Yoon (2021); Wittwer (2020, 2021); Baldauf and Mollner (2021)).

net trades with customers. We observe trades in a centrally cleared market with all-to-all trading and make predictions about what would happen if this market cleared like it would in the U.S. This allows us to highlight the importance of all-to-all trading and its effect on netting.

Third, the paper relates to a growing empirical literature that analyzes how financial regulation (such as Basel III) affects market making and, as a result, the liquidity of bond—often corporate bond—markets (e.g., Bao et al. (2018); Bessembinder et al. (2018); Dick-Nilsen and Rossi (2019); Kargar et al. (2020); Bruche and Kuong (2021)). This literature takes the market structure—typically an OTC market—as given. We focus instead on comparing market structures. This allows us to highlight the fact that regulations that affects the balance sheet can be influence which market structure best promotes market liquidity.

Finally, we contribute to a young literature that analyzes events and policy responses during the COVID-19 crisis to infer lessons on how to improve the functionality of bond markets (e.g., Falato et al. (2021); Haddad et al. (2020); He et al. (2022); Ma et al. (2022); Schrimpf et al. (2020); Fleming and Ruela (2020); Pastor and Vorsatz (2020); Eren and Wooldridge (2021); Fleming et al. (2021); Rebucci et al. (2021); Kargar et al. (2021); Vissing-Jorgensen (2021); Benos et al. (2022); Favara et al. (2022)). Most of these studies focus on the U.S; in contrast, we document the nature and severity of the liquidity crisis in another country (Israel). Further, we focus on the period before major policy actions were taken to avoid confounding factors and analyze how liquidity was affected by how bonds are traded: on an exchange or OTC.

2 Institutional environment

Before conducting our empirical analysis, we describe the institutional environment and the data set we construct.

Treasury markets and banking regulations. In most countries, including Israel, government bonds are issued in the primary market to a small set of banks (primary dealers). Primary dealers have a responsibility, as market makers, to buy bonds from the government and trade them with investors, brokers and one another to provide liquidity. In exchange, they enjoy benefits. For instance, in the U.S., they are eligible to participate in the Federal Reserve (Fed)'s standing repo facility, overnight reverse repo facility, and securities lending program. Israel adopted this type of system in 2006 (Sade et al. (2018)). Since then designated (local and foreign) dealers are supposed to and incentivized to make markets similarly to other countries. For instance, they have exclusive access to most primary auctions and an inter-dealer trading platform.

The secondary market is predominantly an OTC market in all countries but Israel (see Benos et al. (2022) for an overview). Traditionally, a buyer or seller had to contact a dealer to negotiate the terms of trade bilaterally. Nowadays, dealers (who are members of a CCP) trade bilaterally or on a limit order book with one another, in which trades are cleared and netted centrally. Customers, on the other hand, have no access to the inter-dealer market, and most still trade bilaterally with a dealer. Only a relatively small but growing fraction of dealer-to-customer trades are executed on electronic platforms, which differ from an exchange (see Bessembinder et al. (2020) for an overview). Typically, investors run (request for quote) auctions with a selected set of dealers without having the option to trade directly with one another. Further, trades are not cleared centrally.

The lack of central clearing in the dealer-to-customer market has no direct but indirect implications for the dealers' balance sheets. A dealer may net trades of the same security with different customers for accounting purposes, for instance, when computing leverage ratios. However, the trade cannot net out for settlement purposes, as customers are not members of the CCP. This means that there is a chance that one side of the trade is delayed or fails, which introduces non-negligible settlement risks that affect the liquidity needs of the dealer and therefore constrain the balance sheet until the settlement is complete.

Whether and how dealer balance sheets affect behavior and liquidity depends on how dealer banks are regulated. Banking regulations have been harmonized across countries over the past decades. Countries like the U.S. and Israel follow the global standards set by the Basel Committee on Banking Supervision.

Exchanges for Treasuries. In stark contrast to the rest of the world, Israel operates a single exchange, the TASE, for both bonds and stocks. The TASE functions as a continuous and anonymous limit order book, including opening and closing auction trading sessions, similar to large exchanges in other economies.[3]

For Israeli government bond trades, the TASE is the primary venue, capturing over 99% of trades on an average day and around 77% of daily trade volume in our sample period (November 2019 to May 2020). Most of the remaining trade volume (about 17%) is executed off-exchange between dealers and customers, typically through large block trades via private negotiations, a practice aimed at minimizing price impact (Burdett and O'Hara (1987); Keim and Madhavan (1996)). Although these bilateral OTC trades are electronically processed through the TASE, they are not cleared or netted by it, as the TASE does not serve as a CCP for these transactions. A small portion of trading volume (about 6%) occurs in an inter-dealer market that operates on a separate limit order book, which we exclude from our analysis due to the common use of limit order books in inter-dealer markets globally.

Besides Israel, a handful of other countries operate sizable exchanges for government bonds (see Figure 4 in Benos et al. (2022)). The largest one is in South Korea, where the market for government bonds is hybrid with the majority of trades being traded OTC, and a smaller fraction of trade volume of roughly 40% being executed on the exchange.[4] Moreover, in many countries, dealers trade certain types of securities, like on-the-run securities in the U.S., on separate exchanges that are not accessible to investors.

[3] The Israeli market may differ from those in other countries due to its unique history. Abudy and Wohl (2018) explain that the TASE was established in 1935 when market conditions were different, with low demand and supply leading to a single daily auction. As the market grew, participants became accustomed to trading on the exchange, preventing the development of an OTC market. In contrast, other countries where markets were more liquid, for example the U.S., saw bond trading shift from exchanges to OTC markets as institutional investors sought better deals, leading to a decline in exchange liquidity by 1940 (Biais and Green (2019)). For more on Israel, see Appendix A.

[4] The Korean Ministry of Economy and Finance acknowledges that "[s]imilar to other bond markets, the OTC market represents the dominant volume of bond and note trading" (South Korean Ministry of Economy and Finance (2024)). This stands in contrast to Israel, where the vast majority of government bonds trade on the exchange.

Exchanges for Treasury futures. In the U.S. and other countries, investors can trade Treasury futures in addition to Treasuries. Futures are standardized derivatives contracts that obligate the owner to purchase or sell a bond on a specific date and at a predetermined price. They share essentially the same fundamentals as government bonds but trade—like stocks—on exchanges; for instance, the Chicago Board of Trade.

In Israel, the futures market is small and inactive. One reason for this is that options are the preferred vehicle for investors to leverage their investments. In addition, investors use interest-rate swaps to hedge their positions in government bonds.

Exchange versus OTC market. Exchange trading differs from traditional OTC trading in at least two key ways that can impact market liquidity.

First, on an exchange, any trader can freely and anonymously trade with others, significantly reducing the search costs common in OTC markets. In an OTC market, a customer seeking to trade with another customer must contact a dealer to find a counterparty and mediate the trade, a process known as agency trading. This method lacks anonymity, involves search frictions, and incurs a dealer markup, potentially hindering some of these trades.

Second, a CCP in exchange trading absorbs all counterparty risk and offsets trades involving the same securities, allowing them to be paired off and eliminated for accounting and settlement. Concretely, netting efficiencies arise because the CCP steps in as counterparty so trades can be netted even if a market participant has not engaged in offsetting trades with any specific counterparty. This reduces dealer settlement risks, lowers liquidity needs, and frees up balance sheet space for dealers.

3 Data

Besides Israel, we include four large developed economies, the U.S., U.K., Germany, and Japan, and five smaller developed countries, Portugal, Greece, Mexico, Poland, and Ireland. We choose the smaller countries because they have roughly the same amount of national debt outstanding in 2020 as Israel, as shown in Appendix Figure A1. Finally, we add South

Korea, because it operates the largest exchange for government bonds in terms of trade volume (Benos et al. (2022)).

Prices and spreads. We obtain prices and bid-ask spreads for government bonds, futures, and stocks from February 1, 2020 until March 31, 2020 from different data sources.

We collect the daily average bid and ask Bloomberg Generic Prices (BGN) for U.S., U.K, German, Japanese, Polish, Portuguese, South Korean, Greek, Irish, and Mexican government bonds. The BNG bid and ask prices are calculated by Bloomberg using prices that are contributed to Bloomberg and any other information that Bloomberg considers relevant with the goal of providing "consensus" pricing. The concrete methodology is proprietary.

To cross-validate the data quality, we show in Appendix Figure A2 that BGN spreads for U.S. Treasuries behave similarly to spreads on TradeWeb—which is a major electronic trading platform that handles about one third of all dealer-to-customer volume in U.S. Treasuries. Existing studies have analyzed the reliability of BNG pricing data for other countries. For example, Allen and Wittwer (2023) show that the BNG midprice closely matches the prices at which Canadian dealers trade Treasuries and that institutional investors' trade prices cluster around this midprice. Given the limited availability of bid-ask spread data in OTC markets, other researchers have also turned to Bloomberg's pricing data to analyze bid-ask spreads in Treasury markets during 2020 (e.g., Figure 2 in Vissing-Jorgensen (2021); Figure 12 in Barth and Kahn (2020)).

For Israeli government bonds, we compute daily average bid and ask prices from all prices on the limit order book of the TASE. Additionally, we collect the highest and lowest prices at which a security is traded during a day, both for exchange trades on the limit order book of the TASE and for Israeli OTC trades.

For the South Korean exchange, we calculate the daily average bid and ask prices using proprietary limit order book data provided by the exchange, similar to our approach for TASE. Given that most trade volume in South Korea occurs OTC, we primarily rely on BGN prices for the analysis, as they are intended to represent an averages of the entire market. We explicitly indicate instances where this is not the case and where we instead use the South Korean exchange data.

We restrict the sample of government bonds to those with maturities above 2 years that were on-the-run sometime between January 2019 and the end of our sample period to obtain conservative estimates. For Israel, this implies keeping all bonds that have a maturity above 2 years at any point in time between January 2019 and March 2020, since all these bonds are re-issued regularly and can all be considered on-the-run.

In addition to government bond data, we obtain the daily average bid-ask spreads of all constituents of the leading large cap stock market indices for all countries in our sample from Bloomberg using the BQL interface: DAX 30 for Germany, NIKKEI 225 for Japan, FTSE 100 for the U.K., S&P 500 for the U.S., FTSE for Greece, ISEQ 20 for Ireland, KOSPI 200 for South Korea, MEXBOL for Mexico, WIG 20 for Poland, and PSI 20 for Portugal. For Israel, we obtain daily average bid and ask prices of the 35 largest Israeli companies—the TA 35—from the TASE.

Finally, we collect the daily (end-of day) bid and ask prices of U.S. futures contracts for the 2-year (ZT), 5-year (ZF), 10-year (TN), and 30-years (UB) from the Chicago Mercantile Exchange (CME).

When comparing prices or spreads in Israel to other countries, there is one complication: the business week is from Monday through Friday in the other countries and from Sunday through Thursday in Israel. To avoid dropping too many observations, we synchronize weeks by interpolating the spreads, using the values from the previous trading day if they are missing.

Trade flows. Complementing the pricing information, we gather intra-day data on the purchases and sales of Israeli government bonds by CUSIP from the TASE from November 2019 until May 2020. Each trade identifies the buyer and seller category from of the following groups: banks, i.e., dealers, foreign investors, mutual funds, pension funds, independent investment advisors, ETFs, and local investors (e.g., retail investors, hedge funds, and algorithmic trading firms). We cannot identify traders individually, but only know which investor group a trader belongs to.

Leverage constraints. To analyze how capital-constrained Israeli dealer-banks were during March 2020, we collect the quarterly Basel III leverage ratio (LR)—which is known as Supplementary Leverage Ratio (SLR) in the U.S.—for all Israeli banks from the Bank of Israel from 2016q3 until 2021q4. The LR measures a bank's Tier 1 capital relative to its total leverage exposure.[5] It must be larger than a specific threshold and, minimally, 3% according to Basel III. This puts a restriction on the balance sheet of an institution, and imposes costs (see CGFS (2016); Duffie (2018)). As comparison, we also gather this information for all U.S. financial institutions that are required to file the "Consolidated Financial Statements for Holding Companies—FR Y-9C" from the Wharton Research Data Services (WRDS).

Data limitation. We encounter two data limitations in our study.

First, the data on Israel's OTC market is more restricted compared to other OTC markets, because the Israeli regulator does not collect detailed information on OTC trades. For example, the best available data lacks information on trader identities and the side of the trade (buy or sell). As a result, we approximate the bid-ask spread in this market using the highest and lowest trade price of a security within a day in the spirit of Corwin and Schultz (2012) and subsequent studies.

Second we have no trade-level information on markets other than the Israeli government bond and stock market. In particular, we don't have access to Trade Reporting and Compliance Engine (TRACE) data on U.S. government bonds—which are currently available only to researchers in the Inter-Agency Working Group on Treasury Market Surveillance, such as the New York Fed or the Board—or similar trade-level data of other countries. Our solution is to rely on prior research in order to compare events in the Israeli market with those in the U.S. We focus on the U.S.—rather than other countries that are more comparable to Israel in terms of size—because existing studies focus on the U.S. In contrast, there are fewer studies for other countries, which renders a cross-country comparison more difficult.

[5] Tier 1 capital consists primarily of common stock and disclosed reserves (or retained earnings), but may also include non-redeemable non-cumulative preferred stock; leverage exposure includes the total notional of all cash and repo transactions of all securities, including government bonds.

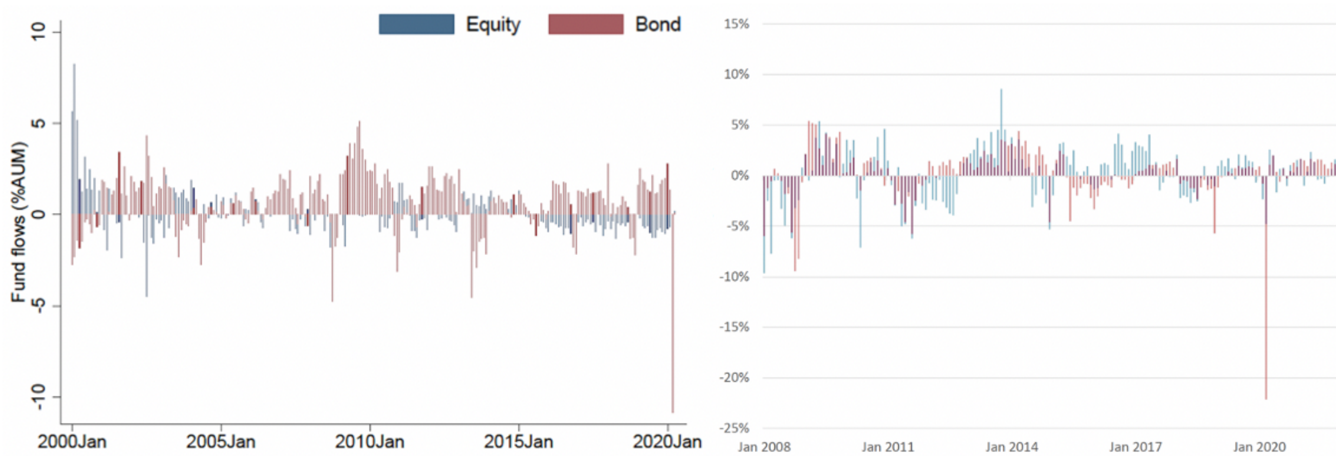
4 The COVID-19 liquidity crisis in Israel

Our goal is to provide evidence suggesting that liquidity in the Israeli market did not decline as sharply as in other countries due to the fact that Israeli Treasuries trade on an exchange, despite the significant liquidity shock relative to the size of the economy. To build this argument, we first demonstrate the severity of the liquidity crisis in Israel and then examine how liquidity, measured through various metrics, responded to the shock. To provide a benchmark for comparison, we draw on existing research which analyzes this episode in other countries, primarily for the U.S. In doing so, we are mindful of cross-country differences, for example, the fact that the U.S. Treasury market is more liquid than the Israeli Treasury market in regular times—see Appendix Tables A1-A2 for more details.

Dash-for-cash. Almost immediately after the WHO raised its coronavirus threat assessment to the highest level on February 28, 2020 (a Friday), financial markets plunged into a liquidity crisis in March 2020. For example, in the U.S., mutual funds, hedge funds, foreign investors, and households wanted to redeem their shares of bond funds, exchange Treasuries for cash, and unwind existing positions (see Barth and Kahn (2020); Cheng et al. (2020); Duffie (2020); Eren and Wooldridge (2021); Ma et al. (2022); Schrimpf et al. (2020); Vissing-Jorgensen (2021)). Similar events occurred in other countries (e.g., Hüser et al. (2021); Moench et al. (2021); Czech et al. (2021)).

