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 and U.S. future market) with markets lacking an exchange (like the U.S. government bond market). 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
Keywords: Exchange, OTC market, government bonds, liquidity, crisis

בורסה לאגרות חוב ממשלתיות? עדויות ממשבר הקורונה

ארי קוטאי, דניאל נתן ומילנה וויטוור

תקציר

במחקר זה אנו משתמשים במאפיין ייחודי של שוק אגרות החוב הממשלתיות בישראל, בו המסחר מתקיים בבורסה (Exchange) ולא מעבר לדלפק (Over-the-counter), כדי לנתח האם ומדוע מסחר באמצעות בורסה בזמן משבר משפיע על הנזילות בשוק. אנו בוחנים כיצד משבר הנזילות שהתרחש במרץ 2020 השפיע על שוק אגרות החוב הממשלתיות בישראל באמצעות ניתוח של הפרש הפרשים (difference-in-differences), במסגרתו אנחנו משווים נתוני מרווח קנייה-מכירה (bid-ask spared) בין שוקֵי בורסה (כמו בשוק אגרות החוב בישראל או ושוק הנגזרים בארצות הברית) לשוקים שבהם המסחר אינו מתקיים בבורסה (כמו שוק אגרות החוב הממשלתי בארצות הברית). ממצאינו תומכים בהיפותזה שבזמן משבר מסחר בבורסה משפר משמעותית את הנזילות בשוק. ניתוח של נתוני עסקאות מהבורסה בישראל מצביע כי התוצאה נובעת מיכולתם של משקיעים לספק נזילות אחד מהשני ומיעילות גבוהה יותר בצורת מסחר בבורסה—האפשרות לקיזוז (netting) של התחייבויות.

מילות מפתח: Exchange, OTC markets, government bonds, liquidity, crisis

מילות מפתח (עברית): בורסה, מסחר מעבר לדלפק, אגרות חוב ממשלתיות, נזילות, משבר.

מספרי סיווג: D4,G1,G12,G14

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 trades be centrally cleared and allow investors to trade with one another, as on an exchange (see Figure 1).[1] Unfortunately, it is difficult to provide evidence for or against this reform, because Treasuries around the world trade on decentralized OTC markets. This means that we do not observe what would happen if these markets operated on an exchange.

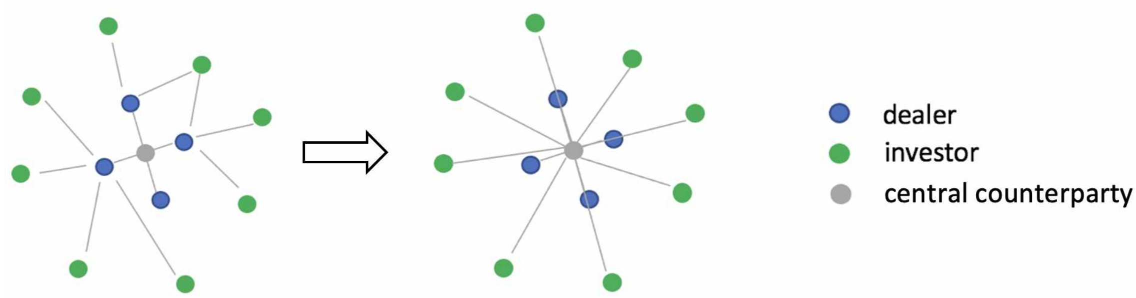
This paper exploits the fact that there is an exception—the Israeli Treasury market, which is on an exchange—to study whether and why having an exchange enhances liquidity during a crisis. After comparing the liquidity crisis in the Israeli Treasury market with the crisis in the U.S. Treasury market,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

To conduct our empirical analysis, we combine daily price data from Bloomberg, the Chicago Mercantile Exchange, and the Tel Aviv Stock Exchange (TASE) with trade-flow information from the TASE. We observe the daily bid-ask spread (henceforth spreads) for fixed-rate nominal government bonds for the U.S., Israel, U.K., Germany, and Japan. We also see the spreads of the U.S. futures market and of stocks of the largest companies in the countries we consider. For each transaction on the TASE, we know what type of trader (e.g., bank, mutual fund) buys or sells, how much, which security, and at what price.

In the first part of the paper, we compare the liquidity crisis in the Israeli Treasury

[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 clearing houses. 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).

Figure 1: **Proposed change in the market structure**



Notes: Figure 1 illustrates the proposed change in the market structure from a decentralized OTC market in which only trades between two dealers are centrally cleared and investors cannot trade with one another (LHS) to a centralized market, such as an exchange, in which investors can trade with one another and all trades are centrally cleared (RHS).

market with that of the U.S. Treasury market during March 2020. Our choice of the U.S. as a comparison country is driven by the extensive research already conducted in that market. We do not intend to imply that these two markets are generally similar. However, both markets experienced significant bond sell-offs triggered by institutional investors, with Israeli mutual funds selling over 20% of their fund size compared to 12% in the U.S (as documented by Ma et al. (2022)). While both markets experienced rising yields, the U.S. market witnessed depth evaporation and spiked spreads, whereas the Israeli exchange market remained relatively more stable.

In the second part of the paper, we examine the extent to which an exchange fosters liquidity, measured by daily spreads. To achieve this, we conduct difference-in-differences analyses, comparing how spreads in markets with exchanges changed relative to those without exchanges when the World Health Organization (WHO) declared COVID a global pandemic. Initially, we contrast the difference between government bond and stock market spreads in the U.S., U.K., Japan, and Germany, respectively, with those in Israel, while controlling for country-date fixed effects. Subsequently, we compare spreads within the U.S. and within Israel, respectively. To examine the U.S. market, we leverage the fact that U.S. Treasury futures trade on an exchange while U.S. Treasuries do not, despite sharing similar fundamentals. In the case of Israel, we utilize the common practice of large trades being conducted off the exchange (OTC) to avoid price impact.

Our findings support the idea that having an exchange enhances liquidity during a crises. The cross-country difference-in-differences comparisons show that the U.S., German, Japanese, and U.K. government bond spreads were roughly 20%–50% higher than in Israel. Additionally, the spreads for U.S. futures rose by 63%–66% less than government bond spreads, while spreads for Israeli government bonds rose by 53%-63% less on the exchange compared to off-exchange trading. Although some differences in spreads may be influenced by unobservable factors that we cannot control for, the consistency of our results pointing in the same direction offers some suggestive evidence in favor of exchanges.

In the third and final part of the paper, 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 counterparts and securities, reducing the number of securities that need to be delivered. This process lowers settlement risks and frees up balance sheet resources (see Fleming and Keane (2021), Boxes A-B, pp. 43-45).

We find that both all-to-all trading and netting played an important role in Israel. About 50% of the total amount sold was bought by investors, such as hedge funds and algorithmic trading firms. Thus non-market makers stepped in to provide liquidity. However, even though many investors were on the buy-side, the Israeli banks (who act as designated market makers) were the largest net buyers among all trader groups.

We conjecture that Israeli banks were able to absorb a substantial portion of the excess supply on their balance sheets, due to efficient netting and all-to-all trading. To support this claim, we conduct a counterfactual analysis. Our findings reveal that if the netting and all-to-all trading capabilities in Israel were as limited as in standard OTC markets, Israeli banks would have had to absorb 2.8 NIS billion instead of the actual 0.6 NIS billion in settlement obligations. This suggests that without efficient netting and all-to-all trading, Israeli banks might have faced a situation similar to U.S. banks, which failed to adequately absorb the sales on their balance sheets (Schrimpf et al. (2020)).

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 some trades are executed bilaterally and some 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

[2] An extensive theoretic 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)).

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 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. (2020); 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 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 those considered in this paper, 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 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. For instance, countries like the U.S. and Israel follow the global standards set by the Basel Committee on Banking Supervision. In Israel, the Banking Supervision Department has adopted regulatory provisions, such as capital adequacy and leverage ratios.

Israeli Exchange. 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. With regards to Israeli government bond trades, the TASE is the primary venue, accounting for approximately 99% of all trades in our sample. Therefore, our analysis primarily focuses on the TASE.

Large (block) trades are often conducted off the Israeli exchange, which is a common practice observed in exchange markets (Burdett and O'Hara (1987); Keim and Madhavan (1996)). In order to minimize any potential impact on market prices, investors engage in private negotiations with dealers to determine the price and size of the trade. This approach is akin to traditional OTC trading, and accounts for 12% of the total trade volume (see Appendix Figure A1). While these OTC trades are electronically processed through the TASE, they are neither cleared nor netted by the TASE, as it does not serve as a CCP for these transactions.[3]

[3]In addition to the TASE and off-exchange trading, there are two smaller market segments in Israeli

A natural question to ask is why the Israeli market differs from those in other countries. Abudy and Wohl (2018) explain that the TASE was created many years ago (in 1935) when market conditions were different from those in the other countries we consider, and different from today. Back then, demand and supply were so low that the exchange ran a single auction per day. This was more efficient than introducing an OTC market which involved higher human resources at the time. Then, as the market expanded, market participants became used to trading all securities on the exchange and an OTC market was not able to attract sufficient liquidity to form.

In other countries, the historical evolution of bond trading was different. For instance, in the U.S. bonds were actively traded on the New York Stock Exchange—a limit order book—before the World War II (Biais and Green (2019)). However, when institutional investors became more influential market players, trades gradually migrated to an OTC market, in which institutional investors obtained better deals. By 1940, the liquidity on the exchange had dried up.[4] For more institutional details about Israel, see Appendix A.

Treasury futures market. 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. On 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.

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government bond trading, representing approximately 2% and 10% of the total amount traded in regular times. The first segment consists of OTC trades that bypass the straight-through processing of the TASE. These trades typically involve in-house transactions for transferring funds between accounts, and are therefore excluded from our analysis. The second segment is the inter-dealer market, which operates on a separate limit order book, similar to inter-dealer markets in other countries. Given the prevalent use of limit order books in inter-dealer markets globally, we also exclude this segment from our analysis.

[4]In contrast, in Israel, institutional investors were mostly banks who would have become dealers in the OTC market. Since "dealer activity could have exposed the banks to conflict of interest and potentially to claims of illegal activity," trades remained on the exchange (Abudy and Wohl (2018)).

Exchange versus OTC market. Exchange trading differs from traditional OTC trading in at least two dimensions, which might trigger differences in market liquidity. First, any trader can freely trade with any other trader, which reduces search costs that are prevalent in OTC markets. Second, a CCP absorbs all counterparty risk, and offsets trades involving the same counterparts and security to be paired off and eliminated (for accounting and settlement purposes). This reduces dealer settlement risks and liquidity needs and opens up balance sheet space.

3 Data

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)—which are real-time composite prices that are based on executable and indicative quotes—for U.S., U.K, German and Japanese government bonds. 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.

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, we obtain the daily average bid-ask spreads of all constituents of the S&P 500, FTSE 100, DAX 30 and NIKKEI 225 index from Bloomberg using the BQL interface. For Israel, we obtain daily average bid and ask prices of the 35 and 125 largest Israeli companies—the TA 35 and TA 125—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.

When comparing prices or spreads in the U.S., U.K., Germany, or Japan with those in Israel, 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. As part of our robustness analysis in Appendix E, we validate that our results are robust to dropping Fridays and Sundays instead.

Trade flows. In order to compare the liquidity crisis in Israel with what we know about the liquidity crisis in the U.S. and to identify reasons for which the exchange may promote liquidity, 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 (including all trading desks), 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 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 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) and 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 (described below) 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)).

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

[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, regardless of which securities are used as collateral.

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.

Cross-country comparisons. When comparing Israel to the U.S., and other large economies, we are mindful of cross-country differences. First, in regular times, the U.S. Treasury market is more liquid that the Israeli Treasury market. U.S. Treasury spreads are lower (on average 0.03%) than spreads of Israeli government bonds (0.05%)—see Appendix Table A1 for more details. Price impact is also higher in Israel in absolute terms. Second, the Israeli economy is small in comparison. This implies lower trade volume but also fewer dealers who handle trades.

Our point is not to ignore these differences. Instead, we want to highlight that liquidity in the Israeli market did not evaporate as drastically than it did in the U.S., despite the fact that the liquidity shock was sizable relative to the size of the economy. Therefore, we think that we can learn from Israel's market setting and experience.

4 The COVID-19 liquidity crisis in the U.S. and Israel

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.

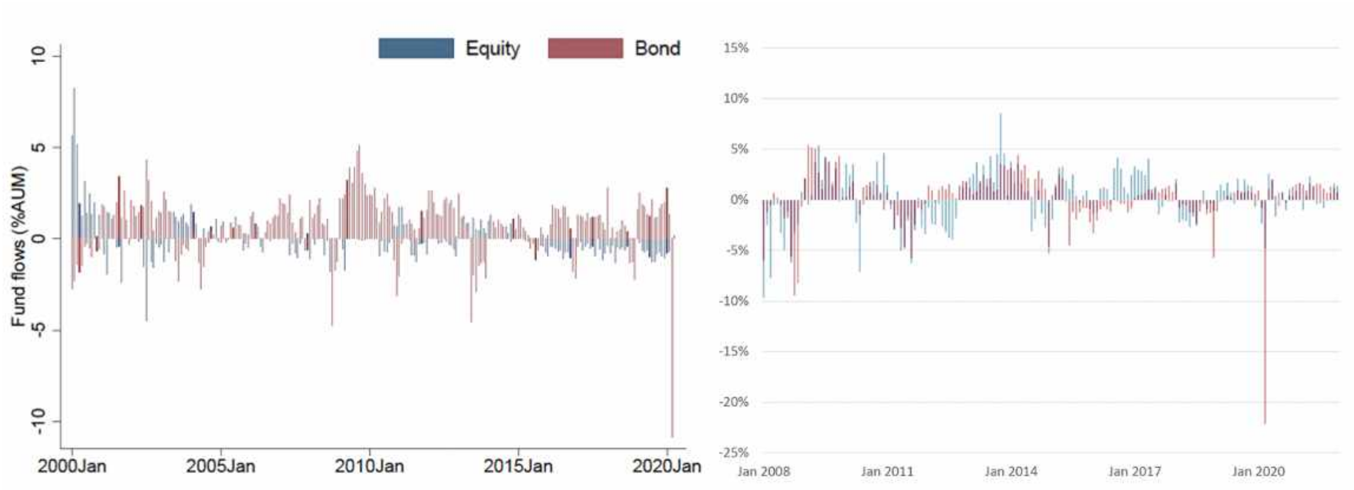
Dash-for-cash. In the U.S., mutual funds, hedge funds, foreign investors, and households wanted to redeem their shares of bond funds, exchange Treasuries for cash, and unwind existing positions (see Barth and Kahn (2020); Cheng et al. (2020); Duffie (2020); Eren and Wooldridge (2021); Ma et al. (2022); 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 2). 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 3).

Yields. The high selling pressure impacted the prices and yields in both the U.S. and Israeli government bond market. 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.

