



School of Finance

University of St.Gallen

**«COLLATERAL CHOICE»**

**BENEDIKT BALLENSIEFEN**

**WORKING PAPERS ON FINANCE NO. 2022/03**

**JUNE 9, 2022**



# Collateral Choice\*

BENEDIKT BALLENSIEFEN<sup>†</sup>

November 13, 2022

## Abstract

This is the first paper studying *collateral choices* in one of the main short-term funding instruments, the repurchase agreement (repo). In general collateral repos, the borrower can choose which bond he posts as collateral out of a predefined list. I show that collateral availability and opportunity cost explain the collateral choice. In the aggregate, on-the-run bonds are more likely to be delivered than cheapest-to-post securities which is surprising given that the former is more expensive. I rationalize those findings in a theoretical framework that links the repo to the bond market and show that bond market spreads depend on repo collateral choices.

KEYWORDS: FUNDING, COLLATERAL, REPO, BOND, ON-THE-RUN, LIQUIDITY.

JEL CLASSIFICATION: E40, E41, E43, G00, G01, G10

Funding markets are crucial for the efficient allocation of money and financial securities as well as for preserving financial stability. Short-term funding markets provide financing for financial institutions and can be used to obtain securities, while long-term funding markets

---

\*I would like to thank Andrea Barbon (discussant), Philippe van der Beck (discussant), Martin Brown, Guido Cozzi, Darrell Duffie, Ralf Elsas, Sebastian Infante (discussant), Sven Klingler (discussant), Peteris Kloks, Edouard Mattile, Ye Qian (discussant), Angelo Ranaldo, Jurij-Andrei Reichenecker (discussant), Kumar Rishabh (discussant), Stefan Ruenzi, Christian Schlag, Fabricius Somogyi, Paul Söderlind, Erik Theissen, and Hannah Winterberg and conference participants at the 5th Short-Term Funding Markets Conference (2022), the SFI Research Days (2022), the 29th Finance Forum (2022), the FMA European Conference (2022), the World Finance Conference (2022), the 6th SAFE Market Microstructure Conference (2022), the 28th Annual Meeting of the German Finance Association (doctoral workshop, 2022), and the GPEF PhD Day (2022) as well as seminar participants at the University of St. Gallen (2022) for their valuable comments and suggestions. Scheduled conferences include the 17th Central Bank Conference on Microstructure of Financial Markets (2022), the New Zealand Finance Meeting (2022), and the American Economic Association (poster session, 2023). This work did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The Online Appendix is available upon request.

<sup>†</sup>University of St. Gallen and World Bank Group, Unterer Graben 21, CH-9000 St.Gallen, Switzerland. Tel. +41 (0)79 808 92 56. E-mail: benedikt.ballensiefen@unisg.ch.

allow governments and firms to finance long-term investments and manage debt sustainably. The two markets are connected by a secured, short-term funding instrument, the repurchase agreement (repo), which is a short-term loan between banks collateralized by long-term assets such as government bonds or asset-backed securities. Bank activity has moved towards the secured market since the Global Financial Crisis, the repo is now the major short-term funding source. The focus of this paper is to study the use of government bonds as collateral in those short-term transactions to improve our understanding of the *interconnection* between short-term and long-term funding markets.

The repo is the main money market instrument, the asset being used as collateral can be a particular government bond (“special repo”) or any bond from a predefined basket (“general collateral or GC repo”).<sup>1</sup> Surprisingly little is known about borrowers’ collateral choices in the GC segment. This is different from other markets such as futures where the “cheapest-to-deliver” concept was developed. In this paper, I study those collateral choices. For this, I focus on the European repo market, which is a centrally cleared market that eliminates many frictions of bilateral, over-the-counter (OTC) markets such as counterparty risk, bargaining power, and banking relationships.

Figure 1 depicts repo delivery volumes and bond market bid-ask spreads for (i) the most recently issued, “on-the-run” (OTR) government bond (blue line), (ii) the “cheapest-to-post” (CTP) bond (orange line), and (iii) an average across all other bonds (yellow line). OTR bonds are more likely to be chosen as collateral than CTP bonds, which seems surprising since posting OTR bonds is more costly (e.g., Krishnamurthy, 2002). In fact, ex ante, the expectation is that bonds less valuable than the OTR bond are parked in GC trades. I provide a theoretical explanation for this by introducing an inventory model that links the repo market to the underlying bond market. Market makers hold inventories of securities, in particular, of OTR bonds, to cater the needs of their clients. This creates cost for which they want to get compensated. In line with this intuition, I show that OTR bonds with higher GC delivery volumes have higher bond market spreads in spite of higher trading volumes.