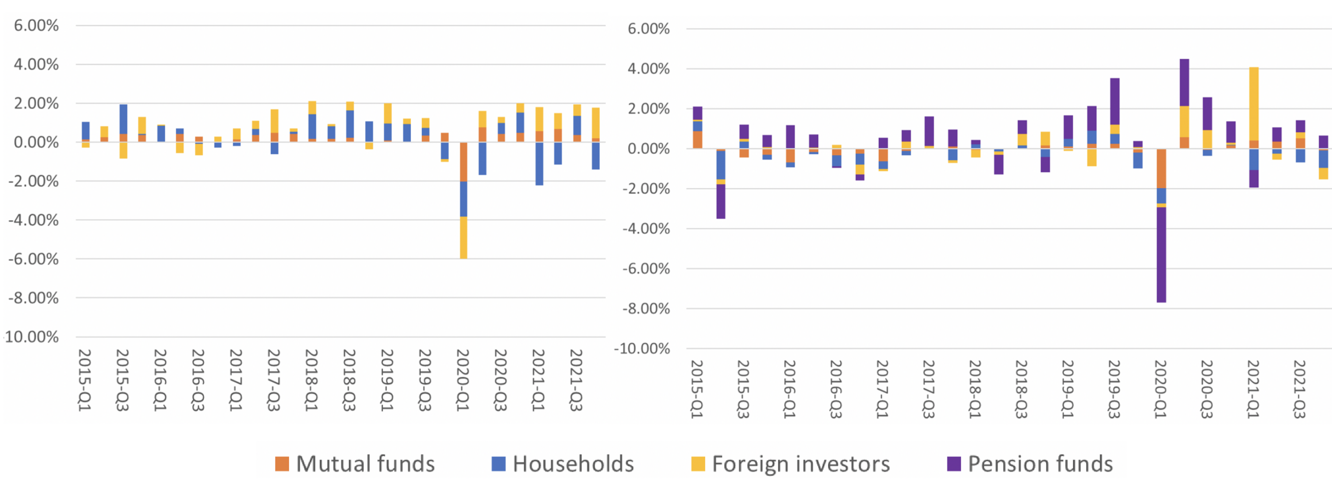
In Israel, the triggers and severity of selling pressure in the government bond market were similar. Within a single month, fixed-income bond mutual funds had aggregate outflows of over 20% of fund size in Israel, compared with 12% in the U.S. (see Figure 1). Aggregated over the first quarter of 2020, mutual funds, households, and foreign investors each sold roughly 2% of U.S. government debt outstanding; in Israel, pension funds, rather than foreign investors, were the largest contributor, selling over 4% of Israeli government debt (see Figure 2).

Figure 1: **Mutual fund fixed-income flows**



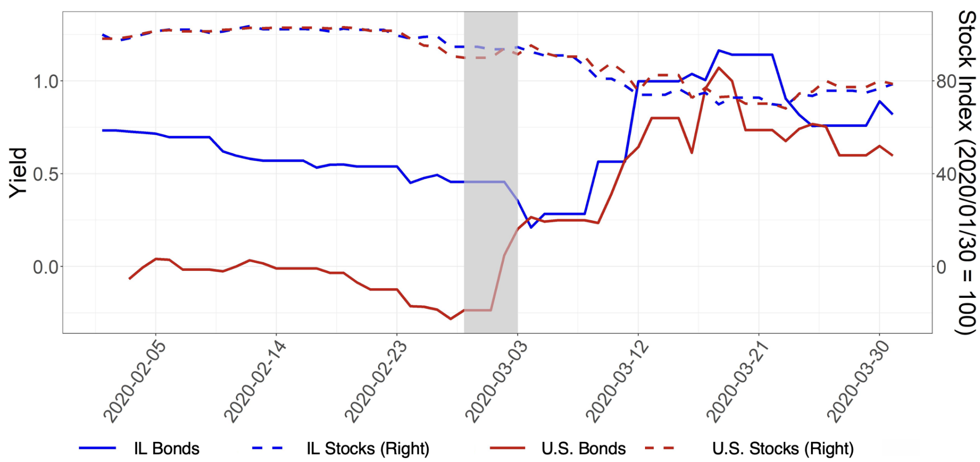
Notes: Figure 1 shows the monthly fund flows of bonds and equities to fixed-income mutual funds in the U.S. on the LHS—taken from Ma et al. (2022)—and in Israel on the RHS as the percentage of fund size (AUM). Source: Ma et al. (2022) and Bank of Israel.

Figure 2: **Quarterly Treasury net transactions by investor type**



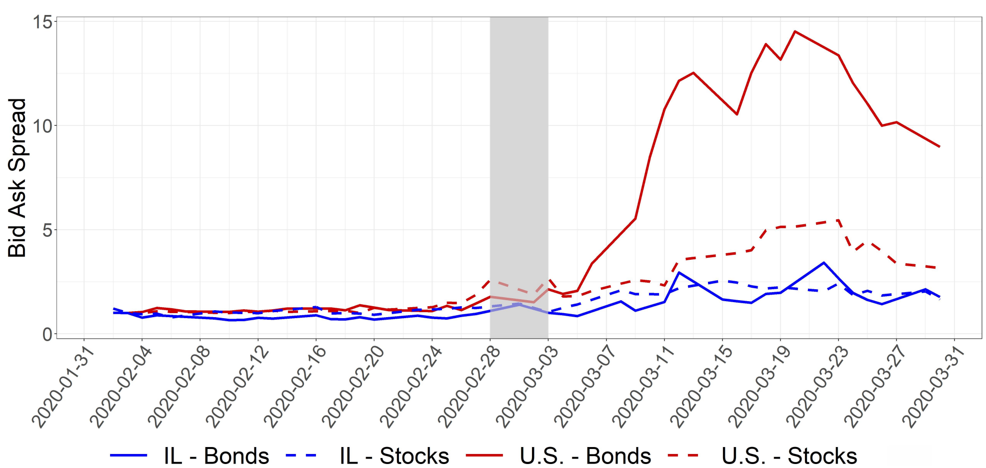
Notes: Figure 2 shows the quarterly net purchases in the percentage of outstanding government debt of U.S. and Israeli government bonds in the secondary market by investor type. The LHS is for the U.S., based on data provided by Eren and Wooldridge (2021). Investors are categorized as households, mutual funds, and foreign investors. The RHS is for Israel, for which we add pension funds. Source: Eren and Wooldridge (2021) and TASE.

Figure 3: **Normalized yields of 10-year government bonds and stock market indices**



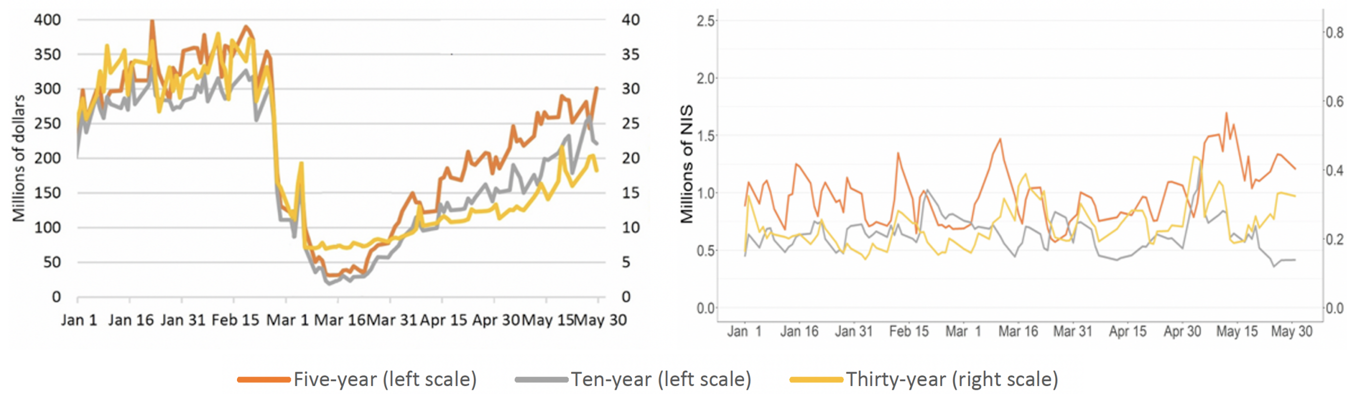
Notes: Figure 3 shows the time series from January 1, 2020, until April 1, 2020, of the daily normalized 10-year government bond yields for Israel and the U.S. (left-axis) and the TA 35 and S&P 500 stock market indices (right axis, January 1, 2020=100). We normalize the bond yields to control for cross-country differences in short-term expectations of changes in monetary policy rates. For the U.S., normalized bond yields are defined as bond yield minus the yield of the next-month federal funds futures contract. For Israel, we substract the forward rate between the 3-month and 1-month TELBOR rates instead, which is Israel's short term interbank interest rate. The shaded area marks the beginning of the liquidity crisis (February 28, 2020 until March 3, 2020). Source: Bank of Israel and Bloomberg.

Figure 4: **Time series of spreads of government bonds and stock indices**



Notes: Figure 4 shows the average daily bid-ask spreads of Israeli and U.S. government bonds, the TA 35 index, and the S&P 500 from February 1, 2020, until March 31, 2020. Spreads on February 1, 2020, are normalized to 1. When averaging bond spreads, we weight by the bonds' notional amounts. The shaded area marks the beginning of the liquidity crisis (February 28, 2020 until March 3, 2020). Source: Bloomberg and TASE.

Figure 5: **Market depth**

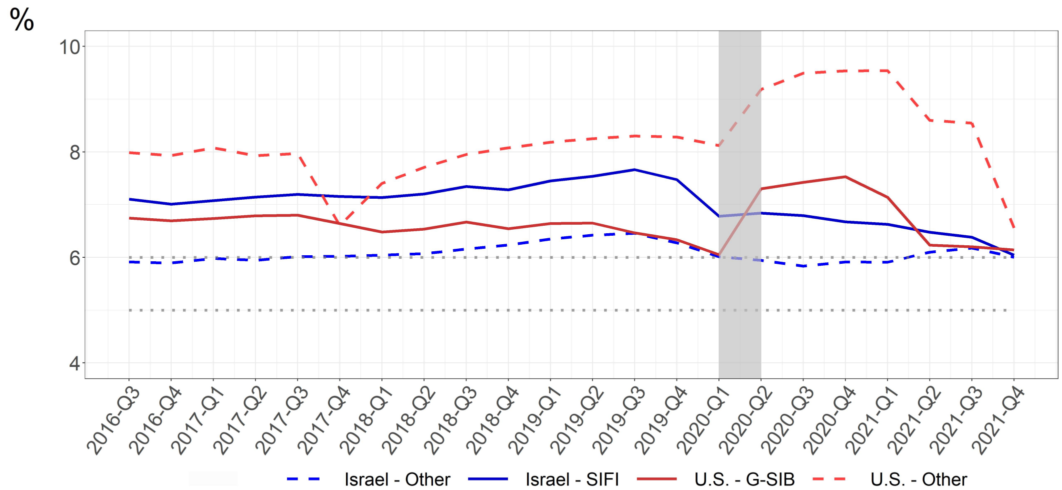


Notes: Figure 5 shows the depth of the limit order book in the inter-dealer market for on-the-run U.S. government bonds on the LHS and for the Israeli government bond market on the RHS. For the U.S., the graph is taken from Fleming et al. (2021). We replicate it for Israel to the best of our ability. We first average the order amount associated with the best bid and the amount associated with the best ask for a security each time the order book changes. We then average over the course of the day to obtain the daily average market depth of a security. Finally, to obtain a daily market depth measure per maturity category, we average over securities in the same maturity category (e.g., 5, 10, 30 years), weighted by the amount outstanding of each security. Market depth is measured in million U.S. dollars and NIS, respectively. Source: BrokerTec, TASE and the Bank of Israel.

Yields, spreads, and market depth. The high selling pressure impacted the prices and yields in government bond markets around the world, including Israel, as illustrated in Figure 3. This is reassuring, in that we would not expect prices or yields to remain entirely stable when demand and supply are unbalanced, even if the market mechanism is efficient. However, in Israel liquidity measures, including market depth, price impact, and spreads, remained relatively stable. This is shown in Figures 4–5, and Appendix Figure A3.

Leverage constraints. One explanation for why dealer banks in OTC markets did not absorb sufficient sales on their balance sheets is that they faced overly stringent balance sheet constraints (Schrimpf et al. (2020); Duffie (2020)). To show that weaker Basel III requirements or slack balance sheet constraints cannot fully explain the higher liquidity in the Israeli market (independent of market structures), we show in Figure 6 that Israeli banks faced stringent requirements and were as close, if not closer, to their LR thresholds than U.S. banks.

Figure 6: **Time series of the LR of an average bank in U.S. and Israel**



Notes: Figure 6 show a time series of the quarterly reported LR (in %) of an average bank on the consolidated basis of two types that face different leverage ratio thresholds in the U.S. and Israel from 2017q1 until 2021q3. In Israel there are 2 Systemically Important Banks (SIFI) banks and 6 non-SIFI banks that face the 6% and 5% leverage constraint, respectively. In the U.S. there are 8 Global Systemically Important Banks (G-SIBs) that face the 5% threshold on the consolidated basis and 14 other institutions that report the Consolidated Financial Statements for Holding Companies—FR Y-9C—and face the 3% threshold. We exclude an outlier, DWS USA corporation, given the huge LR levels. Source: Bank of Israel and WRDS.

Subsequent policy interventions. To restore market liquidity in Treasury markets, central banks around the world quickly announced policy interventions. The Bank of England, European Central Bank, Bank of Korea, Central Bank of Japan, National Bank of Poland, and Bank of Mexico began taking measures on March 11, 12, 12, 13, 16, and 20, 2020, respectively (Bank of England (2020); European Central Bank (2020); Bank of Korea (2020); Bank of Japan (2020); Hertel et al. (2022); Bank of Mexico (2020)). The Fed announced that it would purchase large amounts of government bonds on March 15 and 23, 2020. In addition, to reduce balance sheet costs, government bonds were declared to be exempt from the SLR on April 1, 2020. The Bank of Israel did not exempt government bonds from the LR, but also announced that it would purchase large amounts of government bonds to ensure the smooth functioning of the market on March 15 and March 23, 2020.[6]

[6] For an analysis of the effectiveness of these interventions, see Nathan (2020) and Chapter 3 of the Bank of Israel's 2020 yearly report.

5 To what extent does an exchange affect liquidity?

We hypothezise that exchange trading increases liquidity during a crisis. To avoid confounding our findings by policy interventions, we focus on the time period after the WHO announced its warning on February 28, 2020, but before central central banks started their interventions, which varies across countries. When we compare different countries, we only use data until the first policy intervention, which was on March 11, 2020 (U.K.), to be conservative. When we use data from the same country, we use the country-specific cutoff to be more precise, but our findings are qualitatively robust when using the common cutoff date, instead.

Liquidity measure. To gather evidence for our hypothesis, we use the bid-ask spread as our main measure of liquidity for three reasons.[7] First, this measure is ubiquitous in the literature (e.g., Amihud et al. (2012)). Second, the measure can be read from price data—unlike other liquidity measures that require trade-level information, such as trade speed or frequency; trade size; quote size; price impact coefficients (as in Appendix Figure A3); market depth (as in Figure 5); roundtrip transactions costs; or trade type (e.g., Fleming (2003); Feldhütter (2012); Kargar et al. (2021)). Third, vast theoretic work explains why the spread soars when liquidity evaporates (e.g., Glosten and Milgrom (1985); Bessembinder and Venkataraman (2010)).

We express all spreads as a percentage of the midpoint price. Alternatively, we could use the difference between the bid and ask price without normalizing by the midpoint price; the findings remain robust. Spread summary statistics are provided in Appendix Tables A1 and A2. In all regressions, spreads are in logs. We therefore need to convert all coefficients and interpret them as percentages: $100 \times [\exp(\text{coefficient}) - 1]$ is the percentage change in the spread.[8] We present the estimation results of our preferred fixed-effects specifications in the main text, and report the corresponding OLS-specifications in the appendix.

[7]We use daily rather than more high-frequency data to reduce differences across countries that arise because of different time zones.

[8]Since the estimates are large, the standard log approximation is not accurate.