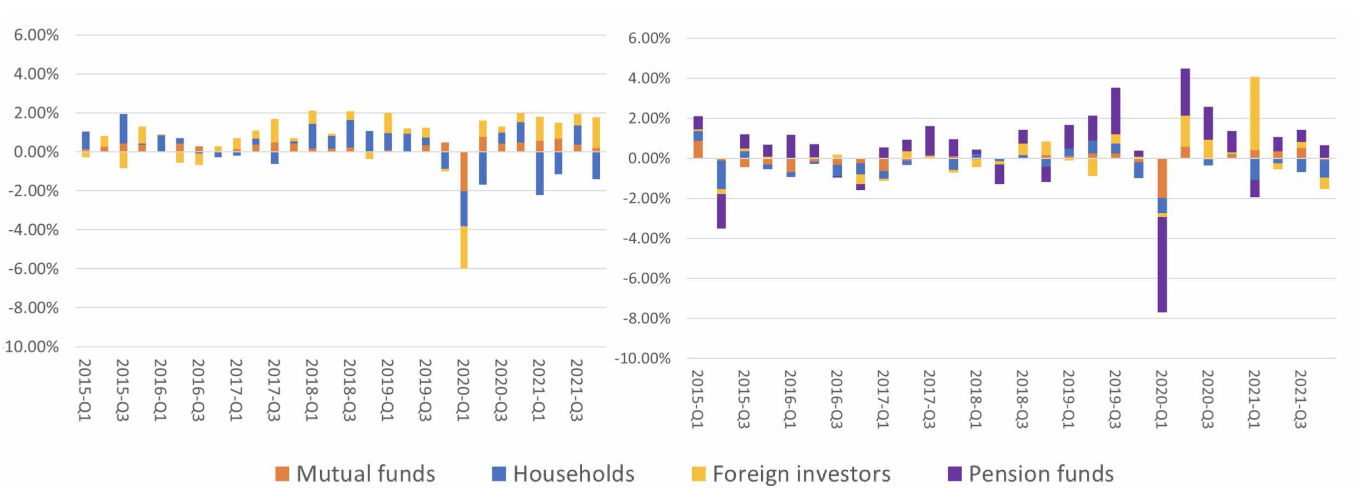
However, U.S. yields rose more strongly than yields on the Israeli exchange (see Figure 4). To see this, we need to control for differences in expectations for monetary policies which can drive yield differences even in absence of other cross-country differences. Going into the crisis, the Fed was expected to lower the federal funds rate to buffer negative effects and lower yields. We see this when analyzing the rate of the next-month federal funds futures contract, which measures short-run market expectations for U.S. monetary policies (Gurkaynak et al.

Figure 2: **Mutual fund fixed-income flows**



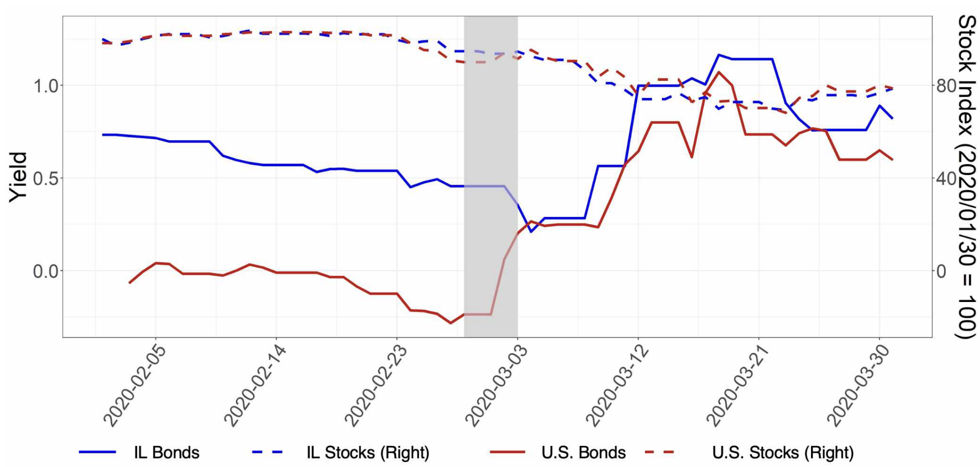
Notes: Figure 2 shows the monthly fund flows of bonds and equities to fixed-income mutual funds in the U.S. on the LHS—taken from Ma et al. (2022)—and in Israel on the RHS as the percentage of fund size (AUM). Source: Ma et al. (2022) and Bank of Israel.

Figure 3: **Quarterly Treasury net transactions by investor type**



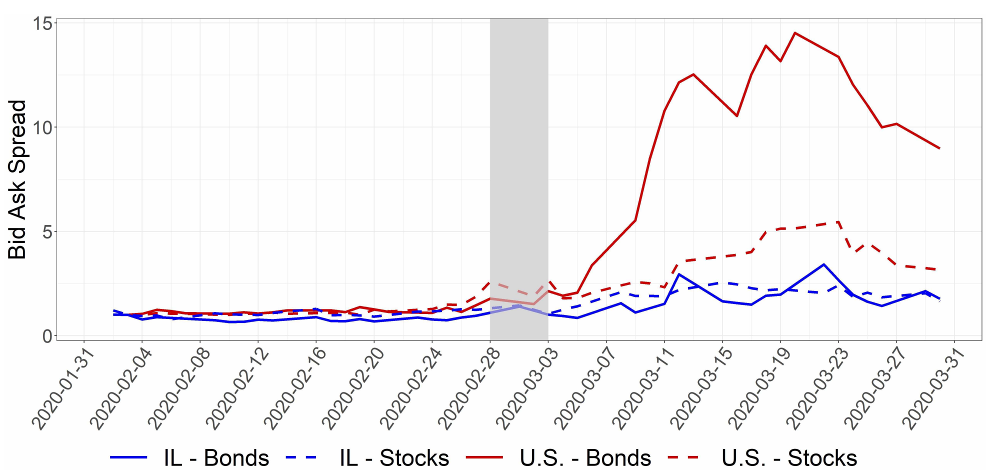
Notes: Figure 3 shows the quarterly net purchases in the percentage of outstanding government debt of U.S. and Israeli government bonds in the secondary market by investor type. The LHS is for the U.S., based on data provided by Eren and Wooldridge (2021). Investors are categorized as households, mutual funds, and foreign investors. The RHS is for Israel, for which we add pension funds. Source: Eren and Wooldridge (2021) and TASE.

Figure 4: **Normalized yields of 10-year government bonds and stock market indices**



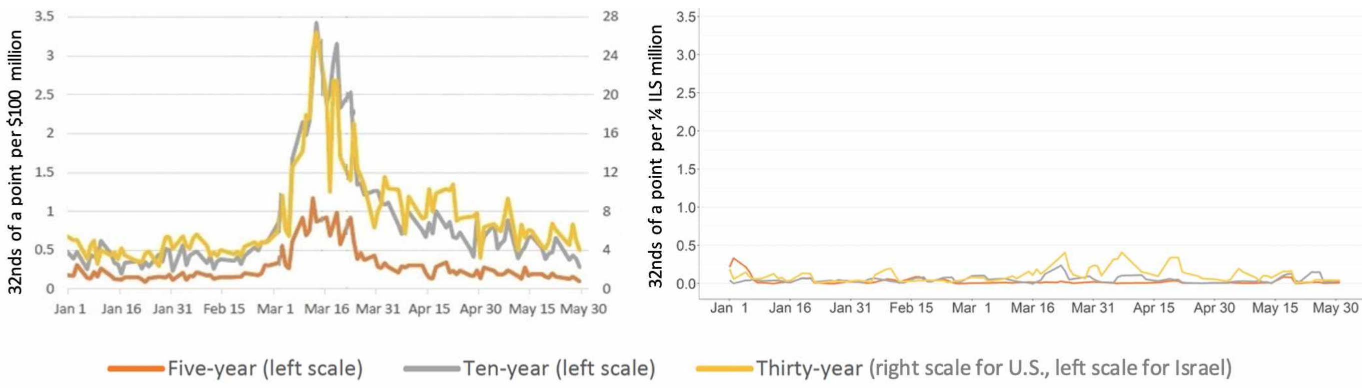
Notes: Figure 4 shows the time series from January 1, 2020, until April 1, 2020, of the daily normalized 10-year government bond yields for the U.S. and Israel (left axis) and the S&P 500 and TA 35 stock market indices (right axis, January 1, 2020=100). For the U.S., normalized bond yields are defined as bond yield minus the yield of the next-month federal funds futures contract. For Israel, we substract the spread of the 3-month-forward versus 1-month-forward TELBOR instead, as explained on page 18. The shaded area marks the beginning of the liquidity crisis (February 28, 2020 until March 3, 2020). Source: Bank of Israel and Bloomberg.

Figure 5: **Time series of spreads of government bonds and stock indices**



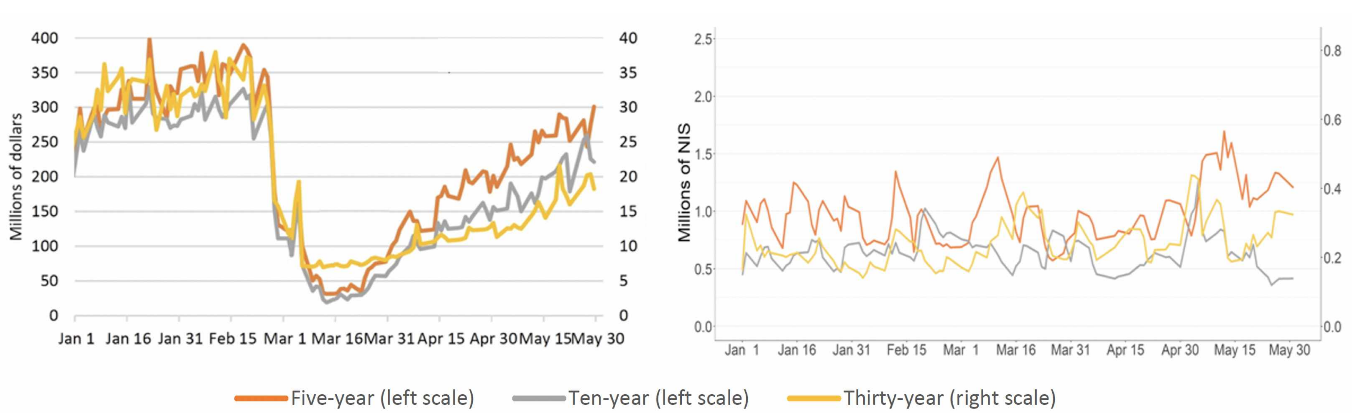
Notes: Figure 5 shows the spreads of U.S. government bonds, Israeli government bonds, the S&P 500, and the TA 35 index compared with the spreads on February 1, 2020, normalized to 1, from January 2, 2020, until March 31, 2020. Appendix Figure A2 shows unnormalized government bond spreads. Government bond spreads are weighted 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 6: **Price impact**



Notes: Figure 6 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 (see Footnote 7 for details). To further 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.

Figure 7: **Market depth**



Notes: Figure 7 shows the depth of the limit order book in the inter-dealer market for U.S. government bonds—taken from Fleming et al. (2021)—on the LHS for the Israeli government bond market and on the RHS. Market depth is measured in millions of U.S. dollars and NIS, respectively. Source: BrokerTec, TASE and the Bank of Israel.

(2007)). In contrast, the Israeli monetary rate was not expected to decrease because it was already close to the zero lower bound. This becomes evident from movements of the best available measure of short-run market expectations for Israeli monetary policies—the difference between the 3-month-forward and the 1-month-forward TELBOR (Israel's short term interbank interest rate).[6] In Figure 4, we subtract each country's short-run expectation measure from the respective government bond yields to control for these differences.

Price impact, market depth, and spreads. Moreover, price impact—a measure of how much trading in a given direction affects prices—increased more strongly in the U.S. (see Figure 6).[7] Market depth evaporated and spreads spiked; on the Israeli exchange market depth was stable and spreads rose by less (see Figures 5, 7, and Appendix Figure A2).

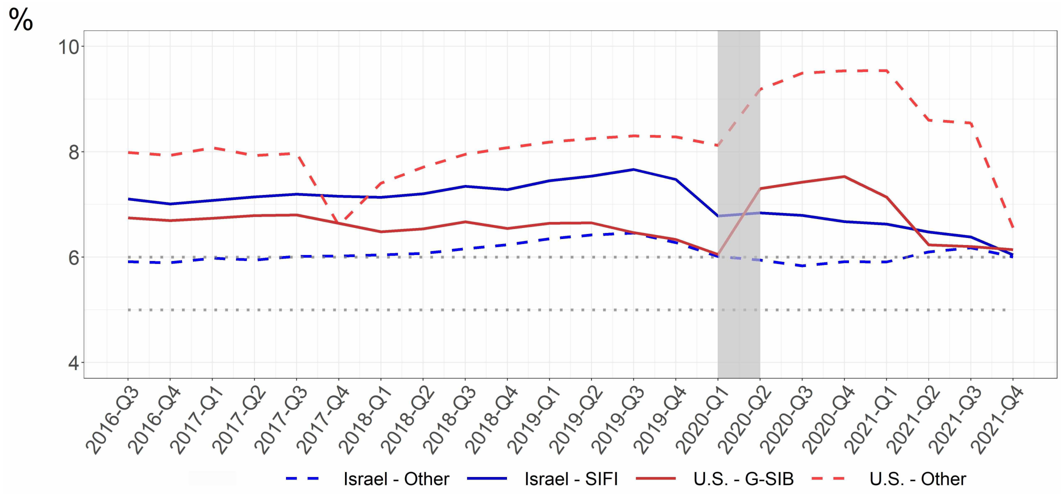
Leverage constraints. One explanation for why U.S. dealer banks did not absorb sufficient sales on their balance sheets is that they faced overly stringent balance sheet constraints (Schrimpf et al. (2020); Duffie (2020)). To show that weaker Basel III requirements or slack balance sheet constraints cannot fully explain the higher liquidity in the Israeli market (independent of market structures), we compare how close Israeli and U.S. banks were to their respective minimal LR thresholds (see Figure 8). We find that Israeli banks faced more stringent requirements and were as close, if not closer, to their thresholds than U.S. banks.

Subsequent policy interventions. To restore market liquidity, 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

[6]The official TELBOR rates for these maturities represent the yields of the OIS contracts, which approximate short-run market expectations for monetary policy, similar to federal funds futures contracts.

[7]Comparing the price impact across countries is not straightforward, given that the U.S. government bond market is much larger and trades faster than the Israeli government bond market. 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.

Figure 8: **Time series of the LR of an average bank in U.S. and Israel**



Notes: Figure 8 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.

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.[8] Similarly, the Bank of England, European Central Bank, and Central Bank of Japan began taking measures on March 11, 12, and 13, 2020, respectively (Bank of England (2020); European Central Bank (2020); Bank of Japan (2020)).

Focus period. For the remainder of the paper, we focus on the time period after WHO announced its warning on February 28, 2020, but before central banks began interventions on March 15, 2020, in the U.S. and Israel and on March 11-13, 2020, in the other countries. We validate that our results are not sensitive to the exact choice of these cutoff dates as part of our robustness checks in Appendix E.

[8]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. In Appendix C, we analyze and discuss yield and price differences, as well as dynamics.