---

<sup>1</sup>A special repo is also referred to as a “specific” repo in the U.S.

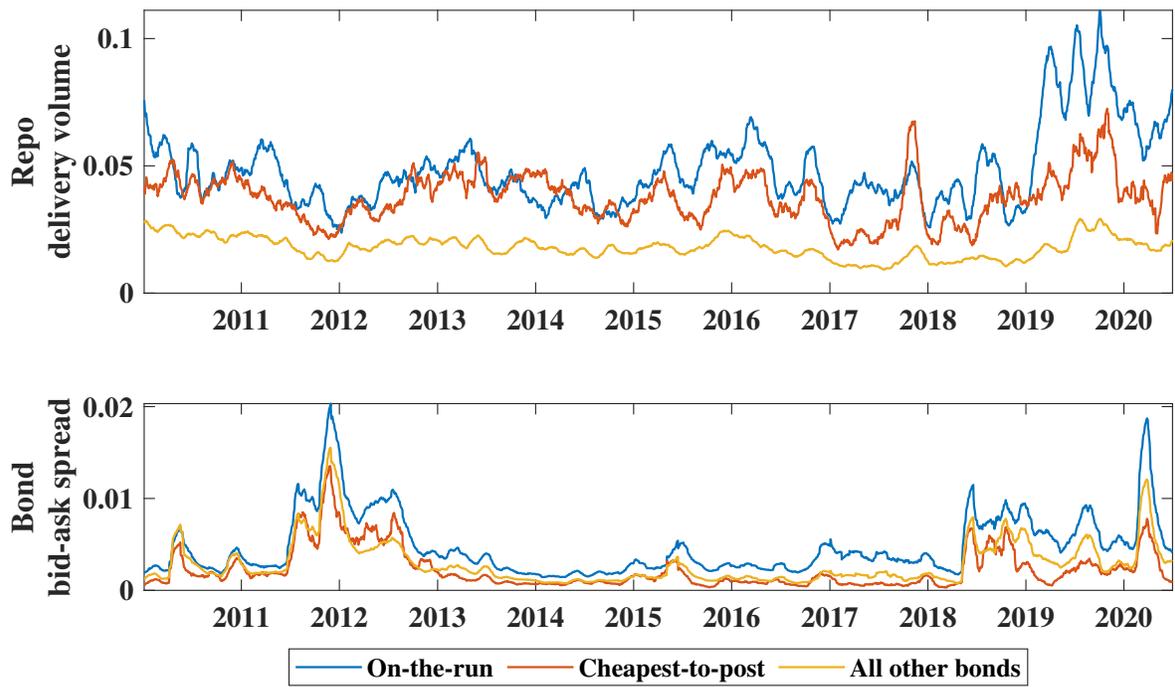


Figure 1 depicts (i) the daily delivery volume of a bond into GC repos relative to its outstanding volume and (ii) the relative bid-ask spread. The results are depicted for OTR bonds (blue), CTP securities (orange), and all other bonds (yellow).

**Figure 1:** Repo delivery volumes and bond bid-ask spread

I find that banks' willingness to post bonds as collateral depends on collateral availability (quantity) and opportunity cost (price). Collateral availability relates to variations in the net supply of collateral assets and asset scarcity. I find that the intensity of bond deliveries declines in the auction cycle and is smaller for bonds targeted by quantitative easing (QE). Collateral opportunity cost is the second driver of collateral choice. The cheapest-to-post idea is a new concept developed in this paper. I identify the CTP bond which is the bond with the highest special repo rate of all bonds that are eligible to be posted as collateral. Conceptually, the CTP bond minimizes the borrowers' opportunity cost. Delivering the OTR bond instead of the CTP security is, therefore, more expensive, as the borrower could refinance himself at a significantly lower rate in the special segment using the OTR bond (Duffie, 1996). In line with this, I find that the GC volume of a bond is highest for low levels in the opportunity cost and decreases as it gets more expensive to post a security.