Warm-up. A first approach to test our hypothesis is to compare spreads in the stock market with spreads in the government bond market in a difference-in-differences (DD) regression. For countries other than Israel, this could tell us by how much liquidity in the stock market differed from liquidity in the government bond market, because stocks are traded on an exchange and bonds are not, if we are willing to assume that the liquidity crisis would have had the same effect on stock and bond spreads if both were traded on an exchange. This is a strong assumption, since bonds and stocks differ in many dimensions and the nature of the dash-for-cash.[9] We, therefore, do not interpret the DD estimation results as causal; instead, we discuss them as groundwork for our main regression, a triple-difference (DDD) analysis.

We estimate two specifications with data from all countries in our sample but Israel. In the first, we regress the log of the daily spread of security i—for instance, the U.S. Apple stock or the U.S. 2-year government bond—, $\log \mathrm{BAS}_{it}$, on a country fixed effects, ξ_c, and an indicator variable, post, that equals 1 in the crisis period and an indicator variable, stock, for whether the security is a stock. In the second, preferred, specification, we add security fixed effect, and country-date fixed effects, ξ_i and ξ_{ct}, respectively:

$$\log \mathrm{BAS}_{it} = \xi_c + \beta_1 \mathrm{stock} + \beta_2 \mathrm{post} + \beta_3 \mathrm{stock} \times \mathrm{post} + u_{it}. \tag{1}$$

$$\log \mathrm{BAS}_{it} = \xi_{ct} + \xi_i + \beta_3 \mathrm{stock} \times \mathrm{post} + u_{it}. \tag{2}$$

In line with our expectation, Table 1 shows that the coefficient β_3 is negative. In contrast, when we run these regressions using proprietary data from the Israeli and South Korean exchanges as a placebo test, the coefficients are statistically insignificant.

Appendix Table A4 presents the β_3 estimates when estimating the fixed-effects specification separately for each country, rather than pooling the data and including a country-day fixed effect. Nearly all country-specific estimates are negative, with the exception of Poland.

In Poland, stock spreads increased more than bond spreads, even though stocks are

[9] For more discussion of how government bonds may differ from other types of securities, see, for example, Nagel (2016), who shows that government government bonds are near money assets, or Boudoukh et al. (2021), who show that in previous crisis periods, investors sold more liquid government bonds.

Table 1: **Within-country DD of bonds vs. stocks**

	OTC	TASE	KRX
stock×post	−0.168***	+0.061	+0.058
	(0.016)	(0.057)	(0.059)
Observations	48,102	1,831	7,169
Adjusted R^2	0.942	0.925	0.814

Notes: Table 1 shows results of DD regression (2) with country-day, and security fixed effects. Appendix Table A3 presents the estimation results of the analogous regressions with only country fixed effects. In column (OTC) we use data from all countries in our sample excluding Israel from February 1, 2020, through March 10, 2020, inclusive. As placebo tests, we show the estimates for the Israeli and South Korean Stock Exchange in columns (TASE) and (KRX). Here, we where we use proprietary price data from the two exchanges, again from February 1, 2020 until each country's first announcement of monetary policy measures. The dependent variable is the daily log spread of a security; stock is 1 for stocks and 0 for bonds; post is 1 starting on February 28, 2020. Standard errors are clustered by security in (FE). *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg, South Korean Stock Exchange, TASE.

exchange-traded while Polish government bonds are primarily traded OTC. While it is difficult to be certain, given the limited research available on Poland, one possible explanation is that the government bond market there did not experience a significant dash-for-cash. This could explain why Polish government bond yields remained more stable and trading volumes did not spike as sharply as in other countries (as seen in Charts 1 and 2 of Polish Ministery of Finance (2020)). Another possibility is that the Polish OTC market functioned more smoothly compared to their stock market than other OTC markets, leading to better liquidity despite comparable selling pressures. Although we lack trade-flow data to confirm this, and existing research is sparse, it seems unlikely, given that Polish OTC market rules do not appear to differ significantly from those of other OTC markets.

Cross-country analyses. With data from Israel, where bonds are traded on an exchange, we can better isolate what effect having an exchange has on spreads because we can control for any fundamental difference between stocks and government bonds. Exploiting variation in the spreads of stocks and government bonds in Israel versus the other countries, we run the following triple differences-in-differences (DDD) specification:

$$\log \mathrm{BAS}_{it} = \xi_{ct} + \xi_i + \delta_1 \mathrm{bond} \times \mathrm{post} + \delta_2 \mathrm{bond} \times \mathrm{IL} \times \mathrm{post} + u_{it}. \tag{3}$$

In our preferred specification, shown in Table 2, we include security fixed effects, ξ_i, and country-date fixed effect, ξ_{ct}, to absorb unobservable factors, including different severity and time-varying of the dash-for-cash shock, between the countries. The main coefficient of interest, δ_2, is identified based on how daily spreads of bonds compared to stocks change in Israel versus the other countries after February 28, 2020, relative to how they were before, once we exclude time-country-specific trends that are common to all securities. Appendix Table A5 shows the analogous regression with only country fixed effects.

We first estimate both regressions using data from all countries: We find that the government bonds' spread over stocks rose by about $100 \times [\exp(-0.317) - 1] \approx 27\%$ less in Israel than in the other countries.[10] Next, we divide the sample into large and small economies. For large economies, we re-estimate the regressions with and without the U.S., as its bond market might have been more affected by the shock relative to its stock market, given the status of U.S. Treasuries as the safest in the world. For small economies, we re-estimate the regressions with and without Poland, given that our earlier analysis identified it as an outlier in the sample. The estimation coefficient is similar for these two cases, and imply an effect of roughly 23%.

We could interpret these estimation findings as causal, meaning that the Israeli government bond spreads were lower because of the exchange, if spread pre-trends were parallel and any effect the dash-for-cash had on the bond-stock difference (unrelated to the trading mechanism) was the same in both countries. Importantly, the magnitude of the dash-for-cash can differ across countries thanks to the country-date fixed effect.

To test for pre-trends, we perform a dynamic DDD analysis for our preferred regression specification with country-date fixed effects (see Figure 7). We find that, in Israel, government bond spreads did not diverge from stock spreads, compared to other countries, before

[10] Appendix Table A6 reports the estimation coefficients when estimating the fixed-effect regression (3) for each country separately, rather than pooling across countries, and absorbing country-differences by including country-day fixed effects. Since many time-varying factors affect demand and supply of government bonds and stocks, we expect the size of the effect to vary across countries. We find that it ranges approximately between 10% and 30% for all countries, excluding the U.S. and Poland. In the U.S. the effect is the largest with 49%.

Table 2: **Cross-country DDD**

	All	Large	No US	Small	No PL
bond×post	+0.168***	+0.217***	+0.120***	+0.042	+0.115***
	(0.016)	(0.017)	(0.021)	(0.037)	(0.040)
bond×IL×post	−0.317***	−0.365***	−0.268***	−0.190***	−0.264***
	(0.063)	(0.063)	(0.065)	(0.071)	(0.073)
Observations	49,780	36,503	17,624	14,955	13,767
Adjusted R^2	0.942	0.926	0.939	0.897	0.897

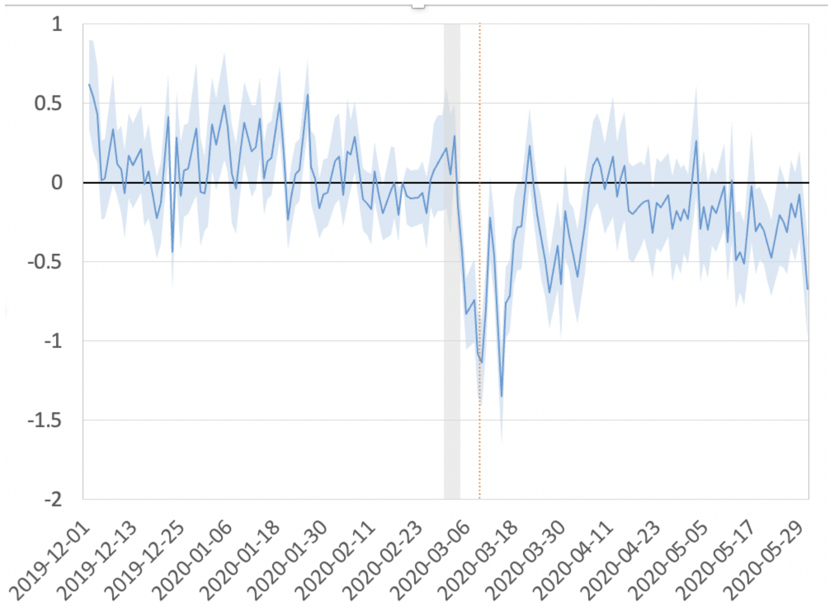
Notes: Table 2 shows results of DDD regression (3) which includes security, and country-day fixed effects. Appendix Table A5 shows the results of the corresponding regressions with only country fixed effects. In column (All), we use data of all countries in our sample from February 1, 2020, through March 10, 2020, inclusive. In column (Large) we compare the large economies, U.S., U.K., Germany, Japan, to Israel, and in column (Small) the small economies, Greece, Ireland, Mexico, Poland, Portugal, and South Korea. We exclude the U.S. from the large countries in column (No US), and Poland from the small countries in column (No PL). The dependent variable is the daily log spread of a security. Indicator variable bond is 1 for bonds and 0 for stocks; IL is 1 for Israeli securities and 0 otherwise; post is 1 starting on February 28, 2020. Standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg and TASE.

the dash-for-cash began but declined afterward. At its peak, the estimated coefficients imply a large effect of above 50%. The effect was not immediately on Friday, February 28, when the WHO raised the coronavirus threat to its highest level. The delay might be due to dealers initially managing selling pressure effectively. However, as their inventories filled up, liquidity declined. Data show this shift occurred in early March (see Duffie (2020)), aligning with spread changes. Spreads rebounded when central banks intervened on March 11. Volatility remained high as more interventions and pandemic news unfolded until late April, when spreads stabilized slightly below pre-crisis levels.

Within-country analyses. Although our main DDD analysis includes country-day fixed effects, unobservable differences across countries could still influence some of the previous findings. The primary concern is that Israel's government bond market experienced a milder shock relative to its stock market compared to other countries. To complement the across-country analysis, we end our analysis with comparisons of markets within the same country, focussing on the U.S., Israel, and South Korea.

In all cases, we estimate DD regressions of the following form:

Figure 7: **Dynamic cross-country DDD**



Notes: Figure 7 shows the $\delta_{2,k}$ coefficients and the 95% confidence bounds of regression: $\log \text{BAS}_{it} = \xi_i + \xi_{ct} + \sum_{k=1}^{182} \delta_{1,k} \text{bond} \times \text{day}_k + \sum_{k=1}^{182} \delta_{2,k} \text{bond} \times \text{IL} \times \text{day}_k + u_{it}$, where BAS_{it} is the spread of security i on day t; day_k equals 1 on the k^{th} day from December 2, 2019, until May 31, 2020, and 0 otherwise; bond is 1 for government bonds and 0 for stocks; ξ_i is a security, and ξ_{ct} is a country-date fixed effect. The baseline is February 19, 2020. The gray area shades the period between February 28, 2020 and March 3, 2020. The red line marks the last day before the first policy intervention, March 10, 2020. Source: Bloomberg and TASE.

$$\log \text{BAS}_{it} = \beta_0 + \beta_1 \text{exchange} + \beta_2 \text{post} + \beta_3 \text{exchange} \times \text{post} + u_{it} \tag{4}$$

where BAS_{it} is the bid-ask spread of security i on day t, indicator variables exchange is 1 if the security i is traded on the exchange, post is 1 starting on February 28, 2020. In our preferred specifications, we include security and day fixed effects, ξ_i, and ξ_t.[11]

For the U.S., we compare U.S. Treasury futures with U.S. government bonds, leveraging the fact that both assets have essentially the same fundamentals, but one is traded on an exchange and the other is not. The estimates of the static DD are reported in Table 3; Figure 8 shows the dynamic analysis. The estimates suggest that the futures spread rose, on average, by 66% less than the government bond spread, which is larger than our previous estimates. We conjecture that some of the estimated effect comes from the higher selling pressure in the Treasury cash market relative to the futures market in light of research that

[11] This implies omitting the post-variable, and for the U.S., where the same security doesn't trade on and off the exchange, also the exchange-variable exchange given perfect collinearity with the fixed effects.

suggests that the Treasury market might have faced larger selling pressure than the futures market (e.g., Schrimpf et al. (2020), Barth and Kahn (2020)).[12]

Lastly, for South Korea and Israel, where a portion of government bond trades occur on an exchange, we can conduct DD analyses comparing bonds traded on versus off the exchange within each country. The advantage of this approach is that it allows us to focus on the same asset class within each country, addressing concerns that arise when comparing across countries and asset classes. The main conceptional disadvantage is that we cannot control for endogenous selection between trading methods that can drive unobserved differences.

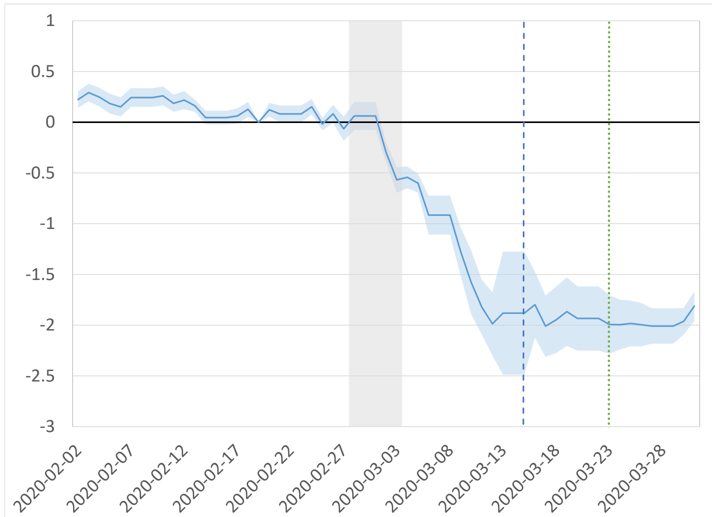
Moreover, there are two practical disadvantages. First, we need to rely on proxy variables to measure the bid-ask spread in the OTC market, given that we don't observe OTC trades. For Israel, we use the high-low spread (the difference between the highest and lowest trade price of a security within a day, normalized by the average of these two prices). For South Korea, we use the Bloomberg spread, which relies on averages, which are likely driven by OTC trades given that the majority of trades are traded off the exchange in South Korea. Second, the sample size is relatively small for both countries. For Israel, this is due to the limited number of bonds that trade OTC given the small share of the market. For South Korea, the issue arises because some bonds predominantly trade either exclusively on the exchange or OTC. For example, less liquid bonds typically trade off the exchange and are excluded when we apply security fixed effects. These and similar observations are absorbed by the security fixed effect, rather than helping to identify our coefficient of interest. Therefore, there is not enough statistical power to conduct the dynamic analyses.

Despite lower statistical power and data limitations, we estimate coefficients that are in line with our hypothesis for both countries. In Israel spreads on the exchange rose on average by 53% and in South Korea by 27% less than spreads in the OTC market (see Table 3).[13]

[12]Sophisticated investors tried to substitute into the futures market and sell futures rather than Treasuries until prices in the cash market were more favorable. They were successful only to the extent that they found a counterparty in the repo-market. In addition, there was an opposing effect. Hedge funds that had taken a short position in Treasury futures and a long position in Treasury securities before the crisis unwound their position when futures became more expensive relative to cash Treasuries (Schrimpf et al. (2020); Barth and Kahn (2020)). Thus, they sold Treasuries and bought futures.

[13]In regular times, the spread on the exchange is larger than off the exchange. This is probably because

Figure 8: **Dynamic DD analysis—U.S. Treasury vs. U.S. futures**



Notes: Figure 8 shows the $\beta_{3,k}$ coefficients and the 95% confidence bounds of regression: $\log \text{BAS}_{it} = \xi_i + \xi_t + \sum_{k=1}^{124} \beta_{3,k} \text{future} \times \text{day}_k + u_{it}$, where BAS_{it} is the spread of security i on day t; day_k equals 1 on the k^{th} day from January 9, 2020, until May 31, 2020, and 0 otherwise; future is 1 for U.S. Treasury futures and 0 for U.S. government bonds; ξ_i is a security, and ξ_t is a date fixed effect. The baseline is February 19, 2020. The gray area shades the period between February 28, 2020 and March 3, 2020. Blue and green lines correspond to the Fed's interventions on March 15 and 23, 2020, respectively. Source: Bloomberg and the Chicago Mercantile Exchange.