Liquidity measure. To gather evidence for our hypothesis, we use the bid-ask spread as our main measure of liquidity for three reasons.[9] 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 Figure 6); market depth (as in Figure 7); 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 (see Appendix E). 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.[10]

Israel and U.S. A first approach to test our hypothesis could compare spreads in the U.S. stock market with spreads in the U.S. government bond market in a difference-in-differences (DD) regression (see Appendix B.1). 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. However,

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

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

given that bonds and stocks differ in many dimensions and the nature of the dash-for-cash, this assumption might fail to hold.[11]

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 the U.S. versus Israel (recall Figure 5), we run the following triple differences-in-differences (DDD) regressions as our main specification in two versions:

$$\log \text{BAS}_{it} = \delta_0 + \delta_1 \text{bond} + \delta_2 \text{IL} + \delta_3 \text{post} + \delta_4 \text{bond} \times \text{IL} + \delta_5 \text{bond} \times \text{post} + \delta_6 \text{post} \times \text{IL} + \delta_7 \text{bond} \times \text{IL} \times \text{post} + u_{it}, \quad (1)$$

$$\log \text{BAS}_{it} = \xi_i + \xi_{ct} + \delta_5 \text{bond} \times \text{post} + \delta_7 \text{bond} \times \text{IL} \times \text{post} + u_{it}. \quad (2)$$

Here we use data on all government bonds in our sample (those that were on-the-run sometime between January 2019 and the end of our sample period) from February 1, 2020, until March 13, 2020. In Appendix B.3, we split the sample into more versus less liquid bonds to analyze differences across bond liquidity. In all cases, $\log \text{BAS}_{it}$ is the log of the spread of security i—for instance, the U.S. Apple stock or the U.S. 2-year government bond—on day t; indicator variables bond and IL assume value 1 if the security is a bond and traded in Israel, respectively; and post is 1 starting on February 28, 2020.

In our preferred specification, we include a security fixed effect, ξ_i, and country-date fixed effect, ξ_{ct}, to absorb unobservable factors between the countries. The main coefficient of interest, δ_7, is then identified based on how daily spreads of bonds compared to stocks change after February 28, 2020, relative to how they were before, once we exclude time-country-specific trends that are common to all securities.

We find that Israeli government bonds' spread rose by about 43%–49% less than the rise in U.S. government bond spreads (see Table 1).[12] The negative δ_7 estimate would tell us

[11] 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.

[12] Other coefficients of Table 1 are also informative: The first coefficient in regression (1) reveals that

that 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. Note that the magnitude of the dash-for-cash can differ across countries thanks to the country-date fixed effect.

To analyze the persistence of the effect and test for pre-trends, we perform a dynamic DDD analysis (see Figure 9). We find that government bonds' spreads did not differ from stock spreads before the dash-for-cash began, but drop afterwards. Relative to the reaction in the U.S. futures market, which we analyze below, the spreads did not change immediately on Friday, February 28, when the WHO raised the coronavirus threat assessment to the highest level. One explanation for the time lag is that dealers could handle the selling pressure at the beginning. Only when their inventory positions were filling up were they no longer able to provide sufficient liquidity. Aggregate data suggest that this happened at the beginning of March (see Duffie (2020)), which is when we see the change in spreads.

One might argue that government bond market liquidity deteriorated more in the U.S. than in Israel for reasons other than the exchange. In particular, higher selling pressure in the U.S. government bond market relative to the U.S. stock market might have affected market liquidity more strongly than was the case in Israeli markets, irrespective of the trading mechanism. Confounding factors could, for instance, stem from spill-overs between the U.S. government bond, futures, or repo market, which are negligible in Israel. While we have provided evidence above that demonstrates that the dash-for-cash in the Israel government bond market was (in relative terms) comparable to that in the U.S., we cannot rule this out with certainty.[13]

before February 28, 2020, the spreads of U.S. government bonds were lower than that of U.S. stocks. The second and fourth coefficients in regression (1) show that before February 28, 2020, Israeli stocks were less liquid than their U.S. counterparts and that Israeli government bonds were more liquid than Israeli stocks. Furthermore, as before, we see that the dash-for-cash raised the spreads of all securities in our sample, both Israeli and U.S.

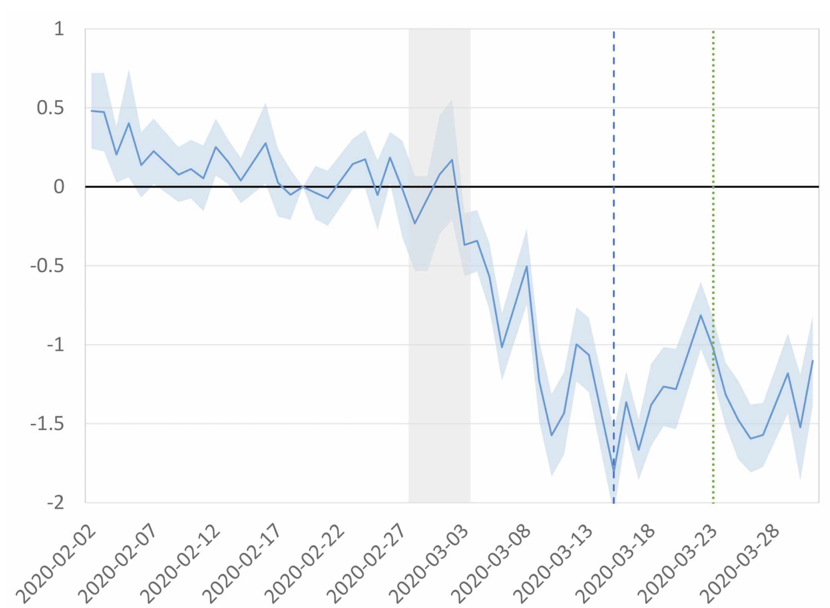
[13]Another concern is that our findings might be driven by the differential impact the Fed's policy intervention on March 3 had on different markets. However, given that this intervention was targeted to lower yields, and we are unaware of a systematic, long-lasting negative relationship between interest-rate cuts and increases in spreads, we are less worried about this possibility.

Table 1: **Static DDD analysis—Israel vs. U.S.**

	OLS		FE	
bond	−0.503***	(0.013)		
IL	+1.414***	(0.016)		
post	+0.642***	(0.009)		
bond×IL	−1.251***	(0.041)		
post×IL	−0.165***	(0.030)		
bond×post	+0.514***	(0.033)	+0.604***	(0.024)
bond×IL×post	−0.561***	(0.083)	−0.665***	(0.061)
Observations	22,438		22,438	
Adjusted R^2	0.391		0.906	
Security fixed effect	−		+	
Country-Day fixed effect	−		+	

Notes: Table 1 shows results of DDD regressions (1) and (2) in columns (OLS) and (FE), respectively, using data from February 1, 2020, until March 13, 2020. 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 that was on-the-run sometime between January, 1, 2019, and March, 31, 2020). 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. In column (FE), standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg and TASE.

Figure 9: **Dynamic DDD analysis—Israel vs. U.S.**



Notes: Figure 9 shows the $\delta_{7,k}$ coefficients and the 95% confidence bounds of regression: $\log \text{BAS}_{it} = \xi_i + \xi_{ct} + \sum_{k=1}^{60} \delta_{5,k} \text{bond} \times \text{day}_k + \sum_{k=1}^{60} \delta_{7,k} \text{bond} \times \text{IL} \times \text{day}_k + u_{it}$, where BAS_{it} is the spread of security i on day t; day_k equals 1 on the k^{th} day from February 1, 2020, until March 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. Blue and green lines correspond to the Fed's and Bank of Israel's interventions on March 15 and 23, 2020, respectively. Source: Bloomberg and TASE.

Israel and other countries. To alleviate the concern that our estimates are driven by the fact that the U.S. Treasury market is special or faced (relatively) higher selling pressure, we repeat the DDD analysis for the U.K., Japan, and Germany.

We choose these countries, because they possess developed OTC markets for bonds and a developed exchange for stocks, and because we know from Barone et al. (2022) that they experienced similar "dash-for-cash" episodes to Israel. Of these countries, Japan is particularly interesting because—unlike the other countries—it offers central clearing of all OTC-traded government bonds (but no all-to-all trading or efficient netting, as on an exchange) to a large set of market participants.[14] We therefore expect the estimated effect to be smaller in Israel versus Japan relative to the other countries.

Since central banks in the U.K., Japan, and Germany intervened before the Fed did, we shorten our time frame (recall Section 4). For comparison, we repeat the exercise for the U.S. with the shorter time frame and estimate the analogous regression (2) for each country separately.[15]

We find that in the U.K. government bond market, the effect was roughly 30% and in Germany and Japan 20%–23% (see Table 2 and Appendix Figure A3). As expected, the effect is smaller in Japan, where OTC bonds are centrally cleared. The smaller effect in Germany might be related to specific institutional features that drive uncommon pricing behavior in the OTC market, as documented by De Roure et al. (2022).

The fact that the estimate for the U.S. is the largest might suggest that part of the effect we measure for the U.S. is due to the special role the U.S. government bond market plays in the world economy. At the same time, we cannot statistically rule out that there is no U.S.-specific effect, given that the point estimate of the U.S. lies in the confidence intervals of the estimates of the other countries.

[14] See `https://www.jpx.co.jp/jscc/en/cash/jgbcc/seisan.html` for more information; accessed on 07/25/2023.

[15] There is a small difference regarding the security fixed effects we use in different regressions. For Israel and the U.S., the fixed effect is per CUSIP. In the other three countries, government bonds in our sample are reissued, which implies that the new on-the-run benchmark bond has the same CUSIP. To incorporate this, we treat a reissued bond as a new security. Equivalently, we could use CUSIP fixed effects for all countries. The results are practically identical.

Table 2: **Static DDD analysis—Israel vs. U.S., U.K., Germany, and Japan**

	US	UK	Japan	Germany
bond×post	+0.356***	+0.213***	+0.106***	+0.067*
	(0.024)	(0.058)	(0.026)	(0.036)
bond×IL×post	−0.504***	−0.362***	−0.254***	−0.216***
	(0.065)	(0.084)	(0.066)	(0.071)
Observations	20,557	5,817	11,487	3,676
Adjusted R^2	0.915	0.927	0.941	0.944
Security fixed effect	+	+	+	+
Country-day fixed effect	+	+	+	+

Notes: Table 2 shows results of DDD regression (2) for the U.S., U.K., Japan, and Germany in columns (US) - (Germany), respectively, using data from February 1, 2020, until March 10, 2020. The dependent variable is the daily log spread of a security (either a constituent of the S&P 500, the FTSE 100, the NIKKEI 225, the DAX 30, or the TA 35 index; or a U.S., U.K., Japanese, German or Israeli government bond with maturity above 2 years that was on-the-run sometime between January, 1, 2019, and March, 31, 2020). 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.

Within country comparisons. To eliminate possible concerns regarding cross-country comparisons, we end our analysis with comparisons first within the U.S. and then within Israel. In both cases, we estimate DD regressions of the following form:

$$\log \text{BAS}_{it} = \beta_0 + \beta_1 \text{exchange} + \beta_2 \text{post} + \beta_3 \text{exchange} \times \text{post} + u_{it} \tag{3}$$

$$\log \text{BAS}_{it} = \xi_i + \xi_t + \beta_3 \text{exchange} \times \text{post} + u_{it}, \tag{4}$$

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, and ξ_i, and ξ_t are security and day fixed effects, respectively.

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, while Appendix Figure A4 shows the dynamic analysis. The estimates suggest that the futures spread rose by 63%–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 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)).[16]

For Israel, we exploit the fact that some trades with government bonds occur OTC, rather than on the TASE, and conduct a DD analysis within the Israeli government bond market. By focusing on the same asset class within the Israeli market, this approach enables us to address concerns that may arise not only when comparing different countries but also when comparing different asset classes. Since there are only few OTC trades, the sample is relatively small.[17] Despite this, and the fact we use a noisy spread measure, we find statistically significant effects. In line with the previous findings, the spread on the exchange rose by 53%–63% less than the spread in the OTC market (see Table 3). In regular times, the spread on the exchange is larger than off the exchange. This is probably because 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.

Interpretation. We view all specifications as complementary. The cross-country analyses compare the same market—i.e., the cash market for government bonds—across countries. Here we worry about unobservable differences across countries that affect the difference in liquidity in each country's stock versus bond markets differently. Instead, the within-U.S. analysis compares two types of government bond markets—the cash versus futures market. Here, our concern is unobservable differences across these markets—for instance, futures may be traded by different types of traders or used for different purposes than government bonds. Lastly, the within-Israel analysis compares the same type of asset within the same country.

[16] 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.

[17] Therefore, there is not enough statistical power to conduct the dynamic analysis.

Table 3: **Static DD analysis within U.S. and Israel**

	U.S. OLS	U.S. FE	IL OLS	IL FE
exchange	−1.408***		+0.287	+1.130***
	(0.089)		(0.309)	(0.189)
post	+1.156***		+2.141***	
	(0.032)		(0.439)	
exchange×post	−0.982***	−1.073***	−0.994**	−0.761**
	(0.164)	(0.084)	(0.458)	(0.353)
Observations	2,643	2,643	496	496
Adjusted R^2	0.497	0.932	0.199	0.788
Security fixed effect	−	+	−	+
Day fixed effect	−	+	−	+

Notes: Table 3 shows results of DD regression (3) in columns (OLS) and (4) in columns (FE) for the U.S. and Israel, respectively, using data from February 1, 2020, until March 13, 2020. For the U.S., the dependent variable is the daily log spread of a security (either a 2-, 3-, 5-, 10-, or 30-year U.S. Treasury futures contract or a U.S. government bond with maturity above 2 years that was on-the-run sometime between January, 1, 2019, and March, 31, 2020); exchange is 1 for futures and 0 for bonds. For Israel, exchange is 1 when the trade is on the TASE and 0 when it is OTC. The dependent variable is the daily log 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) of an Israeli government bond in our sample. 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). 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, and the TASE.

Here, we are concerned about unobservable differences across market segments, such as the size of the trade or the type of trader, that lead traders to choose one market segment over the others.

Neither of our analyses alone can establish causality perfectly. However, taken together, they 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 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)).

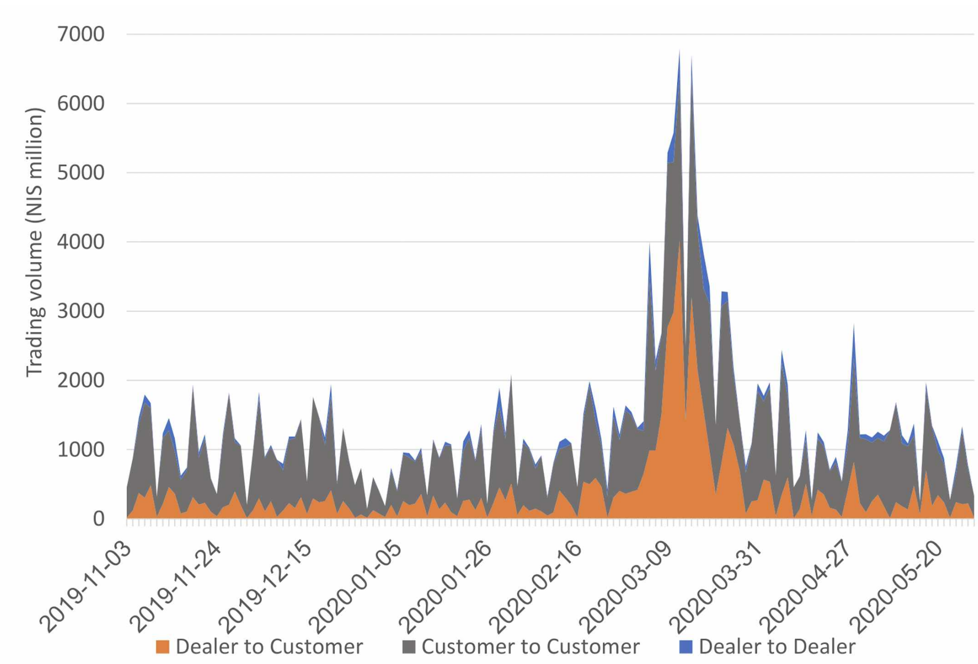
All-to-all trading. To find out whether all-to-all trading enabled investors to provide liquidity for one another on the Israeli exchange, we start by analyzing the trade volume between dealers, between dealers and customers, and between customers. Next, we use trade-flow data provided by TASE to study who bought the large amounts of government bonds that mutual funds, pension funds, and others sold in March 2020: banks, foreign investors (FI), mutual funds (MF), pension funds (PF), independent investment advisors (IIAs), ETFs, or local investors (LIs), who include retail traders, hedge funds, and algorithmic trading firms.