Looking at the joint effect, I find that OTR bonds (with the highest availability) are more likely to be posted than CTP bonds (with the lowest opportunity cost). For example, when bonds with high opportunity cost are delivered, those are likely to be OTR securities. Opportunity cost for OTR bonds are economically meaningful as they go up to 50bps. In line with Keane (1996), I show that OTR bonds become increasingly special until the next auction. Repo deliveries reverse this pattern. Inspired by the safe asset literature, I also consider the level of short-term rates. Nagel (2016) theorizes that the convenience benefits of assets are more valuable in a high interest rate environment. Consistent with this idea, I find that the delivery volume of OTR bonds is lower in a high interest rate environment when the superior liquidity services of OTR bonds are more valuable.

Extending my analysis to the U.S. Treasury market, I confirm that the economic intuition derived from the euro area also applies to the U.S. setting. The borrower in a repo trade always has the option to post the OTR bond into a GC *or* special trade. I show that the share of OTR bonds posted into GC versus special trades depends on the opportunity cost. In addition, even for U.S. Treasuries, the intensity of OTR deliveries into GC trades is substantial as the share reaches up to 40%.

I introduce a theoretical framework that explains the use of OTR bonds in GC repos and relates it to the bond market for the collateral.<sup>2</sup> My framework is based on Stoll (1978) and considers an inventory model with a dealer who is a market maker for government bonds. The dealer holds OTR bonds in excess in his inventory to distribute them to his clients over time. In the meantime, he uses repos to finance his portfolio. The dealer can access the GC and special segment, however, the use of special repos is limited due to settlement and search frictions. By holding the inventory and having to finance it with repos, the dealer faces financing and opportunity cost for which he requires a compensation. The dealer's resulting cost function predicts that the bid-ask spread charged to his clients in the bond market increases in the size of the dealer's portfolio of OTR bonds and in the OTR opportunity cost. In line with the theoretical predictions, *tomorrow's* bid-ask spread tends to be higher when *today's* GC delivery volumes and *today's* collateral opportunity cost are higher.

My results are important to understand the systematically important role of *financial intermediaries*. Market makers provide a service to governments by subscribing to government bond auctions as they ensure demand and thus price certainty. Market makers are also important to clients as they are fulfilling an important financial intermediation role. My results, thereby, have (intermediary) *asset pricing* implications. Transaction cost in the bond market are time-varying, I show that collateral choices in the repo market are one reason for it. At first, it seems surprising that OTR bonds can have higher bond market spreads in spite of higher trading volumes. At the same time, the proposed mechanism is intuitive as market makers need to hold OTR inventories, which is risky and costly. In addition, my results suggest an explanation for the lacking OTR premium in the euro area. Lastly, my results are important for *monetary policy* as they suggest frictions in the money market, which is important given the repo market's key role in the monetary policy transmission.

My analysis mainly contributes to two strands of the literature. First, I contribute to the literature on short-term funding markets and the choice of the collateral asset. Our understanding of which and why safe assets are pledged as collateral in short-term funding

---

<sup>2</sup>Related studies include, for example, Krishnamurthy (2002), Huh and Infante (2021), and Bartolini et al. (2011).

markets if the borrower is presented with a choice is very limited. I complement the existing literature by analyzing borrowers’ collateral choices and determine what characteristics make bonds more likely to be used as collateral.<sup>3</sup> Song and Zhu (2019) analyze a different notion of collateral choice by focusing on the “to-be-announced” market for mortgage-backed securities.

Second, I contribute to the literature focusing on the linkage between short-term and long-term funding markets.<sup>4</sup> I provide an extension of the theoretical framework in Stoll (1978) to incorporate a dealer’s funding decision and how this relates to the market liquidity for the collateral. Related to it is the literature on auction cycles.<sup>5</sup>

## 1. Setting

I start by explaining the main characteristics of the European repo market and my data.