Take away. We presented a series of complementary regression specifications to support the hypothesis that exchange trading increases liquidity during a crisis compared to over-the-counter markets. The extent to which an exchange reduces spreads during the crisis varies, depending on the specific market analyzed, being roughly 25% on average, and over 50% at the peak.

None of the analyses alone can establish causality definitively. In the cross-country analysis, we are concerned that unobservable differences across countries, not captured by the country-day fixed effects, could affect the results. In the within-U.S. analysis, which compares the cash and futures markets, the worry shifts to differences across these markets, such as varying trader types or purposes. Finally, in the within-South Korea and within-Israel

investors that trade large amounts OTC are more similar to dealers, and therefore trade at a lower spread, than the average investor on the exchange.

Table 3: **Within-country DD—U.S., Israel, South Korea**

	US	IL	KR
exchange×post	−1.073***	−0.761**	−0.318**
	(0.084)	(0.353)	(0.112)
exchange		+1.130***	+0.233
		(0.189)	(0.212)
Observations	2,643	496	878
Adjusted R^2	0.932	0.788	0.659

Notes: Table 3 shows results of DD regression (4) but adding security, and day fixed effects for the U.S. in column (US), for Israel (IL), and for South Korea (KR), respectively, using data from February 1, 2020, through the first day of each country's central bank intervention. Appendix Table A7 shows the analogue estimates for the regression without fixed effects. For the U.S., the dependent variable is the daily log spread of a security; exchange is 1 for futures and 0 for bonds. For Israel and the South Korean exchange, exchange is 1 when the trade is on the exchange and 0 when it is OTC. For Israel, the dependent variable is the log of the difference between the highest and lowest trade price of a security within a day, normalized by the average of these two prices. We exclude cases when there is a single trade of a security within a day, or the highest and lowest trade prices are identical (likely, because all investors execute trades in the same direction). For South Korea, we use the daily bid-ask spread from the South Korean stock exchange for trades on the exchange and the Bloomberg bid-ask spread for all trades on and off the exchange. In all specifications, post is 1 starting on February 28, 2020. Standard errors are clustered by security in (FE). *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: Bloomberg, the Chicago Mercentile Exchange, the TASE, South Korean Stock Exchange.

analysis, which compares the same asset within each country, the concern is unobservable differences across market segments, like trade size or trader type, influencing market choice.

However, taken together, our analyses produce suggestive evidence that points in the same direction: Trading government bonds on an exchange can increase liquidity during a crisis period. Next, we discuss and analyze why.

6 Why does an exchange promote liquidity?

An exchange may promote liquidity for two main reasons. First, everyone can anonomously trade with everyone. This implies that customers can provide liquidity for one another if dealers cannot or do not want to. Second, a CCP absorbs any counterparty and settlement risk by netting trades. Naturally, counterparty risk is lower for government bonds than for stocks because trades settle quickly and involve a single transaction of a safe asset (Duffie (2020)). However, some counterparty risk can build up when trades fail to settle as planned, especially during times of distress. Then the settlement date is moved forward until the security is ultimately delivered (see Fleming and Keane (2021)).

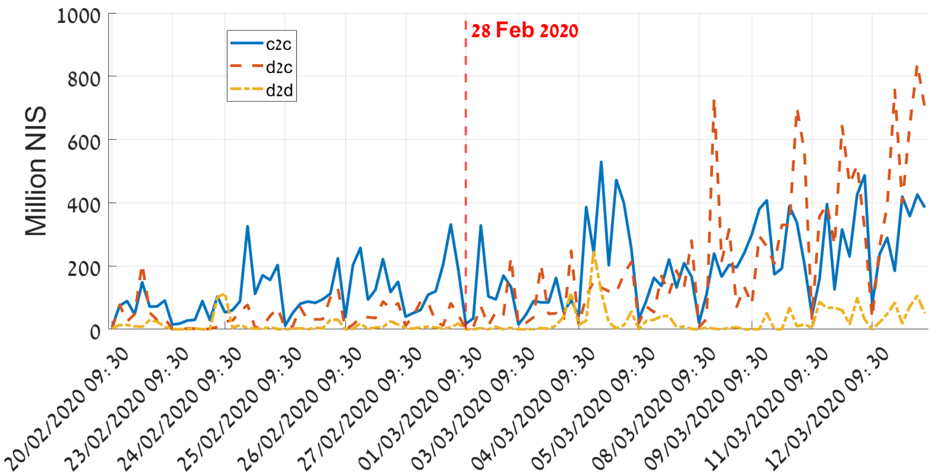
All-to-all trading. We begin by documenting that customers traded significant volumes with each other on the Israeli exchange, with the key takeaway being that customer-to-customer trading remained substantial throughout the crisis.

We see this in Figure 9 which visualizes the hourly trade flow between dealers, between dealers and customers, and between customers. During the crisis period, between February 28, 2020, and March 13, 2020, 56% (51%) of the amount customers bought in an average hour (day) was sold to other customers, i.e., the average ratio between the amount bought by customers through customer-to-customer transactions in an hour over the total amount customers bought in that hour is 56%. An alternative scenario could have been a complete drying up of customer-to-customer trading during the crisis, leaving dealers as the only buyers of Treasuries, but our findings suggest otherwise.

To identify which types of traders leaned against the wind and bought government debt during the crisis, we analyze daily trade-flow data from TASE, where we can separate the following types: banks, i.e., dealers, foreign investors (FIs), mutual funds (MFs), pension funds (PFs), independent investment advisors (IIAs), ETFs, and local investors (LIs), which encompass retail traders, hedge funds, and algorithmic trading firms. Figure 10 shows the daily purchases and sales by each trader group from February 02, 2020 to March 13, 2020. If only dealer banks had been buying while non-dealers were selling during the crisis, all upward bars would appear in orange—the dealer's color. While we see that dealers played an important role in taking the buy-side, the multi-colored positive bars indicate that non-dealers also made purchases.

In total, roughly 43% of the total amount sold by customers during the crisis period was bought by non-dealers. Local investors—which include hedge funds and algorithmic and high-frequency trading firms—bought the largest share among non-dealers, with roughly 24%; while pension funds, mutual funds, and foreign investors purchased less. Moreover, local investors were net buyers during a substantial part of the crisis period (until March 8,

Figure 9: **Hourly trade volume per market segment**



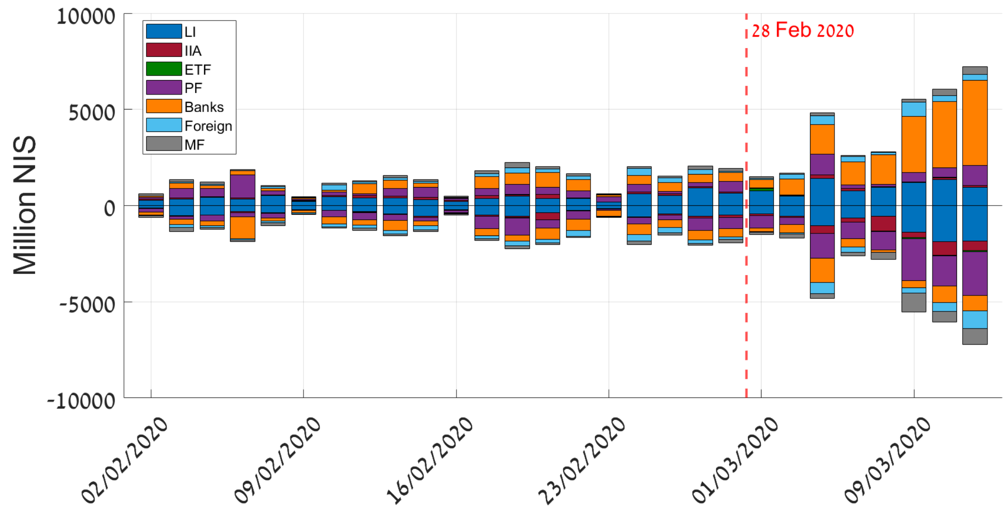
Notes: Figure 9 shows the hourly buying volume of customers from customers (c2c, in blue), dealers from customers (d2c, in orange) and dealers from dealers (d2d, in red) in million NIS from February 20, 2020 until March 13, 2020. The vertical line marks the beginning of the crisis period, February 28, 2020, a Friday, where no trades took place in Israel. Fleming and Keane (2021) show the analogous graph for the U.S. market at the daily-level. Source: TASE.

2020), meaning that, on the aggregate, local investors bought more than they sold in a day. This suggests that allowing sophisticated traders, such as algorithmic trading firms, to trade directly with investors may help balance unbalanced demand and sell sides during times of crisis.

We link customer-to-customer trading to market liquidity, with our hypothesis being that all-to-all trading on an exchange enhances liquidity by facilitating these customer-to-customer transactions, to complement the evidence we provide in Section 5. Ideally, we would want to show that higher customer-to-customer trading causes bid-ask spreads to be narrower. This is difficult to show, because we cannot rule out that customers select into trading bonds that are more liquid without conducting an experiment that randomly shuts of all-to-all trading for some Israeli bonds. We can, however, test whether higher customer-to-customer trading activity is negatively correlated with bid-ask spreads. To demonstrate this, we aim to control for confounding factors that could drive this negative relationship, for example, the fact that spreads are lower when trade volume is high.

We first consider the pre-crisis period, using data from November 1, 2019 until Febru-

Figure 10: **Daily trade flows by investor group**



Notes: Figure 10 shows the total amount bought (the positive bars) and the total amount sold (the negative bars) of Israeli government bonds in a day by trader type—i.e., banks (who are dealers), local investors (LI), mutual funds (MF), pension funds (PF), independent investment advisors (IIA), ETFs, and foreign investors (Foreign)—from February 20, 2020 until March 13, 2020. The vertical line marks the beginning of the crisis period, February 28, 2020, a Friday, where no trades took place in Israel. Trade flows are measured in million NIS. Source: TASE.

ary 27, 2020, and regress our liquidity measure, $\log \text{BAS}_{it}$, on the total daily volume of security i traded by dealers (both with each other and with customers) and the total daily volume traded between customers. We include security- and day-fixed effects to account for unobservable security-specific and time-varying factors that affect demand and supply:

$$\log \text{BAS}_{it} = \xi_i + \xi_t + \beta_1 \log \text{dealer\_volume}_{it} + \beta_2 \log \text{customer\_volume}_{it} + u_{it} \tag{5}$$

In Table 4, we find that a 1% increase in dealer trading volume corresponds to an approximately 1.8% reduction in spreads, while a 1% increase in customer-to-customer trading results in a reduction of around 5%.

In a second specification, we add data from the crisis period until March 13, 2020, when the Bank of Israel announced policy measures, with the results remaining robust even when the sample is narrowed to include fewer pre-crisis days. To distinguish the effects during regular times (November 1, 2019 until February 27, 2020) from those during the crisis (February

Table 4: **Customer-to-customer trading and the bid-ask-spread**

	Pre-crisis		Crisis vs. regular	
log dealer_volume	-0.018^{**}	(0.008)	-0.018^{**}	(0.008)
log customer_volume	-0.050^{***}	(0.013)	-0.050^{***}	(0.013)
log dealer_volume× crisis			-0.048	(0.050)
log customer_volume×crisis			$+0.004$	(0.048)
Observations	1,289		1,417	
Adjusted R^2	0.669		0.696	
Security, and day fixed effect	+		+	
Security-period, and day fixed effect	−		+	

Notes: Table 4 shows the estimation findings of regression (5) in column (Pre-crisis). In column (Crisis vs. regular), we include interaction terms with the crisis period, and two security fixed effect for each security, one for the crisis period and one for regular times. In both cases, we use data for Israeli government bonds from November 2019 until March 13, 2020. The dependent variable is the daily log spread; log dealer_volume is the log of the total daily amount dealers trade with each other or with a customer, and log customer_volume is the log of the daily total amount that customers trade with each other, both measured in NIS. To avoid excluding cases when trade volume is zero, we replace log(0)=0, but the findings are robust to excluding the zeros. Indicator variable, crisis, is zero before February 28, 2020, and one afterwards. Standard errors are clustered by security in (FE). *** p<0.01, ** p<0.05, * p<0.1. Source: TASE.

28, 2020 until March 13, 2020) we introduce interaction terms between the two trade volumes and a crisis period indicator. Moreover, we include two fixed effects for each security—one for the crisis period and one for the pre-crisis period—to control for unobserved security-specific demand or supply shifts across these periods.

Our findings indicate that the relationship between customer-to-customer trading and liquidity remains stable during the crisis period, consistent with its behavior in normal times. Given the increase in customer volume during the crisis (see Figure 9), this supports our hypothesis that all-to-all trading enhanced liquidity even amid market turmoil.

Trade netting. Now we assess the importance of netting trades which helps to mitigate counterparty and settlement risk by conducting a counterfactual exercise. We ask how much Israeli dealer banks' gross settlement obligations would have increased if customers could only trade with dealers and netting on the Israeli exchange was like it is in the U.S.

This analysis complements Fleming and Keane (2021), who quantify how much less U.S.

banks' gross settlement obligations would have had decreased under central netting.[14] Unlike Fleming and Keane (2021) we observe a market with central clearing and all-to-all trading. Therefore, we can (approximately) disentangle the change in dealers' gross obligations when eliminating all-to-all trading relative to U.S. market rules—while still excluding central clearing of customer trades—from the overall effect observed when transitioning from a market with central clearing and all-to-all trading to one without either central clearing or all-to-all trading.

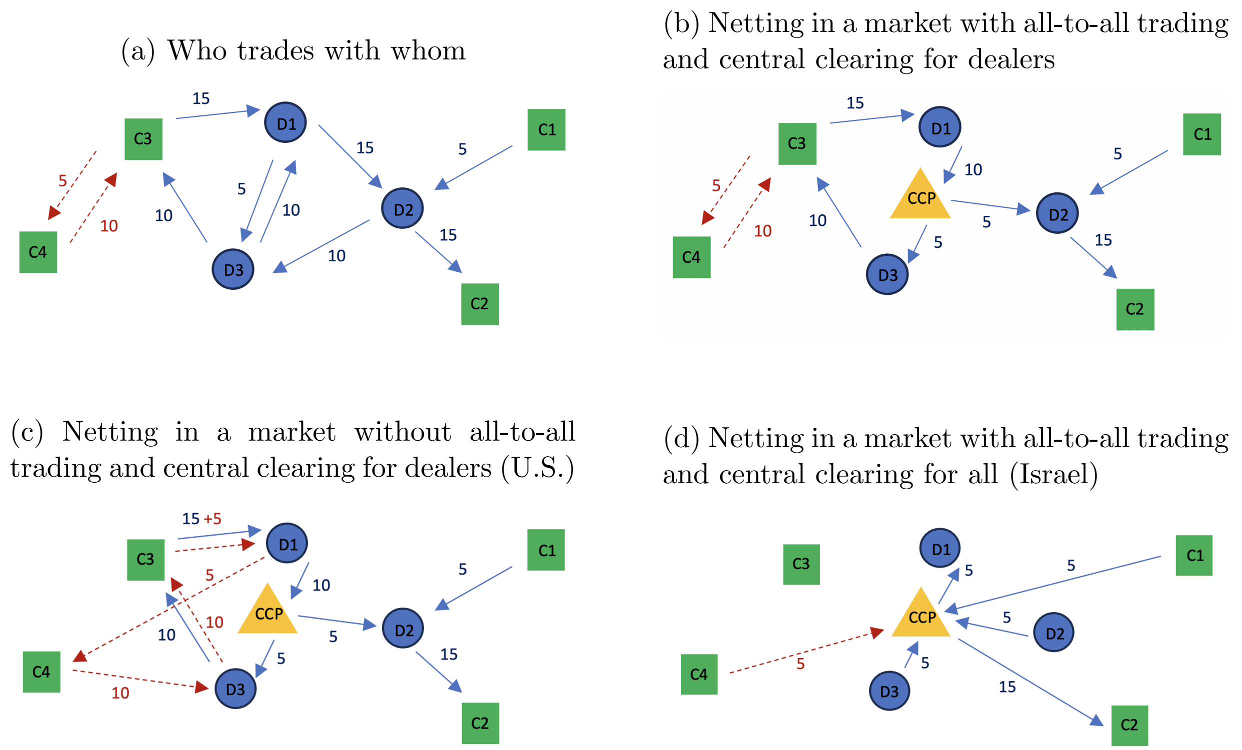
To illustrate, consider an example with three dealers and four customers trading a security. The example mirrors Fleming and Keane (2021)'s example in Boxes A and B of the appendix, but with the addition of a customer-to-customer trade between customers to highlight the role of all-to-all trading. Figure 11a visualizes the trade flows, showing who trades with whom. For instance, dealer 1 (D1) sells 5 units to dealer 3 (D3) and buys 15 units from customer 3 (C3). Assuming all trades settle on the same day, we calculate gross settlement obligations by summing trade flows for each participant in a market with all-to-all trading but no CCP. Collectively, the dealers face gross obligations of (10+5+10+15)*2 = 80 among themselves and (15+10+5+15) = 45 with customers.