We find that dealer banks leaned heavily against the wind (see Figures 10 and 11). During the peak of the dash-for-cash, roughly 50% of the amount sold was bought by banks, which highlights the importance of dealers in a financial crisis. Further, banks were by far the biggest net buyers, which suggests that the banking sector absorbed the largest amount of debt on the balance sheets.

However, investors also played a significant role in absorbing the selling pressure. Of these, local investors—which include hedge funds and algorithmic and high-frequency trading firms—bought the largest share, with roughly 25%, while pension funds, mutual funds, and foreign investors purchased less. 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.

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

Figure 10: **Daily trade volume per market segment**



Notes: Figure 10 shows the total trade volume between dealers, between dealers and customers, and between customers and customers in Israel, in million NIS. Fleming and Keane (2021) show the analogous graph for the U.S. market. Source: TASE.

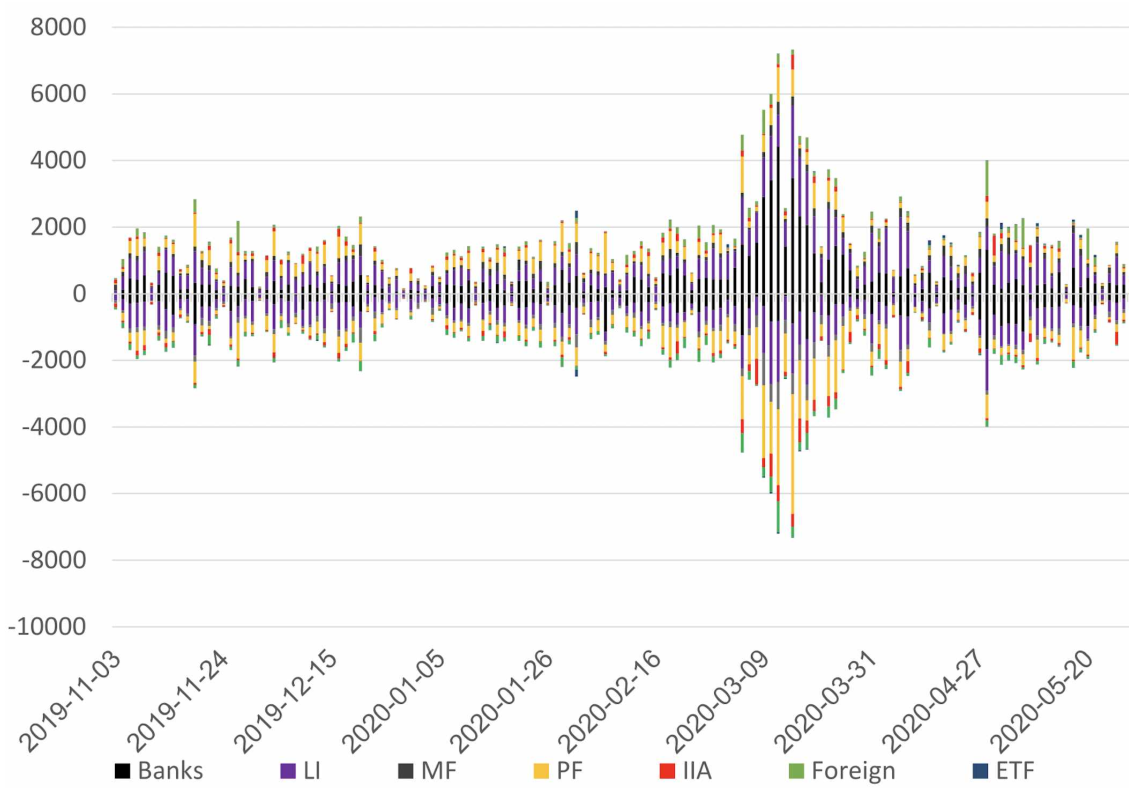
only trade with dealers and netting on the Israeli exchange was like it is in the U.S.

This analysis complements contemporaneous work by Fleming and Keane (2021), who quantify how much less U.S. banks' gross settlement obligations would have had decreased under central netting.[18] Besides conducting the counterfactual in opposite directions and with different data, the key difference between our analyses is that Fleming and Keane (2021) consider changes in netting in the absence of all-to-all trading. We can add all-to-all trading and analyze how this affects netting.

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. Since we cannot distinguish between dealers, but only

[18]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: **Daily trade flows by investor groups**



Notes: Figure 11 shows the aggregate gross trade flows (total purchases and total sales) in million NIS with Israeli government bonds by trader type—i.e., banks, local investors (LI), mutual funds (MF), pension funds (PF), independent investment advisors (IIA), ETFs, and foreign investors (Foreign)—from November 2019 until May 2020. Source: TASE.

know the types of the counterparties (dealer or customer), we cannot compute the dealers' gross obligations exactly. However, we show in Appendix F that we can derive upper and lower bounds. Here we only present formulas for the exact gross obligations, given that these bounds turn out to be rather tight.[19]

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 gross settlement obligation is

$$Q_t^{IL} = \sum_{s \in S} \sum_{i=1}^{N} \left| \sum_{k=1}^{K_i} (d2c\_buy_{i,k,s,t} - d2c\_sell_{i,k,s,t}) + \sum_{j=1, i \neq j}^{N} (d2d\_buy_{i,j,s,t} - d2d\_sell_{i,j,s,t}) \right|, \quad (5)$$

[19]Part of the reason for this is that the inter-dealer market, which is the market whose gross obligations we cannot capture precisely with our data, is small in Israel (see Figure 10).

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.

Under U.S. settlement arrangements, according to which none of the trades with customers but all inter-dealer trades net out (for settlement purposes), the gross obligation would be

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

if customers who trade with one another under Israeli rules stopped trading in the counterfactual. When we account for the fact that these trades must now go via the dealers, the counterfactual gross obligation becomes

$$Q_t^{CF} = Q_t^{CF\_D} + \sum_{s \in S} \sum_{k=1}^{K} \sum_{l=1}^{K} \left(c2c\_buy_{k,l,s,t} + c2c\_sell_{k,l,s,t} \right), \quad (7)$$

where $c2c\_buy_{k,l,s,t}$ is the amount customer k buys from l, and similarly for the sell side.

We find a substantial increase in settlement obligations for Israeli banks without netting and all-to-all trading (see Figure 12a). On March 16, 2020, obligations in the counterfactual spike up to over 10 billion NIS, while actual obligations in Israel stayed below 4 billion NIS (see Appendix Figure A12). On other days, on which more customers traded with one another, the difference between the counterfactual and status quo is even higher. On average, settlement obligations under the counterfactual were about 2.8 NIS billion but only 0.6 NIS billion in the status quo for the weeks preceding and following the market disruption (i.e., January-April 2020). Fleming and Keane (2021) find that central netting (without all-to-all trading) would have lowered dealers' daily gross settlement obligations by roughly 60% in the weeks preceding and following the market disruptions of March 2020 and by nearly 70% when trading was at its highest.

The fact that Fleming and Keane (2021), who consider a market structure that does not allow for all-to-all trading, find significantly lower gains than we do by accounting for all-to-all trading, suggests that all-to-all trading plays an important role. Figure 12b confirms this conjecture. We see that the amount of settlement obligations dealers have to absorb because customers are forced to trade with dealers can be larger than the amount dealers have to absorb because they can no longer net out trades when trading with those customers who also trade with a dealer in the status quo.

Interpretation. 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.

The fact that all-to-all trading and efficient netting also have significant effects in regular times, even when the traditional OTC market without these features tends to function well, suggests that other factors play a role in determining when having an exchange enhances liquidity. Drawing inspiration from previous studies (including Schrimpf et al. (2020); Duffie (2020); Allen and Wittwer (2022)), we conjecture that one such factor could be time-varying balance sheet costs or constraints arising from financial regulation, such as Basel III. To explore this hypothesis, we analyze market liquidity during the financial crisis of 2007–2008, a period when U.S. dealers faced lower balance-sheet constraints and overall selling pressure was lower (Vissing-Jorgensen (2021); see Appendix D). In line with our conjecture, we find no significant difference in Treasury liquidity between the U.S. and Israel during this period.

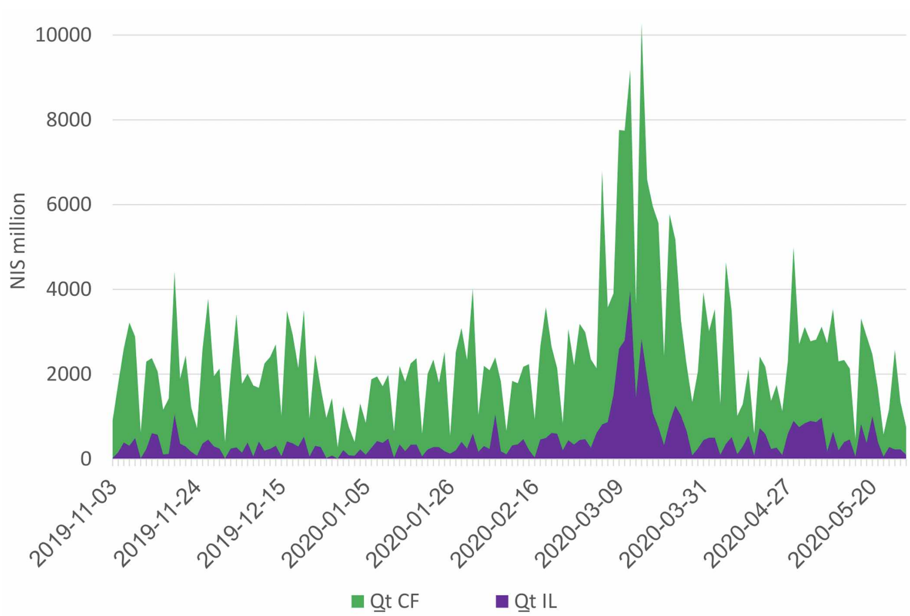
Taken together, our findings highlight the fact that trading mechanisms and financial regulations or policies that affect dealer balance sheets are intertwined. Thus they must be evaluated together to avoid future market distress, especially in an era in which banks' balance sheets are crowded by unprecedented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

7 Conclusion

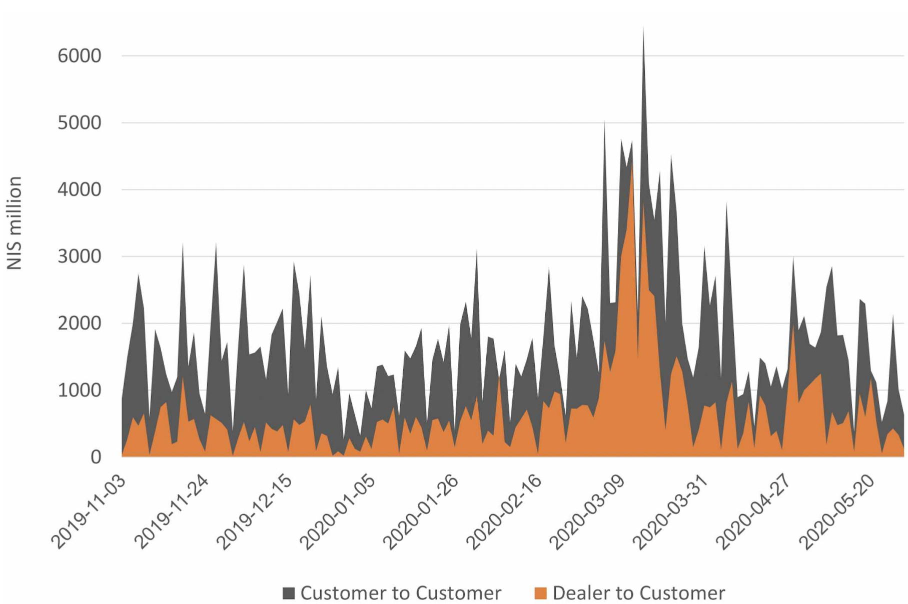
This paper analyzes whether and why shifting the trading of government bonds onto an exchange can protect market liquidity against negative shocks in times of crisis. We leverage

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

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



(b) In the counterfactual (U.S.) by market segment



Notes: Figure 12a shows the lower bound of dealers' daily gross obligations (formally defined in Appendix F) in Israel (violet) and under U.S. settlement rules (green) from November 1, 2019 until June 30, 2020. Figure 12b splits dealers' daily gross obligations in the counterfactual into dealer-to-customer (orange) and customer-to-customer trades (gray). All obligations are are expressed in NIS million. Source: TASE.

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 banks and investors leaned against the wind in March 2020 and conduct a counterfactual to highlight the importance of trade netting.

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ONLINE APPENDIX

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

Appendix **B** shows additional evidence to support our hypothesis on exchanges and liquidity.

Appendix **C** analyses the effects of an exchange on prices and yields.

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

Appendix **E** discusses robustness of the main empirical findings.

Appendix **F** derives bounds on settlement obligations for the counterfactual exercise.

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%.

Tick size on the TASE. The minimum tick size for regular trading sessions on the TASE is 30,000 NIS, equivalent to approximately $9,000. During the auction session preceding the start of trading, the minimum tick size is reduced to 1 NIS.

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.[20]

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-

[20]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 Additional evidence: Liquidity in 2020

B.1 Difference-in-differences analyses within countries

A starting point to test our hypothesis is to conduct a DD regression for U.S. stocks and government bonds using two specifications. In the first, we regress the log of the daily spread of security i, $\log \text{BAS}_{it}$, on 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 specification, we add security and date fixed effects, ξ_i and ξ_t:

$$\log \text{BAS}_{it} = \beta_0 + \beta_1 \text{stock} + \beta_2 \text{post} + \beta_3 \text{stock} \times \text{post} + u_{it}, \tag{8}$$

$$\log \text{BAS}_{it} = \xi_i + \xi_t + \beta_3 \text{stock} \times \text{post} + u_{it}. \tag{9}$$

As a placebo test, we also estimate these regressions with Israeli data and compare Israeli government bond spreads with stock spreads.

Our primary interest is the coefficient β_3, which tells us by how much stock spreads differed from government bond spreads after the dash-for-cash. In our preferred specification, β_3 is identified based on how the daily spread of a security changes after February 28, 2020, relative to how it was before, once we exclude time trends that are common to all securities.