### 1.1 Repo market infrastructure

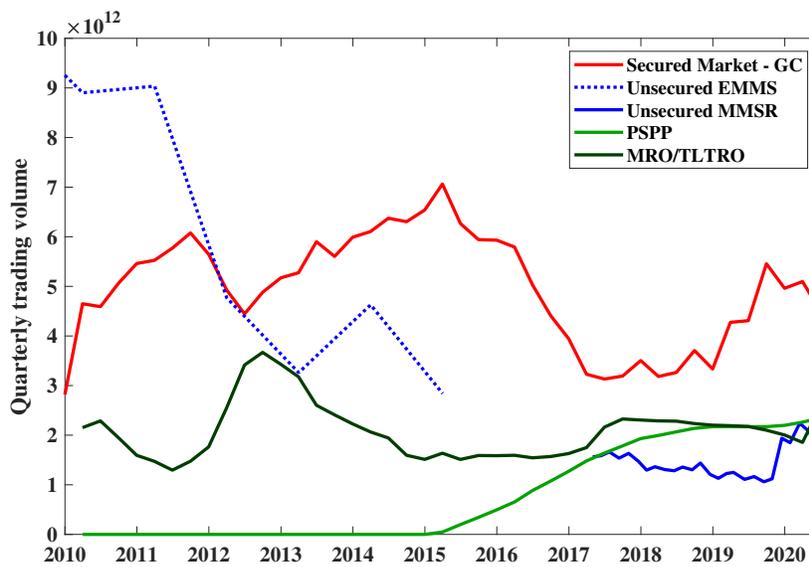
In a repo contract, two counterparts exchange cash for collateral (first leg) for a predefined period with a fixed repurchase obligation (second leg). Repos are a form of short-term borrowing as collateral is typically sold on an overnight basis. The motive to enter into a repo trade can either be to obtain funding or collateral; the repo market, therefore, serves a dual role, it represents the main market for banks to obtain short-term funding and rebalance

---

<sup>3</sup>Literature on the GC repo segment includes e.g., Longstaff (2004), Bartolini et al. (2011), Mancini, Ranaldo, and Wrampelmeyer (2016), and Boissel et al. (2017). Papers focusing more on special repos, for instance, include Duffie (1996), Jordan and Jordan (1997), Buraschi and Menini (2002), Krishnamurthy (2002), D’Amico, Fan, and Kitsul (2018), Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020), Infante (2020), Corradin and Maddaloni (2020), and Ranaldo, Schaffner, and Vasios (2021).

<sup>4</sup>Seminal work linking the bond and repo market include Duffie (1996), Krishnamurthy (2002), and Vayanos and Weill (2008). More recent studies include, for example, Fontaine and Garcia (2012), Chen et al. (2019), Huh and Infante (2021), and D’Amico and Pancost (2022). Brunnermeier and Pedersen (2009) model the reinforcement of market and funding liquidity. Related literature focuses on the impact of dealers’ funding cost on asset prices, e.g., He and Krishnamurthy (2013), Rytchkov (2014), Adrian, Boyarchenko, and Shachar (2017), and He, Kelly, and Manela (2017), and asset liquidity, e.g., Comerton-Forde et al. (2010), Andersen, Duffie, and Song (2019), and Goldstein and Hotchkiss (2020).

<sup>5</sup>Work focusing on the repo market goes back to Keane (1996) and includes e.g., Lou et al. (2013), D’Amico et al. (2018), and Sigaux (2018). Related literature on the impact of asset supply on the bond market includes e.g., Brandt and Kavajecz (2004), Pasquariello and Vega (2009), Krishnamurthy and Vissing-Jorgensen (2012), D’Amico and King (2013), Krishnamurthy and Vissing-Jorgensen (2015), Beetsma et al. (2016), Beetsma et al. (2018), and Eisl et al. (2019). Other papers such as Klingler and Sundaresan (2020) look at auction results from a demand perspective.



The figure depicts the quarterly trading volumes in the secured and unsecured market segments as well as the total cumulative Public Sector Purchase Program (PSPP) purchases and volumes of the European Central Bank's (ECB) main refinancing operations (MRO) and targeted longer-term refinancing operations (TLTRO). The data for the secured market refer to the total general collateral repo trading volume. The data for the unsecured market stem from the Euro Money Market Survey (EMMS) until 2015 and from the Money Market Statistical Reporting (MMSR) thereafter. To be conservative, I sum reported borrowing and lending activity in the unsecured market, which may entail double-counting. The data on PSPP purchases and refinancing operations are from the ECB. All data are in euro.

**Figure 2:** Different market turnovers

their portfolios. While a large body of the literature has analyzed the special segment with seminal work going back to Duffie (1996), the focus of this paper is on GC repos as I investigate which bond the borrower chooses to post as collateral if presented with a choice.