Now assume that a CCP clears trades in the inter-dealer market. This allows dealers to fully net their trades with one another, as the CCP acts as the counterparty, illustrated in Figure 11b. Due to this netting, the dealers' gross settlement obligations decrease to 20 with the CCP while remaining at 45 with customers.

Next, in Figure 11c, we eliminate customer-to-customer trading to align with the rules of modern OTC markets like those in the U.S. Customers 3 and 4, who previously traded directly with each other, now must trade via dealers. As a result, dealers' gross settlement obligations with customers increase to (45+5+5+10+10) = 75 while obligations with the CCP remain at 20. In contrast, under Israeli market rules, where customers can trade

[14] Like Fleming and Keane (2021), we focus on the uncleared portion of intermediating cash trades and abstract from the outright long and repo positions, which might be balance-sheet intensive. This implies that we abstract from other reasons institutions may pull back from intermediating cash trades, such as margins in a CCP, unsecured credit to intermediate unsetteled trades, and risk management practices.

Figure 11: **Example of netting benefits**



(a) Who trades with whom

(b) Netting in a market with all-to-all trading and central clearing for dealers

(c) Netting in a market without all-to-all trading and central clearing for dealers (U.S.)

(d) Netting in a market with all-to-all trading and central clearing for all (Israel)

Notes: Figure 11 illustrates a trading example between four customers (C1, C2, C3, C4) and three dealers (D1, D2, D3), and a central counterparty (CCP). Arrows indicate trade flows, for example, in Figure 11a customer 4 sells 10 units to customer 3, and buys 5 units from customer 3.

directly with one another and all trades are centrally cleared (Figure 11d), dealers' gross settlement obligations reduce significantly to 15.

With our data we can approximate the changes in dealers' gross settlement obligations when going from the status quo in Israel to a U.S. rules. Because we lack information on specific trading counterparts, we cannot precisely calculate settlement obligations. Instead, as shown in Appendix B, we establish upper and lower bounds for these obligations.

Figure 12 displays a substantial total effect on daily settlement obligations for Israeli banks when shutting off netting and all-to-all trading. On average daily settlement obligations in Israel were in between 0.59 NIS billion and 1.06 NIS billion around the market disruptions (from January until April 2020). Under the counterfactual netting rules, these obligations rise by 1.98 NIS billion at the lower bound, and by 2.46 NIS billion at the upper bound. This implies that Israeli netting rules reduced settlement obligations by 65%–81% compared to U.S netting rules.[15] Fleming and Keane (2021) find an effect of similar, yet slightly smaller magnitude—60%—for the U.S.

Figure 12b illustrates the significant impact of eliminating all-to-all trading while keeping central clearing like it is in the U.S. and many other OTC markets (i.e., Figure 11c). It splits the dealers' daily gross obligations in our counterfactual world (at the upper bound) into obligations coming from forcing customers who would want to trade with each other to trade with dealers—customer 3 and 4 in the example—, and the remaining obligations. We see that the increase in dealers' settlement obligations—caused by customers being forced to trade through dealers—can exceed the obligations arising from the inability to net trades with customers who would otherwise trade with a dealer under the current setup.

Since we don't observe the counterfactual scenario of Israel without all-to-all trading and netting, it is difficult to estimate how the (counterfactual) increase in settlement obligations would have impacted liquidity—measured, for example, by bid-ask spreads—in the Israeli market during March 2020 if there had been no exchange. However, a recent study by Duffie et al. (2023) provides valuable insights by showing that liquidity in the U.S. Treasury market is highly sensitive to dealers' balance sheet capacity. According to their findings, liquidity declines sharply once dealers reach about 50% of their capacity, as the market becomes illiquid when dealers can no longer accommodate additional trades. Beyond this threshold, illiquidity worsens rapidly, causing significant market disruptions.

Although we don't have the same data to calculate the capacity levels of Israeli dealer banks, the substantial effects shown in Figure 12—particularly the increase in customer-to-dealer trading resulting from the elimination of all-to-all trading—suggest that, without an exchange, Israeli banks might have exceeded the 50% capacity threshold. This implies that the Israeli Treasury market could have experienced severe illiquidity during March 2020, driven by dealers exhausting their balance sheet space in absence of all-to-all trading and

[15] The lower bound of the percentage reduction is: 1- 1/(1.98/1.06+1) = 0.65, and the upper bound is 1-1/(2.46/0.59+1) = 0.81.

netting. To support this conjecture, we analyze market liquidity during the financial crisis of 2007–2008, a period when dealers faced lower balance-sheet constraints, given that Basel III had not yet been implemented, and overall selling pressure was lower (Vissing-Jorgensen (2021); see Appendix C). In line with our conjecture, we find no significant difference in Treasury liquidity between the U.S. and Israel during this period.

Take away. The evidence presented suggests that an exchange for government bonds in the U.S. and other countries could promote liquidity in a crisis because it allows investors to provide liquidity for one another and because it facilitates the netting of trades. Importantly, these two factors are complementary in that a large part of the netting effect comes from the fact that fewer trades go via dealers when investors can trade with one another.

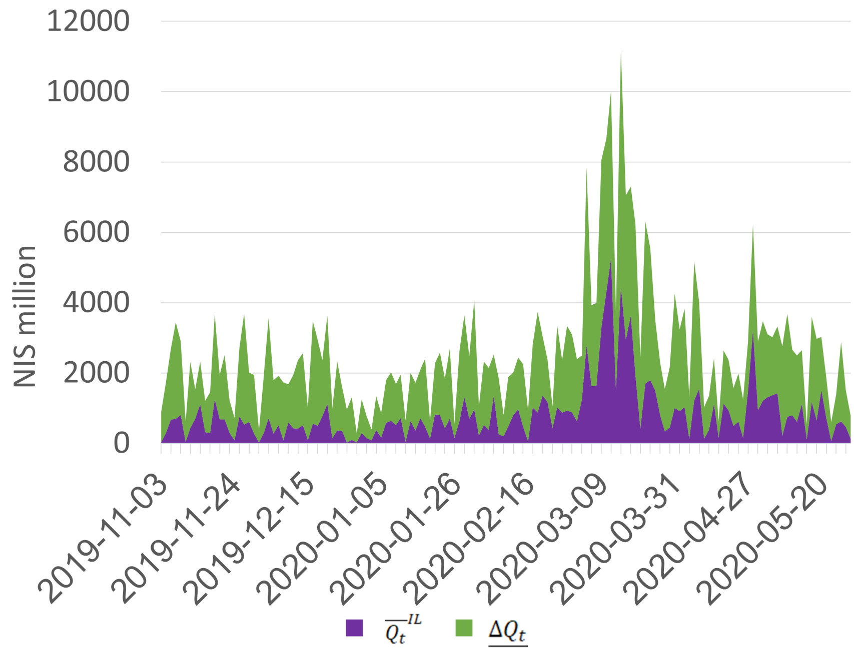
Taken together, our findings highlight the fact that trading mechanisms and financial regulations or policies that affect dealer balance sheets are intertwined. Thus they must be evaluated together to avoid future market distress, especially in an era in which dealer banks' balance sheets are crowded by unprecedented large amounts of government debt.

7 Conclusion

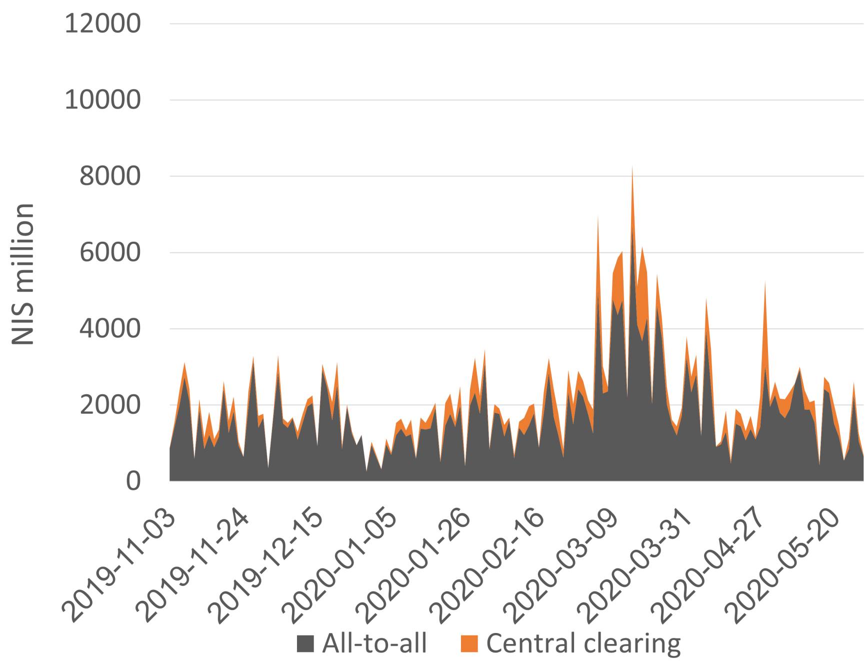
This paper analyzes whether and why shifting the trading of government bonds onto an exchange can protect market liquidity against negative shocks in times of crisis. We leverage the institutional feature whereby only the Israeli bond market trades on exchange. We first provide descriptive evidence that suggests that having an exchange may foster liquidity, then test this hypothesis via difference-in-differences analyses. We show that Israeli dealer banks and investors leaned against the wind in March 2020 and conduct a counterfactual to highlight the importance of trade netting and all-to-all trading.

Figure 12: **Total dealers' gross obligations**

(a) In the status quo (Israel) and the counterfactual (U.S.)



(b) Separating the effect into all-to-all trading vs. central clearing



Notes: Figure 12a shows the upper bound of settlement obligations in Israeli's status quo (in violet), and the increase in obligations when moving to U.S. settlement rules at the lower bound (in green) from November 1, 2019 until June 30, 2020. Figure 12b decomposes the total effect on settlement obligations at the upper bound into the effect coming from all-to-all trading (in gray) versus the additional effect coming from netting (in orange). All obligations are are expressed in NIS million, and stacked on top of each other in both graphs. See Appendix B for details on how we compute all bounds. Source: TASE.

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ONLINE APPENDIX

Appendix **A** provides additional institutional details regarding Israel.

Appendix **B** provides mathematical details for the counterfactual exercise.

Appendix **C** examines liquidity during the financial crisis of 2007-2009.

A Additional institutional details regarding Israel

Basic structure and size of the Treasury market. Historically, the Israeli government bond market was small and undeveloped, with minimal foreign activity. Therefore, government bonds were traditionally traded on the TASE, which already provided a platform for all-to-all trading and the netting of all trades for stocks. However, the last decade saw a significant development in the Israeli government bond market. As a result, the sovereign debt increased from \$100 billion in 2000 to \$324 billion in 2021. To further promote liquidity in the market and lower its financing costs, the Israeli Treasury carried out an auction reform in 2006 to enhance liquidity (Sade et al. (2018)). Since the reform, foreigners' holdings of government debt have increased substantially. For example, in 1995 they held a mere 0.2% of traded government debt; by 2021, their holdings had risen to an average of 11%.

Trade size and tick size on the TASE. The minimum trade size for regular trading sessions on the TASE is 30,000 NIS in the period we examine, equivalent to approximately \$9,000. During the auction session preceding the start of trading, the minimum trade size is reduced to 1 NIS to allow smaller retail traders buy government bonds in the auction session. The minimum tick size (the smallest increment at which prices can move) is 0.01 NIS, which is equivalent to approximately \$0.003.

Market making. The reform in 2006 introduced local and foreign market makers who enjoyed certain privileges (e.g., 80% of primary auctions were designated only for market makers) and also introduced a new trading platform for dealers.

Market makers operating on the TASE have an obligation to provide quotes in the inter-dealer market through the MTS system and to participate in the issuance of Israeli debt. By regulation, market makers are required to purchase a minimum of 4% of the issued debt, or 150 million dollars, whichever is lower, on a quarterly basis. As of December 2020, the TASE had a total of 13 market makers, of which 6 were local banks and 7 were foreign banks.

Repo and futures market. There is currently no repo market in Israel, although—based on conversations with market makers—there is a demand for it, given that the market has grown and become more international. There have been efforts by the Treasury to establish a repo market, but have proved unsuccessful until now. As a substitute for the repo market and to facilitate trading by market makers, the Treasury lets market makers borrow government bonds.[16]

The Treasury futures market never developed, given that the market was historically small. As a result, market makers manage all of their interest-rate risk via interest rate swaps (IRS).

Israeli banking sector. The Israeli banking sector is highly concentrated with a small number of large banks controlling most of the domestic banking system. The seven largest banks in Israel hold approximately 99.6% of the market. At the end of 2019, the five largest banks held over 90% of banking credit, with "Leumi" and "Hapoalim" accounting for over 50% of the market. These banks provide a broad range of financial services, including business, commercial, and retail banking, and some operate abroad through a network of branches and subsidiaries.

Banking regulations. The regulatory framework in the Israeli banking sector is based on the Basel framework, similar to many developed countries worldwide. The Banking Supervision Department of Israel implemented the Basel II framework in mid-2010. It adopted the regulatory provisions, such as capital adequacy and leverage ratios, shortly after publication by the Basel committee, in line with other developed countries. For instance, after the pub-

[16] See `https://www.gov.il/BlobFolder/policy/regulation-05/en/files-eng_Regulations_regulation-05-file-en.pdf`, accessed on July 18, 2023.

lication of the updated framework on capital adequacy, Basel III by the Basel Committee in December 2010, the Israeli banking supervision of Banks published new minimum core capital targets in March 2012 (see Bank of Israel (2012); Israel's Banking System - Annual Survey (2012) pp. 68-71). For more information on supervisory capital requirements and banking capital ratios in Israel and globally, see Bank of Israel (2019).

On the eve of the COVID-19 crisis, analysis of the quality of Israeli banks' credit portfolios showed a high level of performance, comparable to the U.S. banking system and other advanced economies (c.f. Israel's Banking System-Annual Survey (2019) Box 1.3, pp. 47-55).

B Details regarding the netting counterfactual

In this appendix we provide mathematical details regarding the differences in settlement obligations in the government bond market between Israel and the U.S., focusing on how netting practices affect these obligations across dealer-customer and inter-dealer trades. Further, we develop lower and upper bounds for dealers' obligations under different counterfactual scenarios: netting of inter-dealer trades, no netting between dealers and customers, and all customer trades routed through dealers.

Settlement obligations. In Israel, dealers need only absorb trades with customers that do not cancel each other out (for settlement purposes). In practice, such canceling happens when one customer seeks to sell an amount of security s to dealer i and another customer seeks to buy that amount of the same security from dealer i. Assume that N dealers and K customers trade S securities on day t. Dealer i trades with K_i customers. Then, in Israel's status quo—whereby dealers can net all their trades with the same security—the dealers' daily obligation to the CCP is

$$Q_t^{IL} = \sum_{s \in S} \sum_{i=1}^{N} \left| \sum_{k=1}^{K_i} (d2c\_buy_{i,k,s,t} - d2c\_sell_{i,k,s,t}) + \sum_{j=1, i \neq j}^{N} (d2d\_buy_{i,j,s,t} - d2d\_sell_{i,j,s,t}) \right|, \tag{6}$$

where $d2c\_buy_{i,k,s,t} > 0$ is the amount dealer i buys from customer k of security s on day t and $d2c\_sell_{i,k,s,t} > 0$ is the amount the dealer sells to that customer. Similarly, $d2d\_buy_{i,k,s,t}$ and $d2d\_sell_{i,k,s,t}$ denote traded amounts between dealers. This is the case that is depicted in Figure 11d.