Finding a negative β_3 for the U.S. would tell us that stock spreads are lower than government bond spreads because government bonds are not traded on an exchange under two identifying assumptions. The first is the standard "no parallel" trends assumption, for which we provide supporting evidence in Appendix Figure A5. It says that in the absence of the dash-for-cash, spreads in the U.S. government bond and stock markets would follow the same trend. The second assumption is that any effect the dash-for-cash had on the spreads that is unrelated to the trading mechanism was the same for bonds and stocks. This means that any difference in the spreads of stocks and bonds during the crisis comes from the fact that bonds do not trade on an exchange.

We find that U.S. government bonds' spreads rose much more than the rise in stocks' spreads (see Appendix Table A3a). This was not the case in Israel (see Appendix Table A3b). Under the identifying assumptions, this means that U.S. spreads would have risen by about 45% less than they did if there were an exchange for Treasuries. The results are both statistically and economically significant.[21] In contrast—as expected—there is no statistically significant difference in the rise of spreads between Israeli government bonds and stocks, which both clear on the exchange.

B.2 Difference-in-differences analyses with Treasuries only

An alternative specification is to compare the spreads of government bonds across countries. For this, we use the spreads of bonds only and regress

$$\log \mathrm{BAS}_{it} = \beta_0 + \beta_1 \mathrm{IL} + \beta_2 \mathrm{post} + \beta_3 \mathrm{IL} \times \mathrm{post} + u_{it}, \quad (10)$$

$$\log \mathrm{BAS}_{it} = \xi_i + \xi_t + \beta_3 \mathrm{IL} \times \mathrm{post} + u_{it}. \quad (11)$$

The regressions are analogous to (8) and (9), but replace the indicator stock with an indicator IL for whether the bond is Israeli or not.

We find that Israeli bond spreads rose less than U.S. bond spreads (see Appendix Table A4). Similar to before, the negative β_3 would tell us that spreads in Israel were lower than in the U.S. because Israel has an exchange and the U.S. does not under two identifying assumptions. The first is the standard "no parallel" trends assumption, for which we provide

[21] Other coefficients are also informative. For instance, the regression also shows that before February 28, 2020, the spreads of stocks were about 65% lower than those of bonds, which suggests that the stock market is less liquid than the government bond market in normal times.

supporting evidence in Appendix Figure A6. Second, any effect the dash-for-cash had on the spreads that is unrelated to the trading mechanism was the same for Israel and the U.S. We relax this assumption within our main specification, the DDD regression.

B.3 Liquid versus non-liquid bonds

Next, we analyze whether introducing an exchange might affect liquid and illiquid bonds differently. On the one hand, when a bond is liquid, buyers tend to quickly find sellers to realize a trade, even over-the-counter. Therefore, introducing an exchange on which a seller is instantly matched to a buyer might have little effect. On the other hand, it could in theory be possible that during the crisis, investors first sold their more liquid assets. This could have created higher selling pressure for liquid bonds and thus a larger effect of having an exchange because the exchange helps alleviate such pressure.

We re-estimate the dynamic DDD on a subsample of the most liquid bonds (those that were on-the-run between February 28, 2020, and March 13, 2020) and compare the estimates to the estimates we obtain when using all bonds. We detect a weakly positive, but statistically insignificant difference across specifications (see Appendix Figures A7). This could mean that having an exchange affects spreads for liquid and illiquid bonds close to equally. It could also mean that the selling pressure for liquid and illiquid bonds was not the same, which cancels out an effect that would arise in the presence of equally sized selling pressure.

C Does having an exchange affect the price level?

While our main focus lies in understanding how exchange trading affects market liquidity, it is equally interesting to analyze the effect on prices and price dynamics.

DDD using prices. Unfortunately, it is more difficult to tease out what effect an exchange has on prices by comparing prices across countries via DDD analysis (as in regression (2) or Figure 9), because different countries adopted different monetary policies. These policies likely affected the price level—but not necessarily the spread—in a country's government bond market differently relative to its stock market. If this was so, one identifying assumption of the DDD would be violated when using prices. Despite these concerns, we repeat the DDD analysis we conducted using spreads with prices instead.

We find no significant difference in price levels in the Israeli versus U.S. government bond market after March 3, 2020 (see Appendix Figure A8). Before March 3, 2020, we see a small dip in the Israeli government price level relative to the U.S. price level.

Treasury market DD using yields. To understand what is going on, we analyze yield movements in the Israeli versus U.S. government bond market in a dynamic DD regression with a security and date fixed effect (similar to regression (11)). Since we no longer include stocks, we can no longer include a country-date fixed effect. Therefore differences in policies or events across countries might affect the findings more strongly than before. We now use yields to maturity rather than prices because it is more natural to think about how changes in the monetary policy rate affect yields rather than prices.

We find that from February 20, 2020, onward, bond yields in Israel continuously moved upward compared with bond yields in the U.S. (see Appendix Figure A9a). This could occur for at least two reasons. First, the selling pressure could have been lower in the Israeli government bond market than the U.S. government bond market, causing prices in the U.S. market to increase by more than in the Israeli market. We cannot rule this out entirely. However, in light of the descriptive evidence of the selling pressure in both countries presented in Section 4 and Appendix Figure A8, we do not think that this is the main reason for the observed yield pattern. Second, it could also be because the U.S. market expected the Fed to implement monetary policies to lower the U.S. interest-rate level, and with that, U.S. bond yields. In contrast, the Israeli market did not expect the Israeli monetary rate to fall, given that it was already close to the zero lower bound.

To provide evidence for this conjecture, we control for the different expectations for each country's monetary policies by normalizing the government bond yields as we did in Figure 4. We find that the normalized Israeli government bond yields rose less than those of the U.S. (see Appendix Figure A9b). This suggests that expectations for monetary policies might have driven the upward-trending raw yields in Israel versus the U.S. In line with the small dip we found around February 28, 2020, in Appendix Figure A8, in Appendix Figure A9b we see that the normalized yields in Israel rose above those in the U.S. around that time.

DD within Israel using prices. Finally, we perform within-Israel DD regressions (3) and (4) using prices instead of spreads; as with spreads we don't have enough power to conduct a dynamic analysis. We find that prices on the exchange exhibit a stronger decline compared to off-exchange prices (see Appendix Table A5). One possible explanation for this pattern is that investors who wished to sell quickly during the crisis period chose to do so on the exchange rather than through OTC transactions. This has two effects: first, it creates greater selling pressure on the exchange, leading to a downward pressure on prices; second, it suggests that the average daily trade price on the exchange are generally lower (as it includes more bid-prices) compared to the average off-exchange price (which includes more ask-prices). Unfortunately, due to the limitations of our data, we cannot directly verify this conjecture as we do not have information on the specific side of the trade.

Take away. After controlling for differences in monetary policies and expectations over such across countries, we find that bonds' yields rose more in the U.S. than in Israel. This result is consistent with our results, whereby the bond market's liquidity has deteriorated more in OTC markets than in the exchange market. Further, the early price dip and rise in normalized yields could suggest that having the exchange makes prices respond more quickly to large selling pressure. This could help keep a balanced supply and sell side and thus enhance market liquidity.

D 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. 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.[22]

Since the nature of the shock to the Israeli and U.S. markets was 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. 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 (as in Appendix B.1).

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 A6b). For the U.S., we find that stock spreads rose more strongly than bond spreads (see Appendix

[22]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).

Table A6a). This is different from 2020 and in line with the pattern we can observe in the time-series plot of spreads (see Appendix Figure A10a).

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.

Across-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 (10) and (11). Second, we compare the bond-stock spread across both countries, as we did in the main text, with regressions (1) and (2).

We find no significant effect when comparing bond spreads across countries and a significant positive effect when comparing bond-stock spreads (see Appendix Tables A7 and A8). 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 A11 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.

E Robustness analysis of our main findings

Alternative spread measure. To ensure that our main findings are not driven by changes in the mid-price, we report the estimates of regressions (1) and (2) with spreads in absolute terms rather than in percentage relative to the mid-price in Appendix Table (A9). All findings are qualitatively robust for our main specification and all other specifications (not reported here).

Asynchronous trading. When comparing trading in the U.S. to Israel, there is one complication due to the fact that the business week goes from Monday through Friday in the U.S. and from Sunday through Thursday in Israel. Therefore, in our main specification we interpolate the spreads for Friday and holidays by using the values of the previous trading day, if they are mising, to synchronize the week. In Appendix Table A10, we validate that our results are robust to limiting the sample to days when trading occurs in both countries. The results suggest that the spreads of U.S. government bonds would have risen by about 54% less if there had been an exchange, compared with 49% in our main specification in Table 1.

Different cutoff points. In Appendix Table A11, we repeat regressions (1) and (2) for all countries but shift the cutoff date. We find that shifting the sample 2 days backward results in a coefficient that implies that the spreads of U.S. government bonds would have risen by about 57% less. Shifting the sample 2 days forward implies that the spreads of U.S. government bonds would have risen by about 42% less.

TA 125. In Appendix Table A12, we show that the results of regressions (1) and (2) are robust when we use the constituents of the TA 125 index (the 125 largest firms in Israel) instead of the TA 35 index.

F Bounds for the netting counterfactual

With our data, we cannot compute Q_t^{IL} or Q^{CF} as defined in (5) and (7) because we don't observe the identify of any trader. We only observe $\sum_{i=1}^{N}\sum_{k=1}^{K_i} d2c\_buy_{i,k,s,t}$,, $\sum_{i=1}^{N}\sum_{j=1,i\neq j}^{N} d2d\_buy_{i,j,s,t}$, $\sum_{i=1}^{N}\sum_{j=1,i\neq j}^{N} d2d\_sell_{i,j,s,t}$, and all analogous sums. However, we can calculate lower and upper bounds for both Q_t^{IL} and Q_t^{CF}.

Bounds for Q_t^{IL}. 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:

$$\overline{Q}_t = \sum_{s\in S}\sum_{i=1}^{N}\sum_{k=1}^{K_i}\left(d2c\_buy_{i,k,s,t} + d2c\_sell_{i,k,s,t}\right) + \sum_{s\in S}\sum_{i=1}^{N}\sum_{j=1,i\neq j}^{N}\left(d2d\_buy_{i,j,s,t} + d2d\_sell_{i,j,s,t}\right). \tag{12}$$

A lower bound is

$$\underline{Q}_t^{IL} = \sum_{s\in S}\left|\sum_{i=1}^{N}\sum_{k=1}^{K_i}\left(d2c\_buy_{i,k,s,t} - d2c\_sell_{i,k,s,t}\right) + \sum_{i=1}^{N}\sum_{j=1,i\neq j}^{N}\left(d2d\_buy_{i,j,s,t} - d2d\_sell_{i,j,s,t}\right)\right|. \tag{13}$$

Notice the subtle change of the absolute value relative to expression (5), since we can't calculate the netting of each dealer separately. By the triangle inequality, $\underline{Q}_t^{IL} \leq Q_t^{IL}$. This is for two reasons. First,

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

because, among dealers, for every dealer that bought there is always a dealer who sold. Second, 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 (Q_t^{IL}). 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 (Q_t^{IL}). Thus

$$\underline{Q}_t^{IL} \leq Q_t^{IL} \leq \overline{Q}_t. \tag{14}$$

Bounds for Q_t^{CF}. Following the same logic, we can compute a lower bound for $Q_t^{CF\_D}$ given in (6). By the triangle inequality,

$$\underline{Q}_t^{CF\_D} = \sum_{s\in S}\sum_{i=1}^{N}\sum_{k=1}^{K_i}\left(d2c\_buy_{i,k,s,t} + d2c\_sell_{i,k,s,t}\right) + \sum_{s\in S}\left|\sum_{i=1}^{N}\sum_{j=1,i\neq j}^{N} d2d\_buy_{i,j,s,t} - d2d\_sell_{i,j,s,t}\right|. \quad (15)$$

$\overline{Q}_t$ is an upper bound, and

$$Q_t^{CF2} = \sum_{s\in S}\sum_{k=1}^{K}\sum_{l=1}^{K}\left(c2c\_buy_{k,l,s,t} + c2c\_sell_{k,l,s,t}\right) \quad (16)$$

can be computed exactly. Therefore,

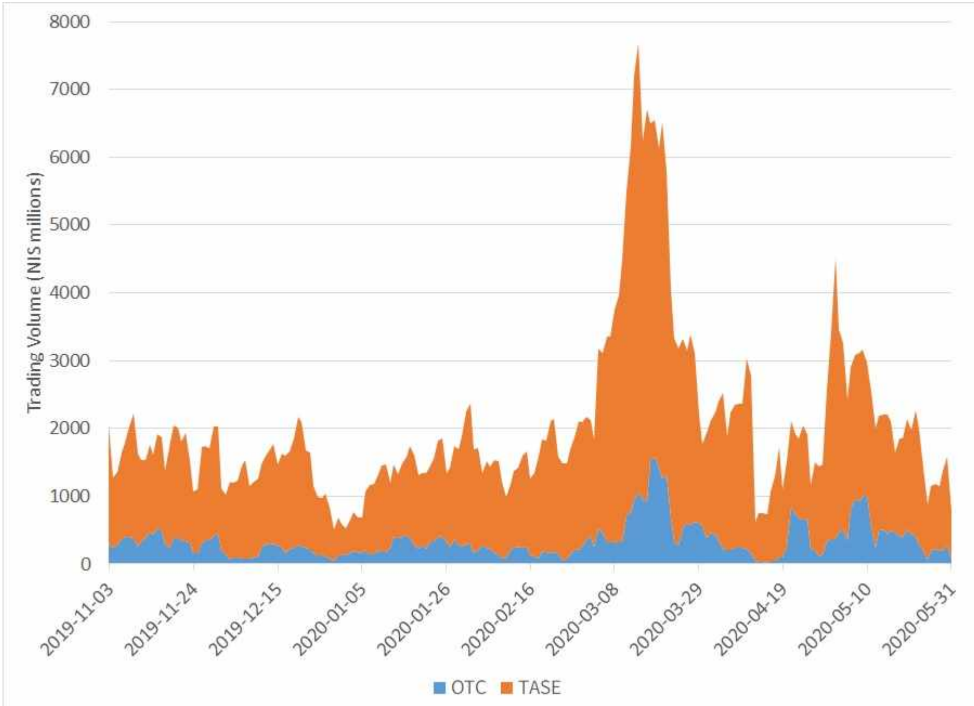
$$\underline{Q}_t^{CF\_D} + Q_t^{CF\_C2C} \leq Q_t^{CF} \leq \overline{Q}_t + Q_t^{CF\_C2C}. \quad (17)$$

Taking (14) and (17) together, we compute bounds for the change in dealers' gross obligations when going from the Israeli rules to the U.S. rules, $\Delta Q_t = Q_t^{CF} - Q_t^{IL}$:

$$\underline{\Delta Q}_t \leq \Delta Q_t \leq \overline{\Delta Q}_t, \quad (18)$$

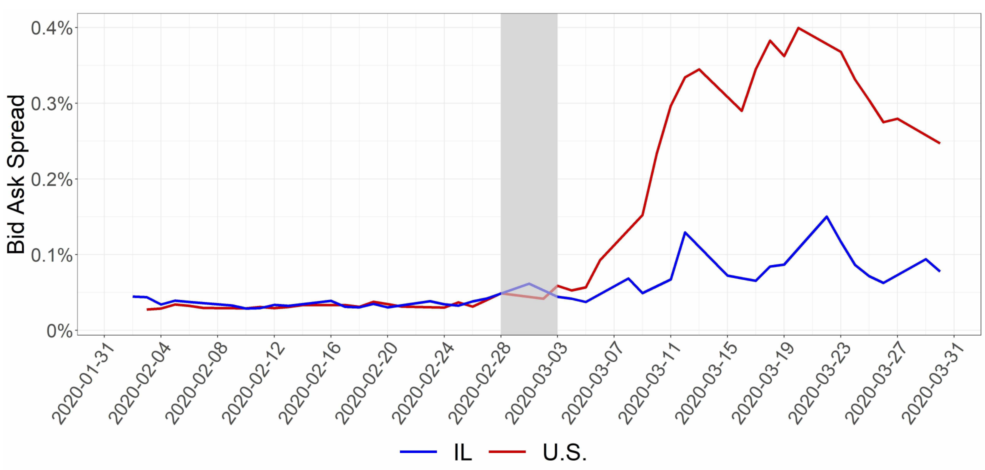
where $\underline{\Delta Q}_t = \underline{Q}_t^{CF\_D} + Q_t^{CF\_C2C} - \overline{Q}_t$ and $\overline{\Delta Q}_t = \overline{Q}_t + Q_t^{CF\_C2C} - \underline{Q}_t^{IL}$.