I study the European repo market which is the largest repo market in the world (ICMA, 2021). Figure 2 depicts trading volumes in the two main euro area money market segments: the red line depicts trading volumes in GC repos, the blue line depicts volumes in the unsecured money market. The repo market is clearly the main money market segment; in particular, an increase in risk aversion after the Global Financial Crisis and European Sovereign Debt Crisis has shifted bank activity towards the secured segment (European Central Bank, 2018). To put the importance of the repo market into perspective, repo trading volumes exceed cumulative bond purchases by the European Central Bank (ECB) under the

largest euro area QE program, the Public Sector Purchase Program (PSPP), as depicted by the light green line, or the ECB’s main refinancing operations (MRO) and targeted longer-term refinancing operations (TLTRO), as depicted by the dark green line. Overall, the GC repo market is now the predominant euro area money market in which banks operate. It is highly representative of banks’ funding and portfolio reallocation decisions and thus the ideal laboratory to study collateral choices and delivery patterns.

Four characteristics of the European repo market infrastructure are noteworthy:<sup>6</sup> First, the most common collateral assets are government bonds whose supply and demand varies depending on auctions, reopenings, and QE purchases. Second, repos are euro-denominated and the usual term types are Overnight (ON), Tomorrow-Next (TN), and Spot-Next (SN), indicating purchase dates tonight, tomorrow, and the day after tomorrow, respectively, and the repurchase date one day thereafter. Third, it mostly operates through central counterparties (CCP) that interpose themselves between each lender and borrower.<sup>7</sup> Through novation, a CCP acts as a clearinghouse and applies the same collateral and (credit) risk policies to all market participants. And fourth, the core segment is the interbank market in which banks trade anonymously via centralized electronic order book platforms supporting liquidity and a transparent price discovery process. All those characteristics allow me to eliminate many confounding factors to collateral choices such currency and counterparty risk, thus buttressing the measurement accuracy of my results. It also ensures that borrower-level characteristics and bank reputation do not affect funding cost and collateral choices.

## 1.2 Data

I observe a unique data set of GC repo trades executed on the MTS platform for the period from January 2010 to June 2020.<sup>8</sup> I also employ data on special repo trades to

---

<sup>6</sup>More detailed information about the European repo market infrastructure can be found in, e.g., Mancini, Ranaldo, and Wrampelmeyer (2016), Nyborg (2016), Bank for International Settlements (2017), and European Central Bank (2018).

<sup>7</sup>CCPs account for more than two-thirds of the total repo market turnover (European Central Bank, 2018).

<sup>8</sup>The MTS market comprises about 70% of all euro area GC repo trades and 38% of the traded volume. For each transaction, I observe the trade date, the term, the trade volume, the rate, the GC basket, the bond being delivered as collateral identified by a unique ISIN, and the aggressor type.

**Table 1:** Breakdown of the repo data

	Transactions (in million)	Volume (in euro trillion)	Transactions (share in %)	Volume (share in %)
General collateral euro repos	1.57	77.94	100.00%	100.00%
Overnight	0.40	15.29	25.13%	19.62%
Tomorrow-next	0.65	30.39	41.61%	38.99%
Spot-next	0.42	24.70	26.41%	31.69%
Other term types	0.11	7.57	6.85%	9.71%
Repo BTP	0.81	39.72	51.67%	50.96%
Repo BOT	0.28	12.95	17.65%	16.62%
Repo CCT	0.20	10.21	12.90%	13.09%
Repo BTP€i	0.16	7.99	10.36%	10.25%
Repo CTZ	0.11	6.11	6.76%	7.84%
OTR in GC and special			100.00%	100.00%
OTR GC volumes	0.33	17.94	24.14%	44.37%
OTR special volumes	1.04	22.49	75.86%	55.63%

The table shows the breakdown of the repo data. My data includes GC repos denominated in euros. The universe of GC repos traded on the MTS platform is broken down by repo term and GC basket. The last part compares volumes of OTR deliveries into GC trades with special trading volumes for OTR securities.

connect collateral choices in the GC segment to special repo rates of the bonds being pledged as collateral.