Under U.S. settlement arrangements, dealer-customer trades are not netted, while all inter-dealer trades are netted for settlement purposes. Let's define $Q_t^{\text{NoCustomerNet}}$ as the gross obligation of dealers in this scenario:

$$Q_t^{\text{NoCustomerNet}} = \sum_{s \in S} \sum_{i=1}^{N} \sum_{k=1}^{K_i} (d2c\_buy_{i,k,s,t} + d2c\_sell_{i,k,s,t}) + \sum_{s \in S} \sum_{i=1}^{N} \left| \sum_{j=1, i \neq j}^{N} d2d\_buy_{i,j,s,t} - d2d\_sell_{i,j,s,t} \right|. \tag{7}$$

When moving from the Israeli status quo to the U.S. counterfactual, customer-to-customer trades need to be routed through dealers. Accounting for this, the total counterfactual gross obligation becomes

$$Q_t^{\text{CF}} = Q_t^{\text{NoCustomerNet}} + Q_t^{C2C} \text{ with } Q_t^{C2C} = \sum_{s \in S} \sum_{k=1}^{K} \sum_{l=1}^{K} (c2c\_buy_{k,l,s,t} + c2c\_sell_{k,l,s,t}), \tag{8}$$

where $c2c\_buy_{k,l,s,t}$ represents the amount customer k buys from customer l, and $c2c\_sell_{k,l,s,t}$ is the amount customer k sells to customer l. This example is depicted in Figure 11c.

Bounds on settlement obligations. Since we cannot distinguish between dealers, but only know the types of the counterparties (dealer or customer), we cannot compute the dealers' gross obligations exactly. Concretely, we cannot compute Q_t^{IL} or Q^{CF} as defined in (6) and (8) because we don't observe the identify of any trader. We only observe $\sum_{i=1}^{N} \sum_{k=1}^{K_i} d2c\_buy_{i,k,s,t}$, $\sum_{i=1}^{N} \sum_{j=1,i \neq j}^{N} d2d\_buy_{i,j,s,t}$, $\sum_{i=1}^{N} \sum_{k=1}^{K_i} d2c\_sell_{i,k,s,t}$, $\sum_{i=1}^{N} \sum_{j=1,i \neq j}^{N} d2d\_sell_{i,j,s,t}$, and all analogous sums.

However, we can calculate lower and upper bounds for both Q_t^{IL} and Q_t^{CF}. An upper bound for Q_t^{IL} is the gross settlement obligations dealers have on a daily basis before any netting occurs. This is the sum of dealers' purchases and sales on day t:

$$\overline{Q}_t^{IL} = \sum_{s \in S} \sum_{i=1}^{N} \sum_{k=1}^{K_i} \left(d2c\_buy_{i,k,s,t} + d2c\_sell_{i,k,s,t} \right) + \sum_{s \in S} \sum_{i=1}^{N} \sum_{j=1, i \neq j}^{N} \left(d2d\_buy_{i,j,s,t} + d2d\_sell_{i,j,s,t} \right). \tag{9}$$

A lower bound is:

$$\underline{Q}_t^{IL} = \sum_{s\in S}\left|\sum_{i=1}^{N}\sum_{k=1}^{K_i}\left(d2c\_buy_{i,k,s,t} - d2c\_sell_{i,k,s,t}\right) + \sum_{i=1}^{N}\sum_{j=1,i\neq j}^{N}\left(d2d\_buy_{i,j,s,t} - d2d\_sell_{i,j,s,t}\right)\right|$$
$$= \sum_{s\in S}\left|\sum_{i=1}^{N}\sum_{k=1}^{K_i}\left(d2c\_buy_{i,k,s,t} - d2c\_sell_{i,k,s,t}\right)\right|. \tag{10}$$

Notice the subtle change of the absolute value relative to expression (6), since we can't calculate the netting of each dealer separately. Given this change of taking the absolute values $\underline{Q}_t^{IL} \leq Q_t^{IL}$ by the triangle inequality.

To intuitively understand why $\underline{Q}_t^{IL}$ is a lower bound note that

$$\sum_{i=1}^{N}\sum_{j=1,i\neq j}^{N}\left(d2d\_buy_{i,j,s,t} - d2d\_sell_{i,j,s,t}\right) = 0$$

because, among dealers, for every dealer that bought there is always a dealer who sold. Moreover, the summation of dealer-to-customer trades is an underestimate because we are essentially netting dealers' trades with customers' trades that did not necessarily occur. For illustration, say there are two dealers, A and B. One is long 100 (bought 100 from customer 1) and one is short 100 (sold 100 to customer 2). Dealers A and B's total obligations are 200. However, in our calculation, we net these trades even though the dealers did not actually trade with each other, so the total obligations are exactly zero.

Taken together,

$$\underline{Q}_t^{IL} \leq Q_t^{IL} \leq \overline{Q}_t^{IL}. \tag{11}$$

Next, we compute bounds for the change in dealers' gross obligations when going from the Israeli rules to the U.S. rules, $\Delta Q_t = Q_t^{CF} - Q_t^{IL}$ as follows:

$$
\begin{aligned}
\Delta Q_t &= Q_t^{\text{NoCustomerNet}} + Q_t^{C2C} - Q_t^{IL} \\
&= \sum_{s\in S}\sum_{i=1}^{N}\sum_{k=1}^{K_i}(d2c\_buy_{i,k,s,t} + d2c\_sell_{i,k,s,t}) + \sum_{s\in S}\sum_{i=1}^{N}\left|\sum_{j=1,i\neq j}^{N} d2d\_buy_{i,j,s,t} - d2d\_sell_{i,j,s,t}\right| + Q_t^{C2C} \\
&- \left(\sum_{s\in S}\sum_{i=1}^{N}\left|\sum_{k=1}^{K_i}(d2c\_buy_{i,k,s,t} - d2c\_sell_{i,k,s,t}) + \sum_{j=1,i\neq j}^{N}(d2d\_buy_{i,j,s,t} - d2d\_sell_{i,j,s,t})\right|\right) \\
&\geq \sum_{s\in S}\sum_{i=1}^{N}\sum_{k=1}^{K_i}(d2c\_buy_{i,k,s,t} + d2c\_sell_{i,k,s,t}) + \sum_{s\in S}\sum_{i=1}^{N}\left|\sum_{j=1,i\neq j}^{N} d2d\_buy_{i,j,s,t} - d2d\_sell_{i,j,s,t}\right| + Q_t^{C2C} \\
&- \sum_{s\in S}\sum_{i=1}^{N}\left|\sum_{k=1}^{K_i}(d2c\_buy_{i,k,s,t} - d2c\_sell_{i,k,s,t})\right| - \sum_{s\in S}\sum_{i=1}^{N}\left|\sum_{j=1,i\neq j}^{N} d2d\_buy_{i,j,s,t} - d2d\_sell_{i,j,s,t}\right| \\
&\geq Q_t^{C2C} := \underline{\Delta Q_t}. \qquad (12)
\end{aligned}
$$

Note that we can cancel the second and fifth term in the expression on the right of the inequality sign. Moreover, we use the fact that the gross sum of dealer-to-customer buys and sales (the first term in that expression) is bigger than the net sum across dealers (the fourth term).

Similarly, for the upper bound:

$$
\begin{aligned}
\Delta Q_t \leq \overline{\Delta Q}_t := \overline{Q}_t^{IL} + Q_t^{C2C} - \underline{Q}_t^{IL} \\
&= \sum_{s\in S}\sum_{i=1}^{N}\sum_{k=1}^{K_i}(d2c\_buy_{i,k,s,t} + d2c\_sell_{i,k,s,t}) \\
&\quad + \sum_{s\in S}\sum_{i=1}^{N}\sum_{j=1,i\neq j}^{N}(d2d\_buy_{i,j,s,t} + d2d\_sell_{i,j,s,t}) \\
&\quad + \sum_{s\in S}\sum_{i=1}^{N}\sum_{k=1}^{K_i}(c2c\_buy_{i,k,s,t} + c2c\_sell_{i,k,s,t}) \\
&\quad - \sum_{s\in S}\left|\sum_{i=1}^{N}\sum_{k=1}^{K_i}(d2c\_buy_{i,k,s,t} - d2c\_sell_{i,k,s,t})\right| \qquad (13)
\end{aligned}
$$

To calculate lower and upper bounds of the effect in percentage of having the U.S. regime instead of the Israeli regime, we use $\overline{Q_t}^{IL}$ and $\underline{\Delta Q_t}$ for the lower bound and $\underline{Q_t}^{IL}$ and $\overline{\Delta Q_t}$ for the upper bound.

Finally, we can decompose the upper bound of ΔQ_t ($\overline{\Delta Q_t}$) into flows that are due to all-to-all trading (customer-to-customer trades) and the change in the netting rules:

$$\begin{aligned}\overline{\Delta Qt} = & \underbrace{\sum_{s\in S}\sum_{i=1}^{N}\sum_{k=1}^{K_i}(c2c\_buy_{i,k,s,t} + c2c\_sell_{i,k,s,t})}_{\text{all-to-all trading}} \\ & + \Bigg(\underbrace{\sum_{s\in S}\sum_{i=1}^{N}\sum_{k=1}^{K_i}(d2c\_buy_{i,k,s,t} + d2c\_sell_{i,k,s,t})}_{\text{central clearing}} \\ & \quad + \underbrace{\sum_{s\in S}\sum_{i=1}^{N}\sum_{j=1,j\neq i}^{N}(d2d\_buy_{i,j,s,t} + d2d\_sell_{i,j,s,t})}_{\text{central clearing}} \\ & \quad - \underbrace{\sum_{s\in S}\left|\sum_{i=1}^{N}\sum_{k=1}^{K_i}(d2c\_buy_{i,k,s,t} - d2c\_sell_{i,k,s,t})\right|}_{\text{central clearing}}\Bigg) \end{aligned} \tag{14}$$

The lower bound equals to customer-to-customer flows.

Appendix Figure A4 shows the the bounds on ΔQ_t are relatively tight. Part of the reason for this is that customer-to-customer trades are very large compared to dealer-to-dealer and dealer-to-customer transactions throughout most of our sample (recall Figure 9).

C Liquidity in the 2007–2009 financial crisis

Financial crisis versus March 2020. The main trigger for the crisis in March 2020 was a global pandemic. In contrast, the main trigger for the 2007–2009 financial crisis was the impairment of the financial system in some countries. For example, in the U.S., “the bursting of the housing bubble forced banks to write down several hundred billion dollars in bad loans caused by mortgage delinquencies. At the same time, the stock market capitalization of the major banks declined by more than twice as much” (Brunnermeier (2009)). Unlike during the COVID pandemic, Israel was not directly affected. There was no housing bubble and the Israeli financial system was mostly stable. Only when stock markets crashed and investors around the world flew to safety were Israeli markets hit.[17]

[17] For a more detailed analysis of the financial crisis and comparison with the distress in March 2020, see Brunnermeier (2009); He et al. (2022), and Vissing-Jorgensen (2021).

Since the nature of the shock to the Israeli and other markets was fundamentally different in the financial crisis, it is difficult to interpret any cross-country analyses. For completeness, we repeat the same DD analyses for the financial crisis as we have presented for March 2020. We focus on comparing Israel with the U.S., where we find the most significant impact during the COVID crisis. However, we warn that cross-country comparisons of the financial crisis should be taken with a grain of salt, since identifying assumptions that validate the DD exercises might not be met.

Additional data. To repeat our analysis of the 2007–2009 financial crisis, we collect analogous data for Israel and the U.S. for 2019–2020 (described in Section 3) but from August 1, 2008 until October 31, 2008. For U.S. government bonds, we use price data from TradeWeb rather than Bloomberg because Bloomberg prices appear stale in that period. We observe daily average bid and ask prices per maturity class (e.g., 2-year) for government bonds with maturity above 2 years. Therefore, the security fixed effect turns in all regressions into a maturity-class-fixed effect for bonds.

As before, we need to choose a cutoff date for the static DD analyses. We use September 15, 2008, as our cutoff because Lehman Brothers filed for bankruptcy on that day. Three days later (September 18, 2008), there was massive selling in the U.S. markets for a total of $550 billion within a few hours, which led the Fed to intervene in the market.

Within-country DD. We start by comparing stock versus government bond spreads within a country. For Israel, we find no significant effect when comparing stock versus government bond spreads, much like 2020 and in line with our hypothesis (see Appendix Table A8). For the U.S., we find that stock spreads rose more strongly than bond spreads (see Appendix Table A8). This is different from 2020 and in line with the pattern we can observe in the time-series plot of spreads (see Appendix Figure A5a).

One explanation is that the U.S. stock market was more strongly affected by the deterioration of the financial system than the bond market. Stock prices fell dramatically as investors sold stocks and flew to safety. At the same time, bond dealers provided sufficient liquidity. In sharp contrast to March 2020, dealers "came into the financial crisis with a short position in Treasuries, and they scrambled to obtain more Treasuries" (He et al. (2022)). Furthermore, dealers did not face the same stringent capital constraints as they did in 2020.

Cross-country DDD. We conduct two cross-country regressions that require two identifying assumptions. First, we compare bond spreads between the U.S. and Israel and estimate regressions the following regressions using data for bonds:

$$\log \mathrm{BAS}_{it} = \beta_0 + \beta_1 \mathrm{IL} + \beta_2 \mathrm{post} + \beta_3 \mathrm{IL} \times \mathrm{post} + u_{it}, \tag{15}$$

$$\log \mathrm{BAS}_{it} = \xi_i + \xi_t + \beta_3 \mathrm{IL} \times \mathrm{post} + u_{it}. \tag{16}$$

The regressions are analogous to (1) and (2), but replace the indicator stock with an indicator IL for whether the bond is Israeli or not. Second, we compare the bond-stock spread across both countries, as we did in the main text with regression (3).

We find no significant effect when comparing bond spreads across countries and a significant positive effect when comparing bond-stock spreads (see Appendix Tables A9 and A10). However, the latter is driven by the large increase in U.S. stock spreads relative to U.S. bond spreads we found above and reported only for completeness. Importantly, this finding is not robust to changes in the cutoff date and should therefore not be taken at face value. The dynamic DDD in Appendix Figure A6 shows that the pattern is noisy and there seems to be no clear trend.

Take away. Taken together, our evidence suggests that there was no significant cross-country difference in market liquidity in the financial crisis of 2007–2009. We conjecture that this might be the case for two reasons. First, the selling pressure was different across countries and across markets compared with 2020. Second, U.S. dealers were not as balance-sheet constrained in 2007–2009. This suggests that exchanges enhance liquidity when intermediaries are hindered in providing the necessary liquidity because they face constraints.

Appendix Table A1: **Descriptive statistics of spreads for all markets—pre-crisis**

Large economies	**Mean (%)**	**S.D (%)**	**Min. (%)**	**Max. (%)**	**# Obs.**	**# Sec.**	**# Days**
GER stocks	0.037	0.012	0.020	0.081	570	30	19
GER gov bonds	0.046	0.045	0.001	0.278	577	30-31	19
JPN stocks	0.093	0.068	0.018	0.503	3825	225	17
JPN gov bonds	0.149	0.127	0.019	0.633	1368	72	19
UK stocks	0.070	0.035	0.015	0.396	1916	100-101	19
UK gov bonds	0.042	0.028	0.010	0.167	464	24-26	19
US stocks	0.056	0.035	0.007	0.463	9054	503	18
US gov bonds	0.032	0.014	0.004	0.111	1290	66-71	19
US futures	0.009	0.006	0.002	0.020	76	4	19
Small economies							
GR stocks	0.299	0.171	0.084	1.142	475	26	19
GR gov bonds	0.301	0.166	0.097	0.836	207	10-11	19
IE stocks	0.482	0.566	0.044	5.398	380	20	19
IE gov bonds	0.132	0.076	0.041	0.412	304	16	19
IL stocks	0.215	0.093	0.059	0.771	700	35	20
IL gov bonds	0.050	0.104	0.010	1.609	317	15-16	20
KR stocks	0.236	0.106	0.076	0.611	3800	200	19
KR gov bonds	0.105	0.159	0.000	0.763	418	22	19
KR gov bonds exchange	0.123	0.080	0.010	0.322	195	6-13	19
MX stocks	0.172	0.172	0.022	2.403	630	35	18
MX gov bonds	0.223	0.136	0.011	0.723	304	16	19
PL stocks	0.184	0.087	0.049	0.676	380	20	19
PL gov bonds	0.112	0.038	0.053	0.233	304	16	19
PT stocks	0.375	0.443	0.039	3.241	342	18	19
PT gov bonds	0.071	0.037	0.015	0.205	285	15	19
High-low spreads							
IL gov bonds–OTC	0.28	0.47	0.00	1.88	29	11	15
IL gov bonds–exchange	0.19	0.20	0.01	1.09	313	15-16	20

Notes: Appendix Table A1 provides descriptive statistics (mean, standard deviation, minimum, and maximum) for the daily average bid-ask spreads across various markets during the pre-crisis between February 1, 2020, and February 27, 2020. We also display the number of observations (# Obs.), and the number of securities we observe in a day (# Sec.), in addition to the number of days (# Days). The number of securities we observe in a day varies, for example due to new bond issuances. The number of days vary because of weekends or holidays. The government bonds analyzed have maturities over two years and were on-the-run between January 1, 2019, and March 31, 2020. For most government bond markets, bid-ask spreads are based on Bloomberg BNG prices, while for the Israeli and South Korean exchanges, proprietary limit order book data is used. The stock indices covered are: DAX 30 (Germany, GER) NIKKEI 225 (Japan, JPN) FTSE 100 (UK, UK) S&P 500 (U.S., US) FTSE (Greece, GR) ISEQ 20 (Ireland, IE) TA-35 (Israel, IL) KOSPI 200 (South Korea, KR) MEXBOL (Mexico, MX) WIG 20 (Poland, PL) PSI 20 (Portugal, PT). The "High-Low Spreads" section presents statistics on the daily high-low spread for Israeli government bonds traded on TASE and OTC. Days with only a single trade or identical high and low prices (likely indicating one-sided trading) are excluded. Source: Bloomberg, South Korean Stock exchange, and TASE.