Appendix Figure A1: **Time series of trade volume on and off the exchange**



Notes: Appendix Figure A1 shows the total trade volume that is executed on the TASE and OTC, in million NIS from November 1, 2019, until May 31, 2020. Source: TASE.

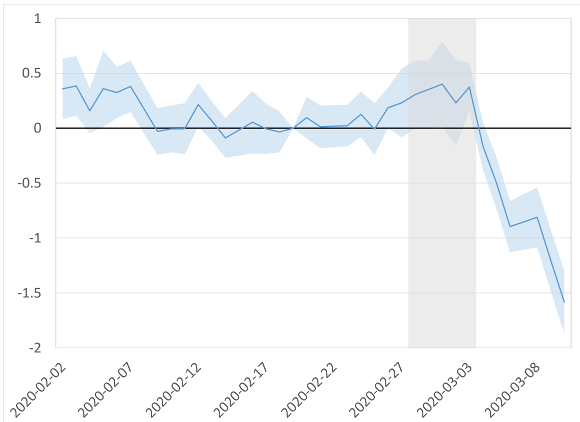
Appendix Figure A2: **Time series of spreads of government bonds**



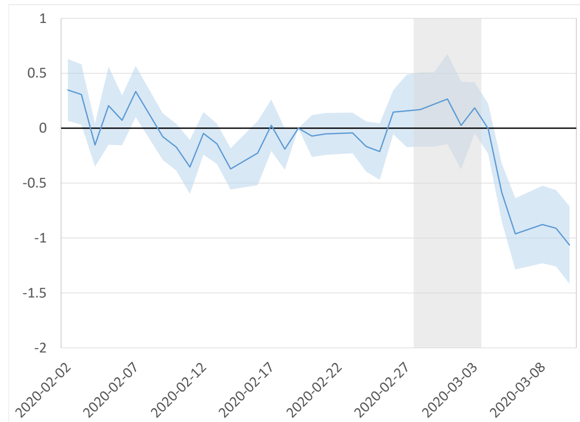
Notes: Appendix Figure A2 shows the spreads of U.S. and Israeli government bonds, from January 2, 2020, until March 31, 2020, weighted by the bonds' notional amounts. The shaded area marks the beginning of the liquidity crisis (February 28, 2020 until March 3, 2020). Source: Bloomberg and TASE.

Appendix Figure A3: **Dynamic DDD analysis—Israel vs. U.S., U.K., Germany, and Japan**

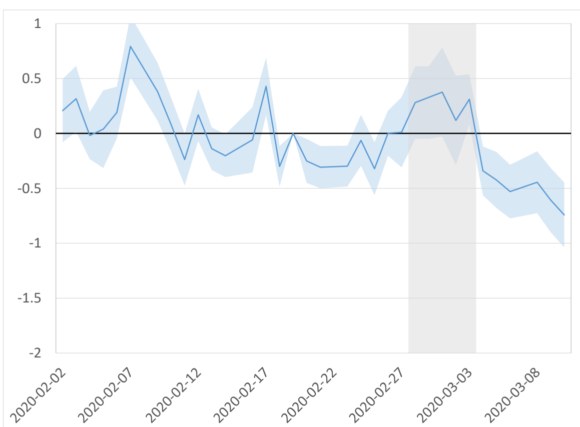
(a) U.S. and Israel



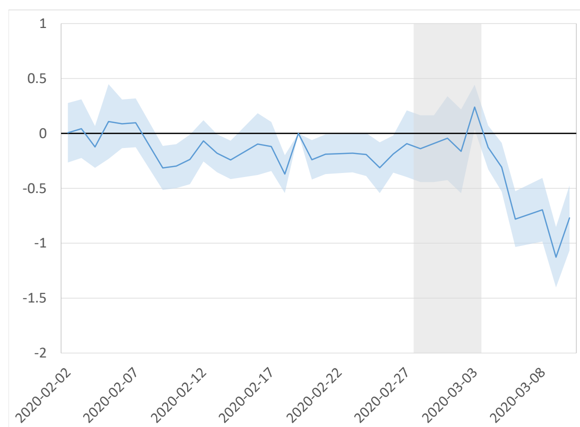
(b) U.K. and Israel



(c) Germany and Israel

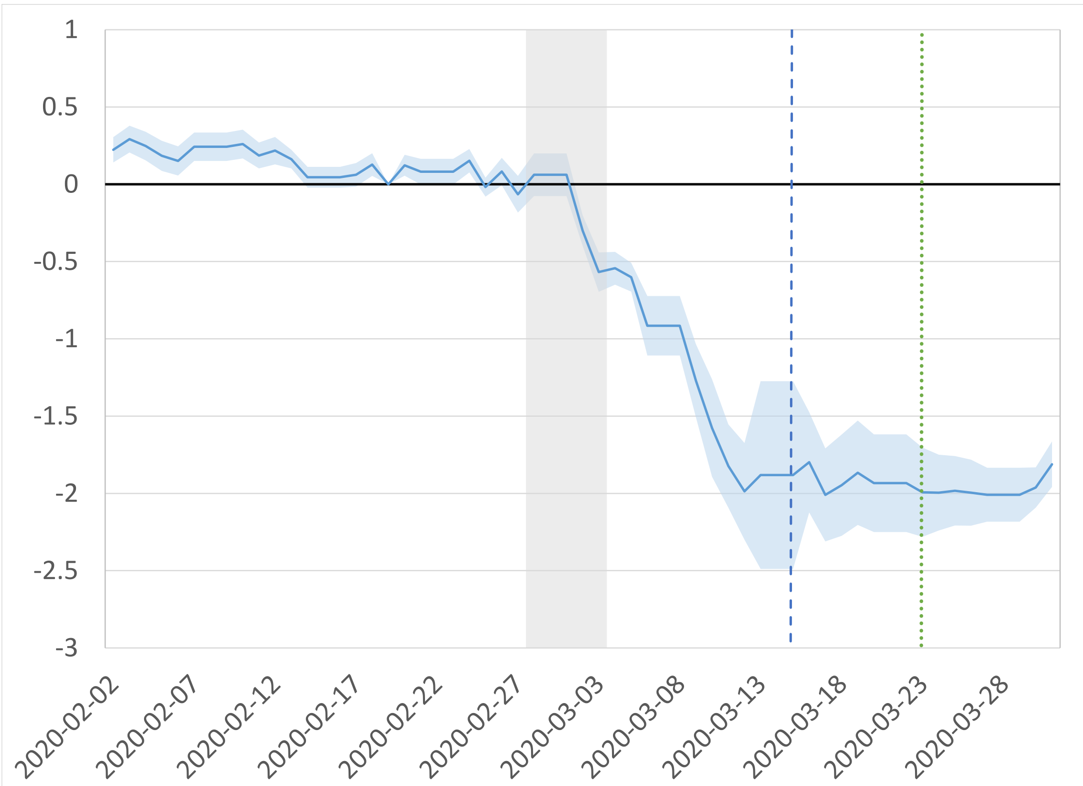


(d) Japan and Israel



Notes: Appendix Figures A3a-A3d show the $\delta_{7,k}$ coefficients and the 95% confidence bounds of regression: $\log \text{BAS}_{it} = \xi_i + \xi_{ct} + \sum_{k=1}^{20} \delta_{5,k} \text{bond} \times \text{day}_k + \sum_{k=1}^{20} \delta_{7,k} \text{bond} \times \text{IL} \times \text{day}_k + u_{it}$ for Israel and the U.S. in (a), U.K. in (b), Germany in (c), and Japan in (d). BAS_{it} is the spread of security i on day t; day_k equals 1 on the k^{th} day from February 1, 2020, until March 10, 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. Source: Bloomberg and TASE.

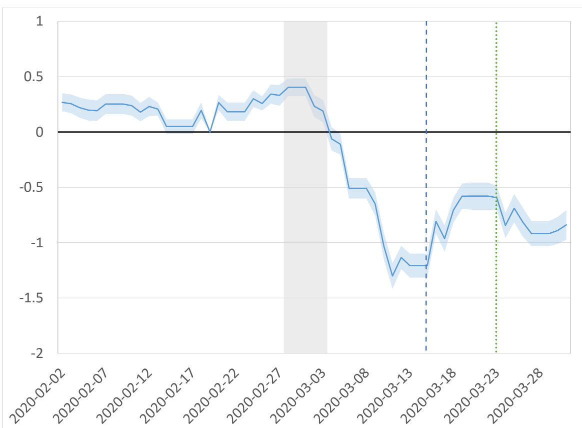
Appendix Figure A4: **Dynamic DD analysis—U.S. Treasury vs. U.S. futures**



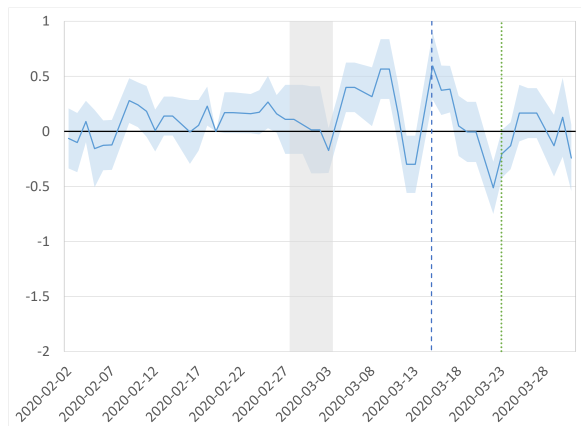
Notes: Appendix Figure A4 shows the $\beta_{3,k}$ coefficients and the 95% confidence bounds of regression: $\log \text{BAS}_{it} = \xi_i + \xi_t + \sum_{k=1}^{60} \beta_{3,k} \text{future} \times \text{day}_k + u_{it}$, where BAS_{it} is the spread of security i on day t; day_k equals 1 on the k^{th} day from February 1, 2020, until March 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 and Bank of Israel's interventions on March 15 and 23, 2020, respectively. Source: Bloomberg and the Chicago Mercantile Exchange.

Appendix Figure A5: **Dynamic within-country DD analysis**

(a) U.S.

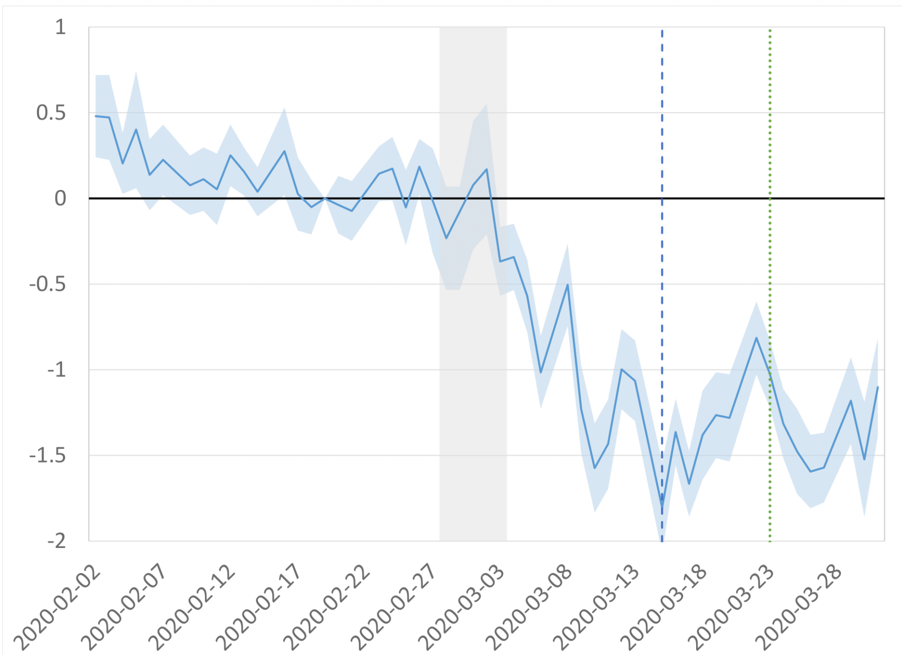


(b) Israel



Notes: Appendix Figure A5 shows the $\beta_{3,k}$ coefficients and the 95% confidence bounds of regression: $\log \text{BAS}_{it} = \xi_i + \xi_t + \sum_{k=1}^{60} \beta_{3,k} \text{stock} \times \text{day}_k + u_{it}$ for the U.S. in (a) and for Israel in (b), where BAS_{it} is the spread of security i on day t; day_k equals 1 on the k^{th} day from February 1, 2020, until March 31, 2020, and 0 otherwise; stock is 1 for stocks and 0 for 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 and Bank of Israel's interventions on March 15 and 23, 2020, respectively. Source: Bloomberg and TASE.

Appendix Figure A6: **Dynamic across-country DD analysis with Treasuries**

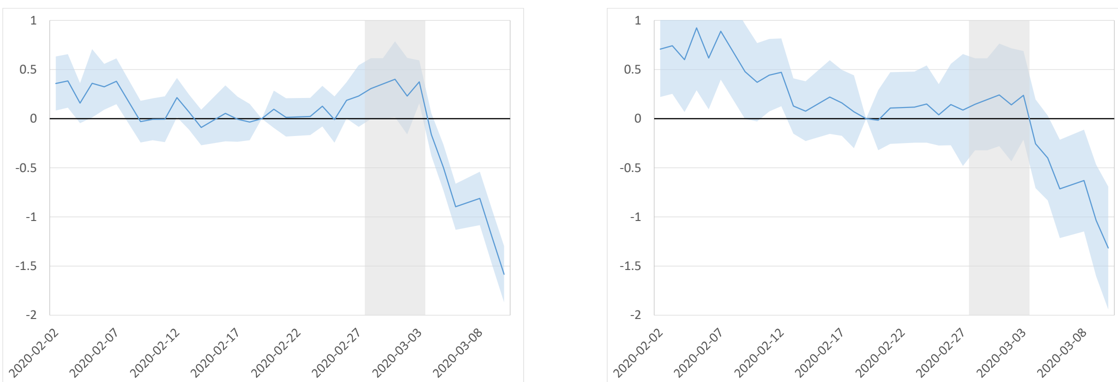


Notes: Appendix Figure A6 shows the $\beta_{3,k}$ coefficients and the 95% confidence bounds of regression: $\log \text{BAS}_{it} = \xi_i + \xi_t + \sum_{k=1}^{60} \beta_{3,k} \text{IL} \times \text{day}_k + u_{it}$, where BAS_{it} is the spread of security i on day t; day_k equals 1 on the k^{th} day from February 1, 2020, until March 31, 2020, and 0 otherwise; IL is 1 Israeli 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 and Bank of Israel's interventions on March 15 and 23, 2020, respectively. Source: Bloomberg and TASE.