Table 1 provides a summary of my data. In total, I observe more than 1.5 million GC trades totalling more than 75 trillion euro in trading volume. In my analysis, I include all trading days, however, to ensure the robustness, I exclude quarter-end and end of ECB maintenance period days in additional tests.<sup>9</sup> All transactions are euro repos and more than 93% of the trades are overnight trades of term types ON, TN, and SN.<sup>10</sup> The MTS repo market covers a sizeable percentage of the European market transactions and the near-total

<sup>9</sup>On quarter- and year-end days as well as on end of ECB maintenance period days, window dressing impacts repo rates (Ranaldo, Schaffner, and Vasios, 2021). As further robustness checks, I also remove observations in the 99th percentile of CTP spreads for on-the-run and off-the-run bonds. The results are virtually unchanged in all those specifications.

<sup>10</sup>I include all term types in my analysis to ensure the general validity of my results. However, my results are fully consistent if I only consider ON, TN, and SN repos in my analysis.

universe of all Italian repo trades (Corradin and Maddaloni, 2020).<sup>11</sup> For the main part of my analysis, I, therefore, focus on Italian trades for which I have almost complete coverage. However, I show that my results are fully consistent for other euro area countries such as Germany and France which ensures the general validity of my analysis. Each government bond type has its own dedicated GC basket on the MTS platform.<sup>12</sup> This ensures that all bonds eligible to be delivered into a basket have the same bond type characteristics and thus guarantees that delivery patterns are not driven by, for example, different regulatory treatment.<sup>13</sup>

The borrower in a repo trade always has the option to post a security in the GC or special segment. In my sample, 44% of the OTR repo trading volume is in the GC segment compared to 56% in the special segment. This means that OTR volumes in the GC and special segment are comparable, which confirms the importance of the GC market. I return to the comparison between the GC market and the special segment when I relate my results to the U.S. Treasury market.

On each day and for each bond, I compute the daily number and volume of trades for which that bond served as collateral in GC trades. I complement this data with results on auctions and reopenings, which allows me to determine the OTR status and the remaining time for which a bond serves as an OTR bond. I also classify bonds into *eligible* and *noneligible* for QE purchases depending on whether a bond fulfilled the purchasing provisions that were valid at a specific point in time.<sup>14</sup> This allows me to measure the number of days a bond has been eligible for QE to capture scarcity effects.<sup>15</sup> Finally, I add haircut information for each bond

---

<sup>11</sup>For example, more than 99% of all Italian GC trades are executed on the MTS platform.

<sup>12</sup>A description of the different baskets traded on the MTS platform as well as a summary of the bond characteristics is provided in the Online Appendix.

<sup>13</sup>For example, all euro area government bonds in my sample qualify as high-quality liquid assets (HQLA) in terms of the liquidity coverage ratio (LCR) requirement for banks.

<sup>14</sup>The ECB has constituted implementation provisions to limit market impacts and distortions of bond purchases under the Public Sector Purchase Program, the largest of the QE programs implemented in the Eurosystem. These provisions specify the conditions under which the ECB (via local central banks) is allowed to purchase government bonds: they contain (i) a maturity restriction that specifies the minimum and maximum remaining maturity of a security, (ii) a yield restriction that states that the yield of a security needs to be above the ECB's deposit facility rate (DFR), and (iii) a restriction limiting the purchase of bonds to those denominated in euros. Over time, the ECB has adjusted and modified the initial implementation provisions.

<sup>15</sup>Time since eligibility is a continuous variable that increases by one day if bond  $i$  on day  $t$  was eligible for purchase under the PSPP. If a bond was eligible in the past but is not at the moment, the variable keeps its

based on the ECB’s collateral framework.<sup>16</sup> To capture collateral opportunity cost, I derive a daily list of bonds that are eligible to be pledged as collateral into a GC basket. Based on this list, I determine, for each GC trade, the CTP bond which is the bond with the highest special repo rate of all bonds that are eligible to be delivered into a particular basket.<sup>17</sup>

To connect the collateral choices in the repo market to the bond market for the collateral, I obtain the corresponding set of tick-by-tick, intraday bond quotes and trades from the MTS Cash market.<sup>18</sup> Finally, I complement my bond data with investor holding information from Bloomberg which allows me to calculate the bond-level buy-and-hold investor share.<sup>19</sup>

## 2. Drivers of collateral choice

Figure 1 highlights that OTR bonds and CTP securities are most likely to be delivered as collateral into GC trades, pointing towards collateral availability and opportunity cost as the two main drivers of collateral choice. I start by analyzing different aspects of collateral availability and opportunity cost separately before looking at their interplay.