Appendix Table A2: **Descriptive statistics of spreads for all markets during the crisis**

Large economies	**Mean (%)**	**S.D (%)**	**Min. (%)**	**Max. (%)**	**# Obs.**	**# Sec.**	**# Days**
GER stocks	0.050	0.015	0.021	0.099	270	30	9
GER gov bonds	0.065	0.059	0.005	0.383	279	31	9
JPN stocks	0.111	0.081	0.023	0.666	2250	225	10
JPN gov bonds	0.206	0.197	0.019	1.295	727	71-73	10
UK Stocks	0.087	0.034	0.021	0.238	800	100	8
UK gov bonds	0.073	0.049	0.017	0.258	208	26	8
US Stocks	0.111	0.074	0.010	0.921	5533	503	11
US gov bonds	0.150	0.157	0.008	1.148	795	72	11
US futures	0.013	0.013	0.002	0.071	44	4	11
Small economies							
GR stocks	0.473	0.254	0.122	1.760	200	26	8
GR gov bonds	0.590	0.318	0.166	1.821	99	11	9
IE stocks	0.554	0.610	0.058	4.191	180	20	9
IE gov bonds	0.161	0.074	0.060	0.392	144	16	9
IL stocks	0.359	0.192	0.065	1.006	280	35	8
IL gov bonds	0.079	0.093	0.015	0.555	128	16	8
KR stocks	0.239	0.103	0.082	0.633	1800	200	9
KR gov bonds	0.141	0.215	0.000	0.913	200	22-23	9
KR gov bonds–Exchange	0.145	0.250	0.000	2.138	74	6-11	9
MX stocks	0.206	0.184	0.027	1.243	490	35	11
MX gov bonds	0.323	0.305	0.010	3.353	240	16	11
PL stocks	0.296	0.127	0.089	0.803	220	20	11
PL gov bonds	0.129	0.049	0.061	0.253	176	16	11
PT stocks	0.533	0.729	0.050	5.670	162	18	9
PT gov bonds	0.104	0.054	0.028	0.278	135	15	9
High-low spreads							
IL gov bonds–OTC	2.09	2.78	0.01	12.31	26	10	8
IL gov bonds–Exchange	0.73	0.94	0.01	5.11	128	16	8

Notes: Appendix Table A2 provides descriptive statistics (mean, standard deviation, minimum, and maximum) for the daily average bid-ask spreads across various markets during the crisis period before monetary policy interventions. Specifically, it covers February 28, 2020 until the first announcement of monetary policy measures in each country. We also display the number of observations (# Obs.), and the number of securities we observe in a day (# Sec.), in addition to the number of days (# Days). The number of securities we observe in a day varies, for example due to new bond issuances. The government bonds analyzed have maturities over two years and were on-the-run between January 1, 2019, and March 31, 2020. For most government bond markets, bid-ask spreads are based on Bloomberg BNG prices, while for the Israeli and South Korean exchanges, proprietary limit order book data is used. The stock indices covered are: DAX 30 (Germany, GER) NIKKEI 225 (Japan, JPN) FTSE 100 (UK, UK) S&P 500 (U.S., US) FTSE (Greece, GR) ISEQ 20 (Ireland, IE) TA-35 (Israel, IL) KOSPI 200 (South Korea, KR) MEXBOL (Mexico, MX) WIG 20 (Poland, PL) PSI 20 (Portugal, PT). The "High-Low Spreads" section presents statistics on the daily high-low spread for Israeli government bonds traded on TASE and OTC from February 28, 2020 until the first monetary policy intervention. Days with only a single trade or identical high and low prices (likely indicating one-sided trading) are excluded. Source: Bloomberg, South Korean Stock exchange, and TASE.

Appendix Table A3: **Within-country DD of bonds vs. stocks—Only country fixed effects**

	OTC	TASE	KRX
stock	+0.243***	−1.754***	+0.762***
	(0.049)	(0.159)	(0.183)
post	+0.439***	+0.430***	−0.073
	(0.024)	(0.052)	(0.076)
stock×post	−0.107***	+0.047	+0.089
	(0.026)	(0.058)	(0.078)
Observations	48,102	1,831	7,172
Adjusted R^2	0.463	0.687	0.136

Notes: Table A3 shows results of DD regression (1). In column (OTC), we use data from all countries in our sample excluding Israel from February 1, 2020, through March 10, 2020, inclusive. As placebo tests, we show the estimates for the Israeli and South Korean Stock Exchange in columns (TASE) and (KRX). Here, we use proprietary price data from the two exchanges, again from February 1, 2020 until each country's first announcement of monetary policy measures. The dependent variable is the daily log spread of a security; stock is 1 for stocks and 0 for bonds; post is 1 starting on February 28, 2020. Standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg, South Korean Stock Exchange, TASE.

Appendix Table A4: **Within-country DD of bonds vs. stocks for each country**

	GER	GR	JPN	IE	MX	PL	PT	KR	UK	US	IL	KRX
stock×post	−0.081**	−0.120*	−0.088***	−0.072	−0.145**	+0.392***	−0.049	−0.249**	−0.213***	−0.604***	+0.061	+0.058
	(0.037)	(0.063)	(0.027)	(0.055)	(0.064)	(0.031)	(0.057)	(0.113)	(0.058)	(0.024)	(0.057)	(0.059)
Observations	2,059	1,073	10,405	1,224	2,091	1,332	1,122	7,308	4,139	20,607	1,831	7,169
Adjusted R^2	0.884	0.846	0.940	0.959	0.785	0.911	0.956	0.812	0.891	0.892	0.925	0.814

Notes: Appendix Table A4 shows results of DD regression (1) with security and day fixed effects, separately for each country (Germany, Greece, Japan, Ireland, Mexico, Poland, Portugal, South Korea, U.K. U.S.), using data from February 1, 2020, until the first announcement of monetary policy measures in each country. Column (KR) shows the results for South Korea, when relying on Bloomberg prices that reflect averages of the entire market which is mostly OTC. In the last two columns, we show the estimates for the Israeli and South Korean Stock Exchange (KRX), respectively, where we use proprietary price data from the exchanges. The dependent variable is the daily log spread of a security; stock is 1 for stocks and 0 for bonds; post is 1 starting on February 28, 2020. Standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg, South Korean Stock Exchange, TASE.

Appendix Table A5: **Cross-country DDD—Only country fixed effects**

	All	Large	No US	Small	No PL
bond×post	+0.156***	+0.194***	+0.137***	+0.055	+0.129***
	(0.021)	(0.025)	(0.027)	(0.036)	(0.039)
bond×IL×post	−0.290***	-0.328***	−0.271***	−0.189**	−0.263***
	(0.069)	(0.070)	(0.071)	(0.075)	(0.076)
Observations	49,780	36,503	17,624	14,955	13,767
Adjusted R^2	0.532	0.328	0.343	0.389	0.387

Notes: Appendix Table A5 shows the main coefficients of interest from the cross-country DDD regression (3) when we only include country fixed effects. The regression becomes: $\log \mathrm{BAS}_{it} = \xi_c + \sum_c (\xi_c \times \text{bond}) + \sum_c (\xi_c \times \text{post}) + \beta_1 \text{bond} + \beta_2 \text{post} + \delta_1 \text{bond} \times \text{post} + \delta_2 \text{bond} \times \text{IL} \times \text{post} + u_{it}$. The dependent variable is the daily log spread of a security; ξ_c is a country fixed effect; bond is 1 for bonds and 0 for stocks; IL is 1 for Israeli securities and 0 otherwise; post is 1 starting on February 28, 2020. In column (All) we use data of all countries in our sample from February 1, 2020, through March 10, 2020, inclusive. In column (Large) we compare the large economies, U.S., U.K., Germany, Japan, to Israel, and in column (Small) the small economies, Greece, Ireland, Mexico, Poland, Portugal, and South Korea. We exclude the U.S. from the large countries in column (No US), and Poland from the small countries in column (No PL). Standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg and TASE.

Appendix Table A6: **Cross-country DDD for each country**

	GER	GR	JPN	IE	MX	PL	PT	KR	UK	US	KRX
bond×post	+0.081**	+0.120*	+0.088***	+0.072	+0.050	−0.385***	+0.049	+0.249**	+0.213***	+0.604***	−0.058
	(0.037)	(0.062)	(0.027)	(0.054)	(0.057)	(0.027)	(0.056)	(0.113)	(0.058)	(0.024)	(0.059)
bond×IL×post	−0.223***	−0.263***	−0.186***	−0.214***	−0.110	+0.324***	−0.191**	−0.391***	−0.362***	−0.665***	−0.084
	(0.070)	(0.086)	(0.063)	(0.081)	(0.081)	(0.063)	(0.082)	(0.128)	(0.084)	(0.061)	(0.084)
Observations	3,788	2,802	12,185	2,953	3,667	3,125	2,851	9,037	5,817	22,438	8,898
Adjusted R^2	0.944	0.930	0.939	0.943	0.879	0.923	0.939	0.880	0.927	0.906	0.885

Notes: Appendix Table A6 shows results of DDD regression (3) with country-day, and security fixed effects, separately for each of the comparison countries (Germany, Greece, Japan, Ireland, Mexico, Poland, Portugal, South Korea, U.K. U.S.), using data from February 1, 2020, until the first announcement of monetary policy measures in each country. Column (KR) shows the results for South Korea, when relying on Bloomberg prices that reflect averages of the entire market which is mostly OTC; while column (KRX) uses proprietary price data from the South Korean exchange. The dependent variable is the daily log spread of a security. Indicator variable bond is 1 for bonds and 0 for stocks; IL is 1 for Israeli securities and 0 otherwise; post is 1 starting on February 28, 2020. Standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg, South Korean Stock Exchange, TASE.

Appendix Table A7: **Within-country DD—U.S., Israel, South Korea—Without fixed-effects**

	US	IL	KR
exchange	−1.408***	+0.287	+0.023
	(0.428)	(0.309)	(0.225)
post	+1.156***	+2.141***	+0.265**
	(0.049)	(0.439)	(0.114)
exchange×post	−0.982***	−0.994**	−0.338**
	(0.094)	(0.458)	(0.122)
Observations	2,643	496	880
Adjusted R^2	0.497	0.199	0.012

Notes: Table A7 shows results of DD regression (4) for the U.S., Israel (IL), and South Korea (KR), respectively, using data from February 1, 2020, through the first day of each country's central bank intervention. For the U.S., the dependent variable is the daily log spread of a security; exchange is 1 for futures and 0 for bonds. For Israel and the South Korean exchange, exchange is 1 when the trade is on the exchange and 0 when it is OTC. For Israel, where we don't observe bid-ask spreads in the OTC market, the dependent variable is the log of the difference between the highest and lowest trade price of a security within a day, normalized by the average of these two prices. We exclude cases when there is a single trade of a security within a day, or the highest and lowest trade prices are identical (likely, because all investors execute trades in the same direction). For South Korea, we use the daily bid-ask spread from the South Korean stock exchange for trades on the exchange and the Bloomberg bid-ask spread for all trades on and off the exchange. In all specifications, post is 1 starting on February 28, 2020. Standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg, the Chicago Mercentile Exchange, the TASE, South Korean Stock Exchange.

Appendix Table A8: **Financial crisis—Within-country DD of stocks vs. bonds**

	US OLS		US FE		IL OLS		IL FE	
stock	+1.724***	(0.219)			+1.620***	(0.222)		
post	+0.421***	(0.069)			+0.532***	(0.056)		
stock×post	+0.508***	(0.072)	+0.527***	(0.072)	+0.020	(0.062)	+0.020	(0.063)
Observations	26,839		26,839		1,855		1,855	
Adjusted R^2	0.223		0.541		0.626		0.926	
Security, and day fixed effects	−		+		−		+	

Notes: Appendix Table A8 shows the results of DD regressions (1) in columns (OLS), and adds security- and day fixed effects in column (FE), respectively, for the U.S. and for Israel, using data from August 1, 2008, until October 15, 2008. The dependent variable is the daily log spread of a security (either a constituent of the S&P 500 or the TA 35 index; or a U.S. or Israeli government bond with maturity above 2 years). Indicator variable stock is 1 for stocks and 0 for bonds; post is 1 starting on September 15, 2008. Standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg, TradeWeb, and TASE.

Appendix Table A9: **Financial crisis—Cross-country DD with Treasuries**

	OLS		FE	
IL	+0.940***	(0.305)		
post	+0.421***	(0.071)		
IL×post	+0.111	(0.091)	+0.111	(0.094)
Observations	954		954	
Adjusted R^2	0.351		0.861	
Security, and day fixed effects	−		+	

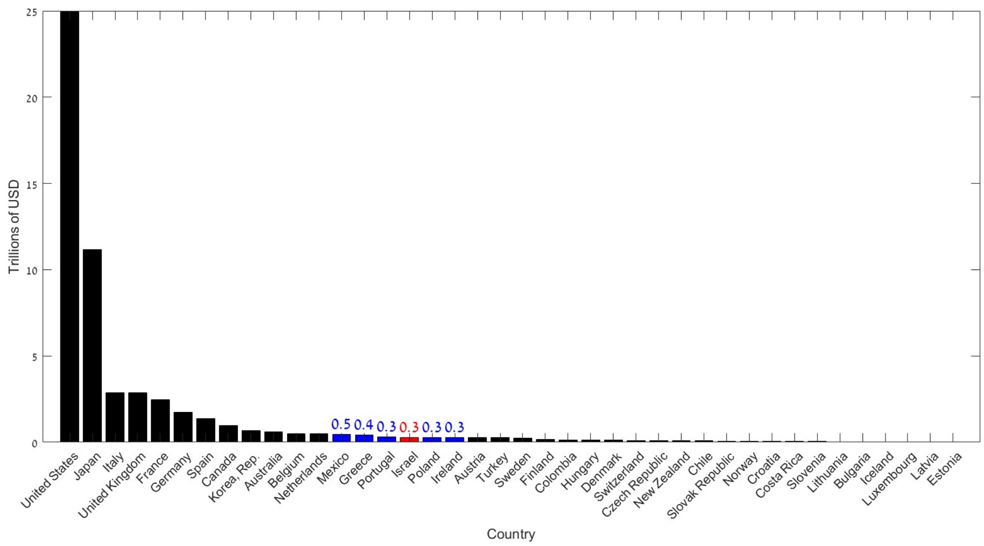
Notes: Appendix Table A9 shows the results of DD regressions (15) in columns (OLS) and adds security and day fixed effects in column (FE), using data from August 1, 2008, until October 15, 2008. The dependent variable is the daily log spread of a security (either a U.S. or Israeli government bond with maturity above 2 years). Indicator variable IL is 1 for Israeli securities and 0 otherwise; post is 1 starting on September 15, 2008. Standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: TradeWeb and TASE.