Appendix Figure A7: **Dynamic DDD analysis—Israel vs. U.S. on- vs. off-the-run**

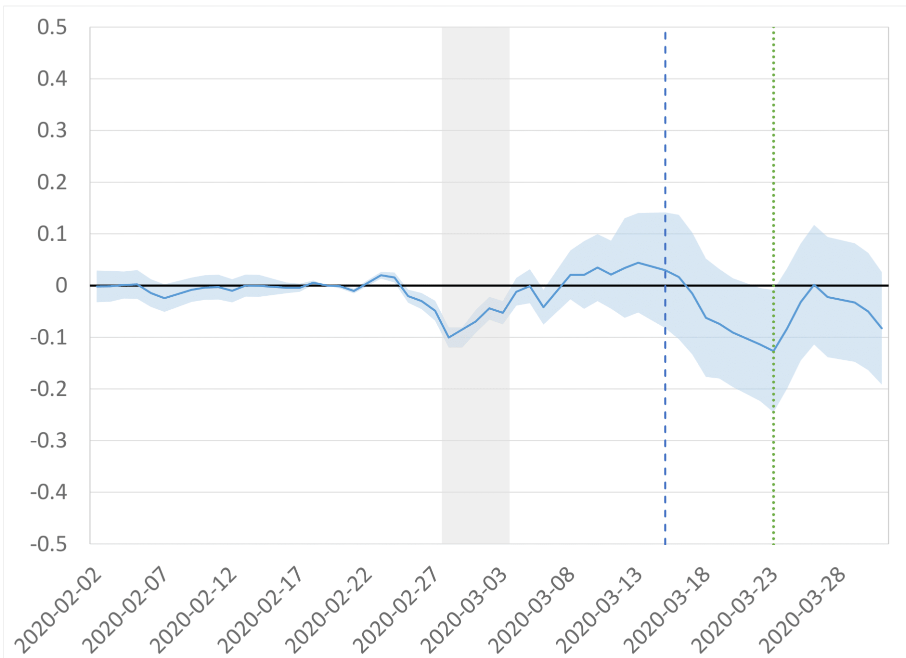
(a) All bonds

(b) Bonds on-the-run



Notes: Appendix Figure A7 shows the $\delta_{7,k}$ coefficients and the 95% confidence bounds of regression: $\log \text{BAS}_{it} = \xi_i + \xi_{ct} + \sum_{k=1}^{60} \delta_{5,k} \text{bond} \times \text{day}_k + \sum_{k=1}^{60} \delta_{7,k} \text{bond} \times \text{IL} \times \text{day}_k + u_{it}$, using data on all government bonds in our sample in (a) and on government bonds that were on-the-run between February 28, 2020, and March 31, 2020 in (b). BAS_{it} is the spread of security i on day t; day_k equals 1 on the k^{th} day from February 1, 2020, until March 10, 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. Source: Bloomberg and TASE.

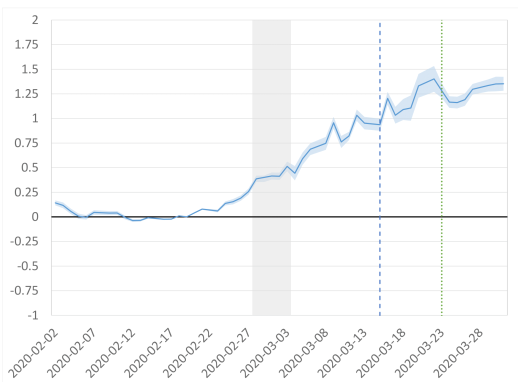
Appendix Figure A8: **Dynamic DDD analysis with prices—Israel vs. U.S.**



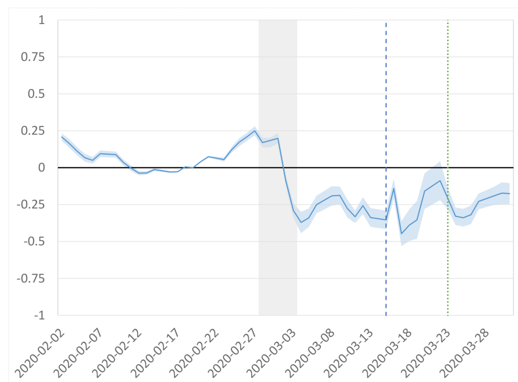
Notes: Appendix Figure A8 shows the $\delta_{7,k}$ coefficients and the 95% confidence bounds of the regression: $\log(\text{price})_{it} = \xi_i + \xi_{ct} + \sum_{k=1}^{60} \delta_{5,k} \text{bond} \times \text{day}_k + \sum_{k=1}^{60} \delta_{7,k} \text{bond} \times \text{IL} \times \text{day}_k + u_{it}$, where price_{it} is the mid-price of bond i and the price-index of stock i on day t; day_k equals 1 on the k^{th} day from February 1, 2020, until March 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. Blue and green lines correspond to the Fed's and Bank of Israel's interventions on March 15 and 23, 2020, respectively. Source: Bloomberg and TASE.

Appendix Figure A9: **Dynamic DD analysis with yields—Israel vs. U.S.**

(a) Government bond yields



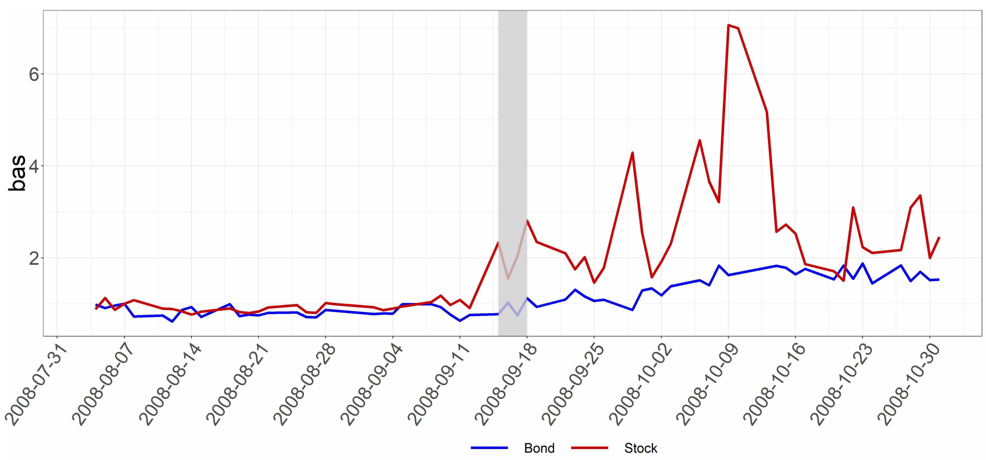
(b) Normalized government bond yields



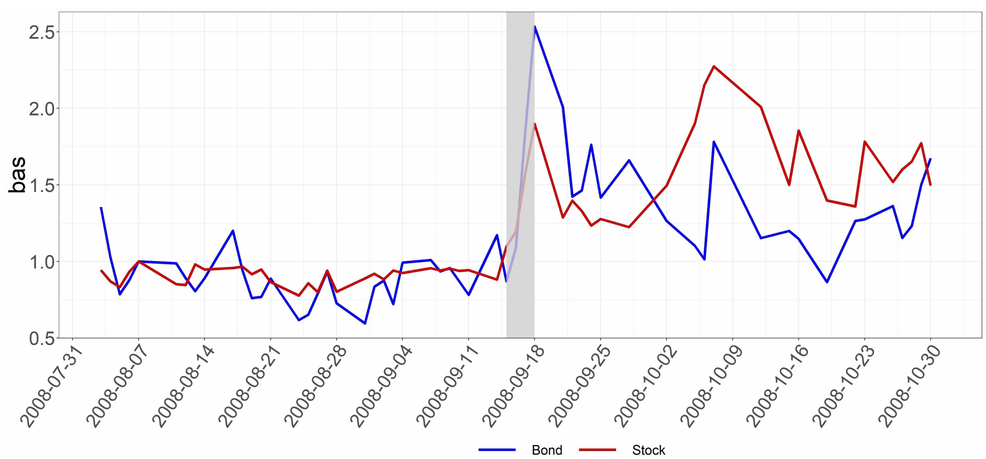
Notes: Appendix Figure A9a shows the β_k coefficients and the 95% confidence bounds of regression: $\log(\text{yield})_{it} = \xi_i + \xi_t + \sum_{k=1}^{60} \beta_k \text{IL} \times \text{day}_k + u_{it}$, where yield_{it} is the yield to maturity of government bond i on day t; day_k equals 1 on the k^{th} day from February 1, 2020, until March 31, 2020, and 0 otherwise; IL is 1 for Israeli rather than U.S. government bonds; ξ_i is a security, and ξ_t a date fixed effect. In Appendix Figure A9b yields are normalized by the U.S. next-month federal funds futures contract for the U.S. and by the spread of the 3-month-forward versus 1-month-forward TELBOR for Israel. In both cases, 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 and Bank of Israel's interventions on March 15 and 23, 2020, respectively. Source: Bloomberg and TASE.

Appendix Figure A10: **Time series of spreads of government bonds and stock indices**

(a) U.S.

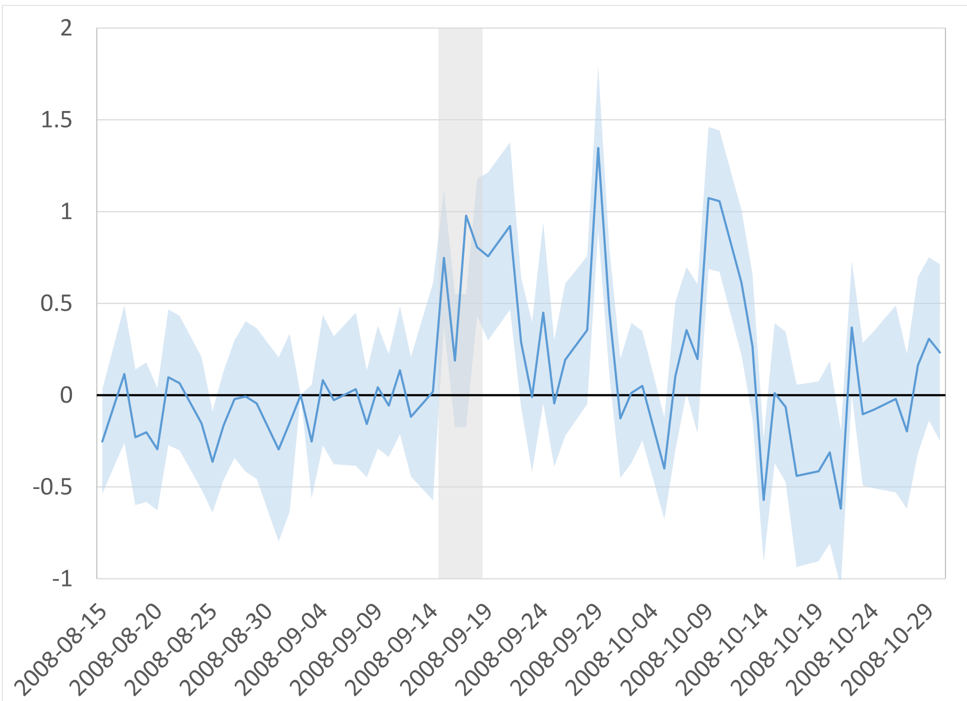


(b) Israel



Notes: Appendix Figure A10 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.

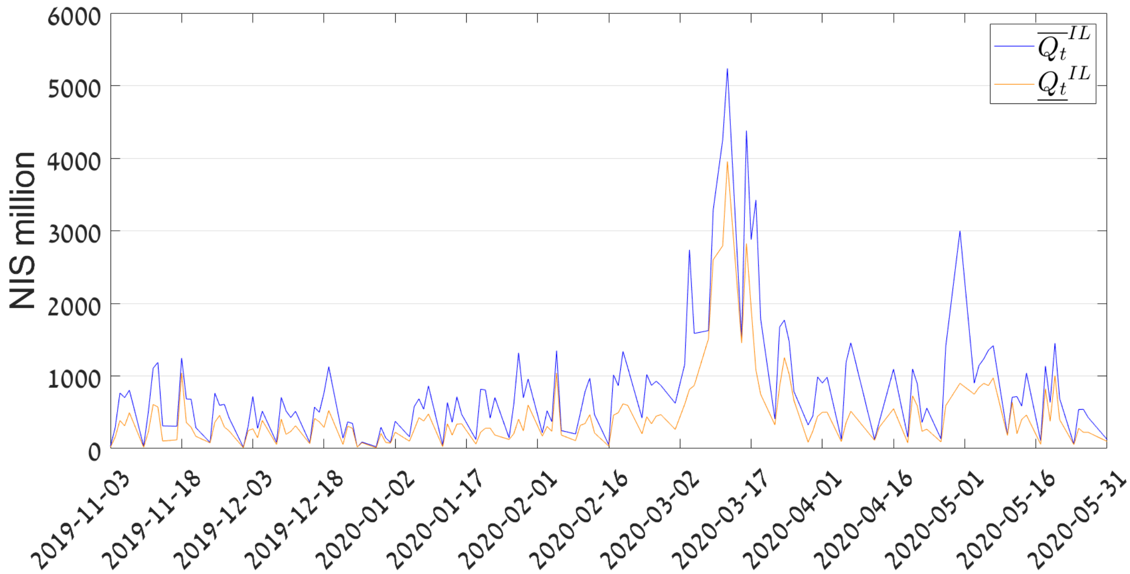
Appendix Figure A11: **Dynamic DDD analysis of spreads in 2008—Israel vs. U.S.**



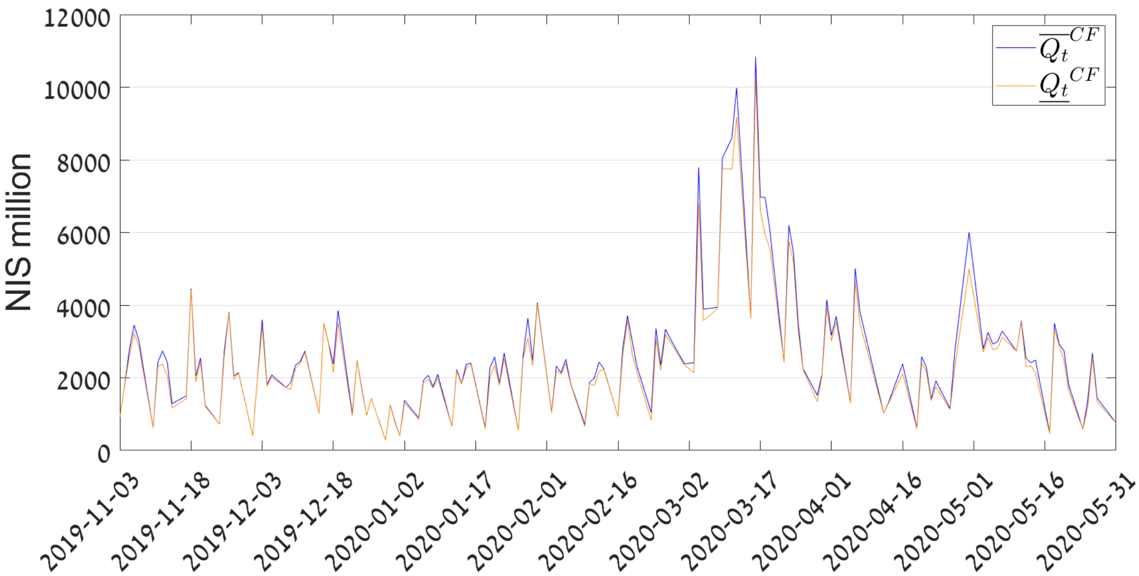
Notes: Appendix Figure A11 shows the $\delta_{7,k}$ coefficients and the 95% confidence bounds of regression: $\log \mathrm{BAS}_{it} = \xi_i + \xi_{ct} + \sum_{k=1}^{77} \delta_{5,k} \mathrm{bond} \times \mathrm{day}_k + \sum_{k=1}^{77} \delta_{7,k} \mathrm{bond} \times \mathrm{IL} \times \mathrm{day}_k + u_{it}$, 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.