### 2.1 Collateral availability

Collateral availability refers to the net supply of collateral assets (*quantity*). The idea is to use variations in long-term government debt to assess the impact on short-term funding value.

---

<sup>16</sup>The ECB collateral framework (<https://www.ecb.europa.eu/paym/coll/assets/html/list-MID.en.html>) provides a reference for individual bonds’ haircut levels. The economics of central bank collateral frameworks have been discussed in, for example, Nyborg (2016).

<sup>17</sup>My results are robust if I determine the CTP bond based on yesterday’s special repo rate.

<sup>18</sup>The MTS cash market is the largest interdealer trading network for European government bonds; liquidity is ensured by active market-making and a quote-driven electronic limit order book. Related studies which have used this data include, for example, Pelizzon et al. (2016), who also provide a detailed description of the MTS market, and Corradin and Maddaloni (2020). The size and liquidity of the MTS market make my bond data highly representative. For my analysis, I focus on the cross-section of sovereign bonds that are posted as collateral into GC trades. On each day, I compute the volume-weighted average mid-quote, bid-ask spread, and amounts quoted at the best bid and ask, as well as the volume-weighted average transaction price and transaction cost.

<sup>19</sup>I derive quarterly bond holding information by institution for ten-year Italian government bonds during the first three years after the initial auction. I classify an institution as a buy-and-hold investor if it reduces its position in less than a third of all observations. My results are robust to alternative classifications. For each bond and for each quarter after the initial auction, I calculate a bond’s buy-and-hold investor share as the sum of the positions held by buy-and-hold investors over the total coverage in the database.

markets. Auction cycles are a first source of variation in the supply of government debt impacting money and bond markets (e.g., Keane, 1996; Krishnamurthy and Vissing-Jorgensen, 2012; Lou et al., 2013; D’Amico et al., 2018; Sigaux, 2018; Huh and Infante, 2021). A second form of variation stems from scarcity induced by QE (e.g., Arrata et al., 2020; Corradin and Maddaloni, 2020). Asset scarcity is the counterpart to collateral availability; while auctions increase the availability, central bank asset purchases reduce it.

Figure 3 illustrates those aspects of collateral availability. Figure 3a plots the repo delivery volume of a bond against its issuance size, separately for initial auctions (orange crosses) and reopenings (blue circles). The delivered volume is measured as the *cumulative* volume of a bond posted into GC repo trades over the first 90 days after an auction relative to the bond’s outstanding volume.<sup>20</sup> It is clearly visible that the delivery volume increases in the auction size. For example, the cumulative delivery volume after initial auctions is about 200% (400%) of the outstanding volume for an auction size of euro 2 billion (10 billion). The results are consistent for reopenings, although the effect is stronger after initial auctions due to their larger issuance size.

Figure 3b looks more closely at the delivery patterns during the first 90 days after an auction; it graphs the *daily* volume delivered (relative to the outstanding volume) against the time since the last auction, again separately for initial auctions (orange crosses) and reopenings (blue circles). Three patterns stand out: the delivery volume (i) is higher for initial auctions than for reopenings, (ii) decreases in the days after an initial auction or reopening, and (iii) peaks again around reopenings. For example, daily delivery volumes are about 20% of the outstanding volume for delivery dates close to the initial auction; those volumes drop to around 6% one month after the initial auction. Around reopenings, the delivery volume peaks again at about 8%. The results are in line with the interpretation that OTR deliveries are due to funding needs from primary dealers who received the OTR security in the auction; this means that the OTR bond is in high availability in the dealers portfolio and can be used as collateral for refinancing.

---

<sup>20</sup>The results are consistent if the delivery volume is measured over a different horizon of, for example, 30 or 60 days.