Appendix Table A10: **Financial crisis—Cross-country DDD**

	OLS		FE	
bond	−1.724***	(0.219)		
IL	+0.835***	(0.089)		
post	+0.929***	(0.022)		
bond×IL	+0.104	(0.310)		
post×IL	−0.377***	(0.034)		
bond×post	−0.508***	(0.072)	−0.527***	(0.072)
bond×IL×post	+0.489***	(0.095)	+0.507***	(0.095)
Observations	28,694		28,694	
Adjusted R-squared	0.246		0.561	
Country-day, and security fixed effects	−		+	

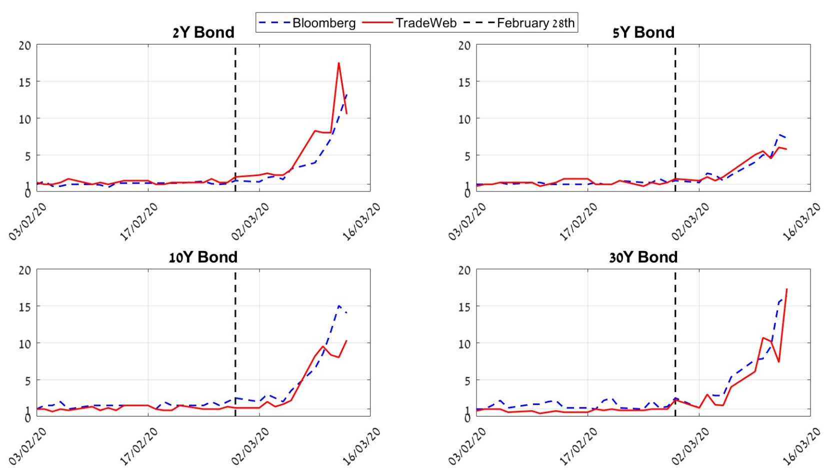
Notes: Appendix Table A10 shows results of our cross-country DDD regression in columns (OLS) and adds country-day, security fixed effects in column (FE), using data from August 1, 2008, until October 15, 2008. The dependent variable is the daily log spread of a security (either a constituent of the S&P 500 or the TA 35 index; or a U.S. or Israeli government bond with maturity above 2 years). Indicator variable bond is 1 for bonds and 0 for stocks; IL is 1 for Israeli securities and 0 otherwise; post is 1 starting on September 15, 2008. Standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg, TradeWeb, and TASE.

Appendix Figure A1: **Size of the government bond market of OECD countries**



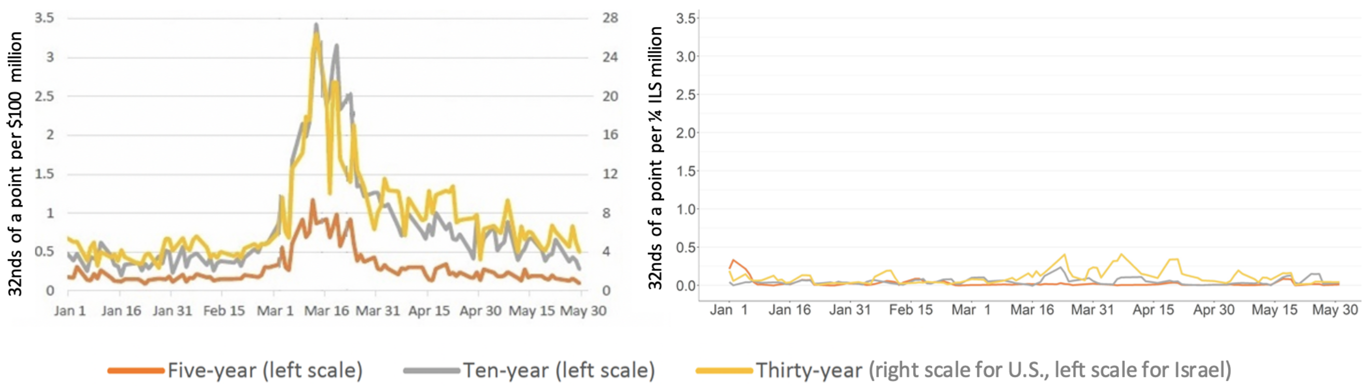
Notes: Appendix Figure A1 shows the amount of national government debt outstanding in 2020, expressed in US$ trillion, for the OECD countries. We compute the amount of debt by multiplying annual ratio of debt to GDP ratio of each country, provided by the International Monetary Fund, by each countries annual GDP, provided by the World Bank. We highlighted (in blue) the comparison countries which have roughly the same amount of national debt outstanding in 2020 as Israel (in red). Source: Data collected by Abudy et al. (2024).

Appendix Figure A2: Comparison of TradeWeb and Bloomberg bid-ask spreads



Notes: Appendix Figure A2 compares the daily average bid-ask spreads using TradeWeb (solid lines) and Bloomberg data (dashed lines) for 2, 5, 10, and 30-year government bonds from February 3, 2020 to March 13, 2020. February 3 is normalized to one. Source: Bloomberg, and TradeWeb.

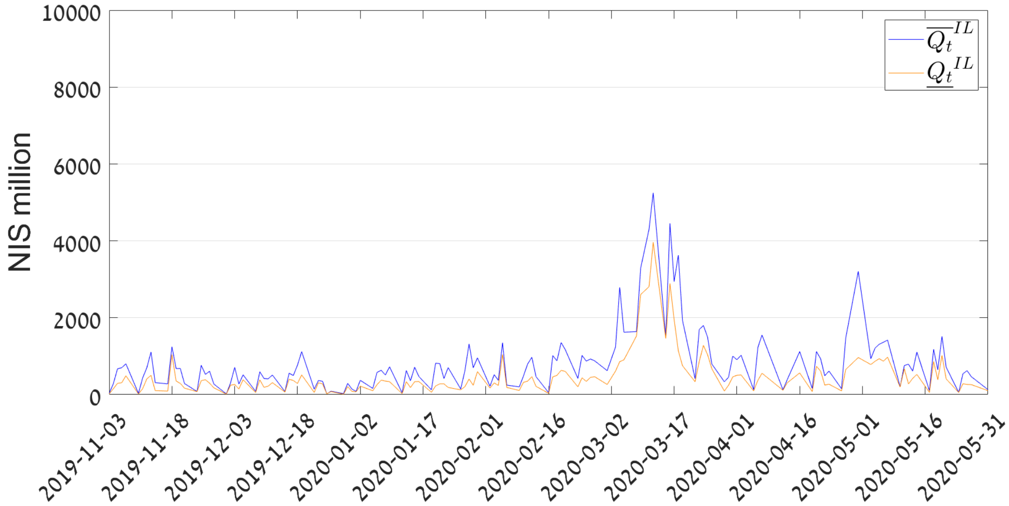
Appendix Figure A3: **Price impact**



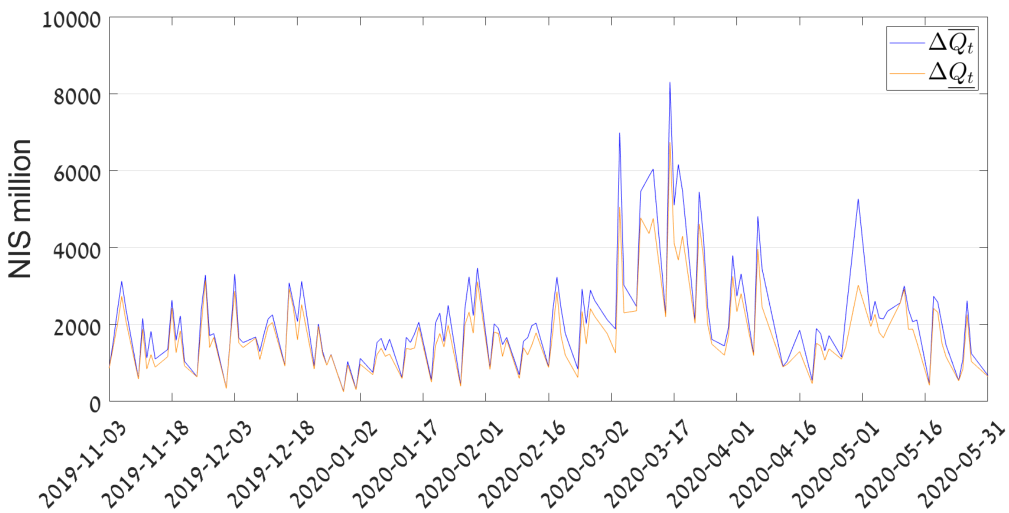
Notes: Figure A3 shows the price impact from January until the end of May 2020 for 5.-, 10-, and 30-year U.S. government bonds in the inter-dealer market on the LHS—taken from Fleming et al. (2021)—and in the Israeli government bond market on the RHS. In the U.S., the price impact is the slope coefficients from daily regressions of 1-minute price changes on 1-minute net order flow—i.e., buyer-initiated trading volume less seller-initiated trading volume. It is measured in 1/32 of a point per \$100 million, where a point equals 1% of par. In Israel, we use a 5-minute time frame and measure the price impact in 1/32 of a point per 1/4 million NIS. This is to adjust for the fact that the Israeli market is slower and smaller than the U.S. market. More specifically, the U.S. total daily trade volume in January–February 2020 was \$500–600 billion, or 1,725–2,070 billion NIS, using the average exchange rate for January–February 2020. The Israeli daily total trade volume was 1.210-1.422 billion NIS; thus the U.S. market is roughly 1,400–1,700 times as big as the Israeli market. Using this ratio, we convert the \$100 million Fleming et al. (2021) use to express the U.S. price impact into roughly 1/4 million NIS, e.g., $(\$100\frac{3.45\text{ NIS}}{\$1})/1{,}400$ NIS. To facilitate the cross-country comparison, we use the same left axis scale (0–3.5) for the U.S. and Israel. Source: BrokerTec, TASE and the Bank of Israel.

Appendix Figure A4: **Upper and lower bounds of dealers' daily gross obligations**

(a) In the status quo (Israel)



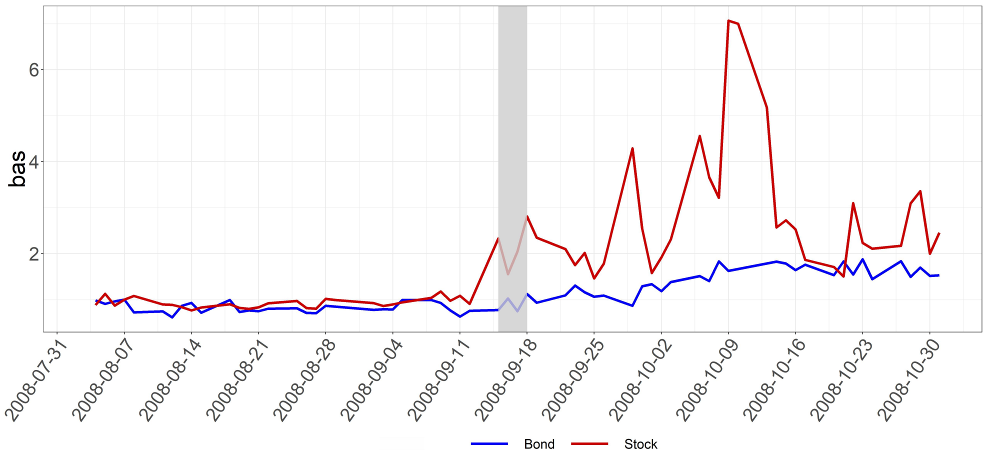
(b) In the counterfactual (U.S.)



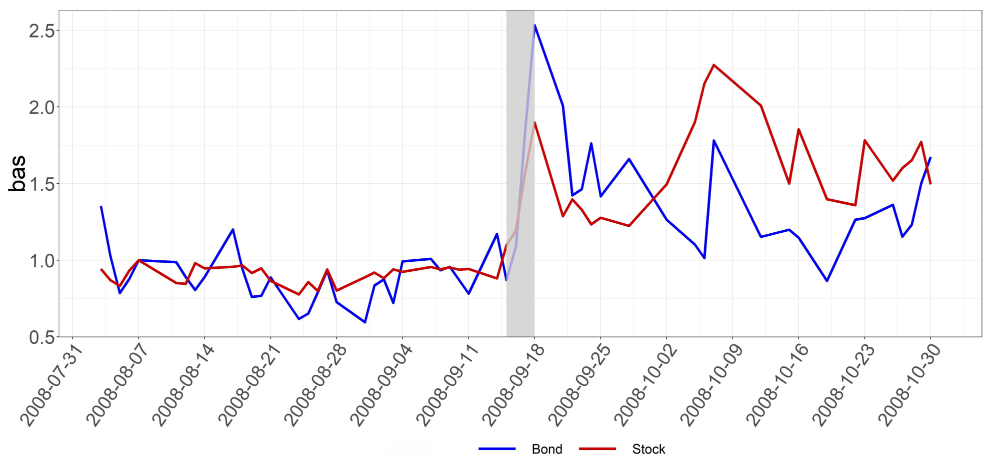
Notes: Appendix Figure A4a shows the upper and lower bounds of dealers' daily gross obligations in Israel—defined in Appendix B in equation (11)—from November 1, 2019, until June 30, 2020. Figure A4b shows the bounds for the difference between the two as in equations (12) and (13). Everything is expressed in NIS million. Source: TASE.

Appendix Figure A5: **Time series of spreads of government bonds and stock indices in 2008**

(a) U.S.

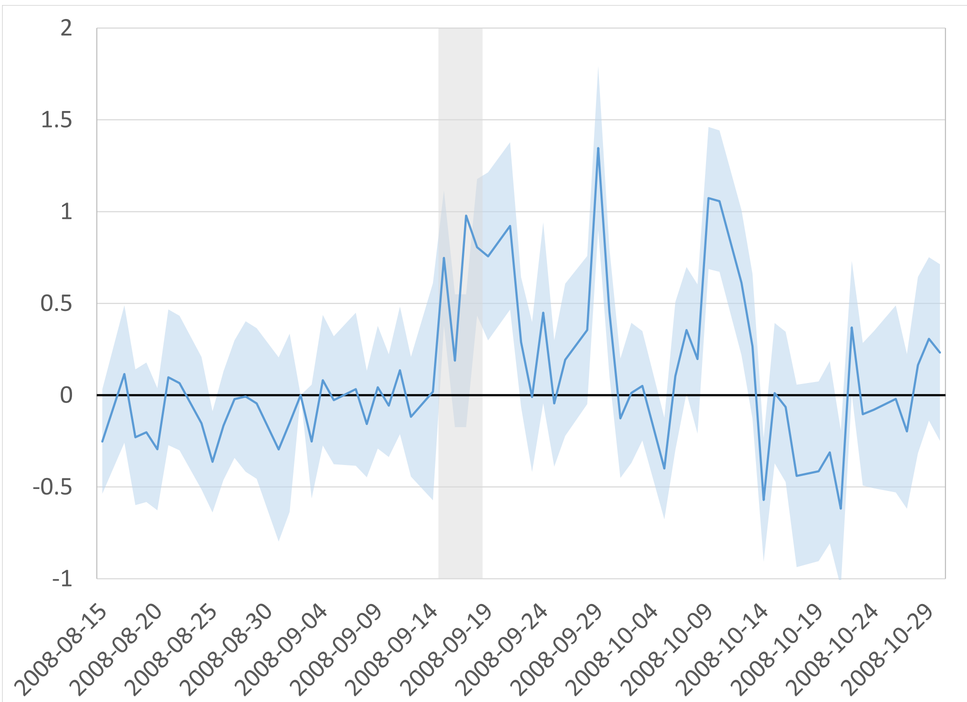


(b) Israel



Notes: Appendix Figure A5 shows the spreads of U.S. government bonds and the S&P 500 index in (a) and of Israeli government bonds and the TA 35 index in (b). The spreads in both countries are presented compared to those on August 7, 2008 (normalized to 1). Government bond spreads are weighted by the bonds' notional amounts. The shaded area marks the beginning of the crisis (September 15, 2008, until September 18, 2008). Source: Bloomberg, Tradeweb, and TASE.

Appendix Figure A6: **Dynamic DDD analysis of spreads in 2008—Israel vs. U.S.**



Notes: Appendix Figure A6 shows the $\delta_{2,k}$ coefficients and the 95% confidence bounds of regression: $\log \mathrm{BAS}_{it} = \xi_i + \xi_{ct} + \sum_{k=1}^{77} \delta_{1,k}\mathrm{bond} \times \mathrm{day}_k + \sum_{k=1}^{77} \delta_{2,k}\mathrm{bond} \times \mathrm{IL} \times \mathrm{day}_k + u_{it}$, where BAS_{it} is the spread of security i on day t; day_k equals 1 on the k^{th} day from August 15, 2008, until October 31, 2008, and 0 otherwise; bond is 1 for government bonds and 0 for stocks; ξ_i is a security, and ξ_{ct} is a country-date fixed effect. The baseline is September 2, 2008. The gray area shades the period between September 15, 2008 and September 18, 2008. Source: Bloomberg, Tradeweb, and TASE.