Appendix Figure A12: **Upper and lower bounds of dealers' daily gross obligations**

(a) In the status quo (Israel)



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



Notes: Appendix Figure A12a shows the upper and lower bounds of dealers' daily gross obligations in Israel—defined in Appendix F in equation (14)—from November 1, 2019, until June 30, 2020. Appendix Figure A12b shows the analogue—defined in equation (17)—for the counterfactual, in which trades clear according to U.S. settlement rules. Everything is expressed in NIS million. Source: TASE.

Appendix Table A1: **Descriptive statistics of spreads for all markets**

(a) Pre-crisis period

	Mean (%)	**S.D (%)**	**Min. (%)**	**Max. (%)**	**# Obs.**	**# Sec.**	**# Days**
U.S. stocks	0.056	0.035	0.007	0.463	9054	503	18
U.S. gov bonds	0.032	0.014	0.004	0.111	1290	66-71	19
U.S. futures	0.009	0.006	0.002	0.020	76	4	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
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
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
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

(b) Post-crisis period

	Mean (%)	**S.D (%)**	**Min. (%)**	**Max. (%)**	**# Obs.**	**# Sec.**	**# Days**
U.S. stocks	0.110	0.074	0.010	0.921	5533	503	11
U.S. gov bonds	0.149	0.157	0.007	1.147	795	72-73	11
U.S. futures	0.013	0.013	0.002	0.071	44	4	11
IL stocks	0.359	0.191	0.065	1.006	280	35	8
IL gov bonds	0.078	0.093	0.015	0.555	128	16	8
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	24-26	8
JPN stocks	0.108	0.079	0.023	0.639	1800	225	8
JPN gov bonds	0.205	0.199	0.019	1.295	581	71-73	8
GER stocks	0.049	0.015	0.021	0.099	240	30	8
GER gov bonds	0.063	0.058	0.005	0.383	248	31	8

Notes: Appendix Table A1 shows descriptive statistics of the daily spread of U.S., Israel, U.K, Japanese, and German government bonds with maturity above 2 years that was on-the-run sometime between January, 1, 2019, and March, 31, 2020, and constituents of the S&P500, TA 35, FTSE 100, NIKKEI 225, and DAX 30 index for two sub-periods. For the U.S. and Israel, the pre-crisis period is February 1, 2020, until February 27, 2020, and the post-crisis period is February 28, 2020, until March 13, 2020. For the other countries, where policy measures started earlier, the post-crisis period ends on March 10, 2020. The number of securities varies, for instance, because new bonds are issued. Source: Bloomberg and TASE.

Appendix Table A2: **Descriptive statistics of high-low spreads in Israel**

(a) Pre-crisis period: 01/02/2020-27/02/2020

	Mean (%)	**S.D (%)**	**Min. (%)**	**Max. (%)**	**# Obs.**	**# Sec.**	**# Days**
TASE	0.19	0.20	0.01	1.09	313	15-16	20
OTC	0.28	0.47	0.00	1.88	29	11	15

(b) Crisis period: 28/02/2020-13/03/2020

	Mean (%)	**S.D (%)**	**Min. (%)**	**Max. (%)**	**# Obs.**	**# Sec.**	**# Days**
TASE	0.73	0.94	0.01	5.11	128	16	8
OTC	2.09	2.78	0.01	12.31	26	10	8

Notes: Appendix Table A2 shows descriptive statistics of the high-low spread, which is the difference between the highest and lowest price at which an Israeli government bond with maturity above 2 years is traded within a day on the TASE and OTC. 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). The pre-crisis period is February 1, 2020, until February 27, 2020, and the post-crisis period is February 28, 2020, until March 13, 2020. Source: TASE.

Appendix Table A3: **Static DD analysis—within country**

(a) U.S.

	OLS		FE	
stock	+0.503***	(0.013)		
post	+1.156***	(0.032)		
stock×post	−0.514***	(0.033)	−0.604***	(0.024)
Observations	20,607		20,607	
Adjusted R^2	0.265		0.892	
Security fixed effect	−		+	
Day fixed effect	−		+	

(b) Israel

	OLS		FE	
stock	−1.754***	(0.039)		
post	+0.430***	(0.071)		
stock×post	+0.047	(0.076)	+0.061	(0.057)
Observations	1,831		1,831	
Adjusted R^2	0.687		0.925	
Security fixed effect	−		+	
Day fixed effect	−		+	

Notes: Appendix Table A3 shows the results of DD regressions (8) and (9) in columns (OLS) and (FE), respectively, for the U.S. in (a) and for Israel in (b), using data from February 1, 2020, until March 13, 2020. 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 that was on-the-run sometime between January, 1, 2019, and March, 31, 2020). Indicator variable stock is 1 for stocks and 0 for bonds; post is 1 starting on February 28, 2020. In column (FE), standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg and TASE.

Appendix Table A4: **Static DD analysis—across countries with Treasuries**

	OLS		FE	
IL	+0.163***	(0.037)		
post	+1.156***	(0.032)		
IL×post	−0.726***	(0.077)	−0.831***	(0.055)
Observations	3,072		3,072	
Adjusted R^2	0.361		0.882	
Security fixed effect	−		+	
Day fixed effect	−		+	

Notes: Appendix Table A4 shows the results of DD regressions (10) and (11) in columns (OLS) and (FE), respectively, using data from February 1, 2020, until March 13, 2020. The dependent variable is the daily log spread of a security (either a U.S. or Israeli government bond with maturity above 2 years that was on-the-run sometime between January, 1, 2019, and March, 31, 2020). Indicator variable IL is 1 for Israeli securities and 0 otherwise; post is 1 starting on February 28, 2020. In column (FE), standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg and TASE.

Appendix Table A5: **Static DD analysis—within Israel using trades prices**

	OLS		FE	
exchange	−0.045	(0.053)	+0.002	(0.002)
post	+0.051	(0.037)		
exchange×post	−0.047	(0.037)	−0.013**	(0.005)
Observations	496		496	
Adjusted R^2	0.013		0.996	
Security fixed effect	−		+	
Day fixed effect	−		+	

Notes: Appendix Table A5 is analogous to columns 3 and 4 in Table 3, but with trade prices instead of spreads. It shows the results of DD regressions (8) and (9) in columns (OLS) and (FE), respectively, using data from February 1, 2020, until March 13, 2020. The dependent variable is the daily log price of an Israeli government bond with maturity above 2 years, calculated from the transactions on the TASE and the Israeli OTC market. We exclude cases when there is a single trade of a security within a day, or the highest and lowest trade prices are identical (probably because all investors execute trades in the same direction). Indicator variable exchange is 1 when a trade is on the TASE and 0 when it is OTC; post is 1 starting on February 28, 2020. In column (FE), standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: TASE.

Appendix Table A6: **Financial crisis—Static DD analysis within country**

(a) Within U.S.

	OLS		FE	
stock	+1.724***	(0.047)		
post	+0.421***	(0.069)		
stock×post	+0.508***	(0.070)	+0.527***	(0.072)
Observations	26,839		26,839	
Adjusted R^2	0.223		0.541	
Security fixed effect	−		+	
Day fixed effect	−		+	

(b) Within Israel

	OLS		FE	
stock	+1.620***	(0.049)		
post	+0.532***	(0.067)		
stock×post	+0.020	(0.073)	+0.020	(0.063)
Observations	1,855		1,855	
Adjusted R^2	0.626		0.926	
Security fixed effect	−		+	
Day fixed effect	−		+	

Notes: Appendix Table A6 is analogous to Appendix Table A3 but for the 2007–2009 financial crisis. It shows the results of DD regressions (8) and (9) in columns (OLS) and (FE), respectively, for the U.S. in (a) and for Israel in (b), 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. In column (FE), standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg, TradeWeb, and TASE.

Appendix Table A7: **Financial crisis—Static DD analysis across countries with Treasuries**

	OLS		FE	
IL	+0.940***	(0.065)		
post	+0.421***	(0.069)		
IL×post	+0.111	(0.096)	+0.111	(0.094)
Observations	954		954	
Adjusted R^2	0.351		0.861	
Security fixed effect	−		+	
Day fixed effect	−		+	

Notes: Appendix Table A7 is analogous to Appendix Table A4, but for the 2007–2009 financial crisis. It shows the results of DD regressions (10) and (11) in columns (OLS) and (FE), respectively, 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. In column (FE), standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: TradeWeb and TASE.

Appendix Table A8: **Financial crisis—Static DDD analysis across countries**

	OLS		FE	
bond	−1.724***	(0.047)		
IL	+0.835***	(0.020)		
post	+0.929***	(0.012)		
bond×IL	+0.104	(0.068)		
post×IL	−0.377***	(0.031)		
bond×post	−0.508***	(0.070)	−0.527***	(0.072)
bond×IL×post	+0.489***	(0.101)	+0.507***	(0.095)
Observations	28,694		28,694	
Adjusted R-squared	0.246		0.561	
Security fixed effect	−		+	
Country-day fixed effect	−		+	

Notes: Appendix Table A8 is analogous to Appendix Table 1, but for the 2007–2009 financial crisis. It shows results of DDD regressions (1) and (2) in columns (OLS) and (FE), respectively, 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. In column (FE), standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg, TradeWeb, and TASE.

Appendix Table A9: **Robustness—Static DDD analysis with ask minus bid spreads**

	OLS		FE	
bond	+5.677***	(0.059)		
IL	+0.468***	(0.020)		
post	−0.334***	(0.017)		
bond×IL	−5.408 * **	(0.072)		
post×IL	−0.168*	(0.098)		
bond×post	+0.717***	(0.039)	+0.808***	(0.025)
bond×IL×post	−0.582***	(0.128)	−0.670***	(0.063)
Observations	22,438		22,438	
Adjusted R^2	0.543		0.980	
Security fixed effect	−		+	
Country-Day fixed effect	−		+	

Notes: Appendix Table A9 is analogous to Table 1, but uses spreads in absolute terms (ask minus bid), rather than normalized by the mid-price. It shows results of DDD regressions (1) and (2) in columns (OLS) and (FE), respectively, using data from February 1, 2020, until March 13, 2020. 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 that was on-the-run sometime between January, 1, 2019, and March, 31, 2020). 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. In column (FE), standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg and TASE.

Appendix Table A10: **Robustness—Static DDD analysis with asynchronous trading**

	OLS		FE	
bond	−0.527***	(0.016)		
IL	+1.390***	(0.020)		
post	+0.628***	(0.013)		
bond×IL	−1.232***	(0.050)		
post×IL	−0.177***	(0.044)		
bond×post	+0.640***	(0.048)	+0.727***	(0.025)
bond×IL×post	−0.666***	(0.113)	−0.766***	(0.054)
Observations	13,083		13,083	
Adjusted R-squared	0.387		0.913	
Security fixed effect	−		+	
Country-day fixed effect	−		+	

Notes: Appendix Table A10 is analogous to Table 1, but without interpolating spreads between trading dates. It shows results of DDD regressions (1) and (2) in columns (OLS) and (FE), respectively, using data from February 1, 2020, until March 13, 2020. 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 that was on-the-run sometime between January, 1, 2019, and March, 31, 2020). 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. In column (FE), standard errors are clustered by security. *** p<0.01, ** p<0.05, * p<0.1. Source: Bloomberg and TASE.

Appendix Table A11: **Robustness—Static DDD analysis with different cutoff dates**

	OLS1	FE1	OLS2	FE2
bond	−0.524***		−0.485***	
	(0.013)		(0.013)	
IL	+1.379***		+1.427***	
	(0.016)		(0.017)	
post	+ 0.572***		+0.628***	
	(0.010)		(0.009)	
bond×IL	−1.227***		−1.266***	
	(0.040)		(0.042)	
post×IL	−0.080**		−0.174***	
	(0.032)		(0.029)	
bond×post	+0.681***	+0.770***	+0.405***	+0.492***
	(0.036)	(0.023)	(0.032)	(0.024)
bond×IL×post	−0.747***	−0.847***	−0.454***	−0.556***
	(0.088)	(0.055)	(0.079)	(0.064)
Observations	22,438	22,438	22,438	22,438
Adjusted R-squared	0.361	0.914	0.382	0.902
Security fixed effect	−	+	−	+
Country-day fixed effect	−	+	−	+

Notes: Appendix Table A11 is analogous to Table 1, but with different cutoff dates. It shows results of DDD regressions (1) and (2) in columns (OLS1), (OLS2) and (FE1), (FE2) respectively, using data from January 30, 2020, until March 11, 2020, in (OLS1) and (FE1) and from February 3, 2020, until March 15, 2020 in (OLS2) and (FE2). 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 that was on-the-run sometime between January, 1, 2019, and March, 31, 2020). 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 26, 2020, in columns (OLS1) and (FE1), and starting on March 2, 2020, in columns (OLS2) and (FE2). In columns (FE1) and (FE2), standard errors are clustered by security. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: Bloomberg and TASE.

Appendix Table A12: **Robustness—Static DDD analysis with TA 125**

	OLS		FE	
bond	−0.503***	(0.013)		
IL	+2.061***	(0.013)		
post	+0.642***	(0.009)		
post×IL	−0.164***	(0.023)		
bond×IL	−1.898***	(0.040)		
bond×post	+0.514***	(0.033)	+0.604***	(0.024)
bond×IL×post	−0.563***	(0.081)	−0.670***	(0.058)
Observations	25,714		25,714	
Adjusted R-squared	0.654		0.947	
Security fixed effect	−		+	
Country-day fixed effect	−		+	

Notes: Appendix Table A12 is analogous to Table 1, but uses spreads of the TA 125 rather than TA 35. It shows results of DDD regressions (1) and (2) in columns (OLS) and (FE), respectively, using data from February 1, 2020, until March 13, 2020. The dependent variable is the daily log spread of a security (either a constituent of the S&P 500 or the TA 125 index; or a U.S. or Israeli government bond with maturity above 2 years that was on-the-run sometime between January, 1, 2019, and March, 31, 2020). 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. In column (FE), standard errors are clustered by security. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: Bloomberg and TASE.