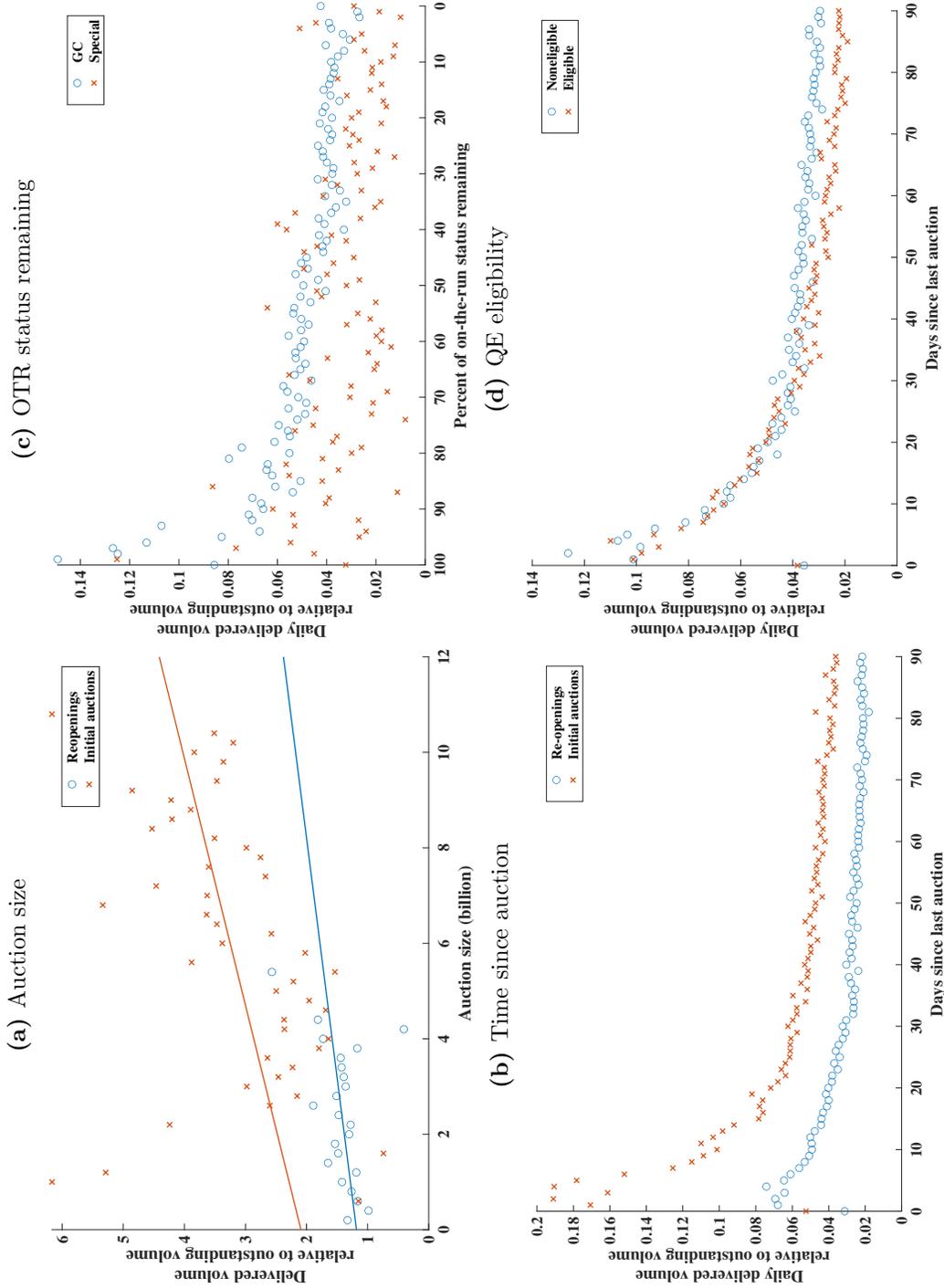


Figure 3a depicts the cumulative delivery volume of a bond into GC trades during the first 90 days after its auction relative to the total outstanding volume. Figure 3b depicts the daily delivered volume of a bond into GC trades relative to its outstanding volume on each of the first 90 days after the auction. Both graphs differentiate between initial auctions (orange crosses) and reopenings (blue circles). Figure 3c depicts the daily delivered volume of a bond relative to its outstanding volume in the GC market (blue circles) as well as the OTR trading volume in the special repo market (orange crosses) in relation to the remaining OTR status. Figure 3d depicts the daily delivered volume of a bond in GC trades relative to its outstanding volume for each of the first 90 days after the initial auction or reopening by differentiating between bonds eligible (orange crosses) and noneligible (blue circles) for PSPP purchases.

**Figure 3:** Aspects of collateral availability

Figure 3c is developed in a similar spirit, it depicts the daily volume delivered against the remaining time for which a bond serves as the OTR (blue circles).<sup>21</sup> The results are consistent: The delivery volume of newly issued, OTR government bonds peaks at the auction and decreases as the OTR bond gets closer to turning off-the-run. The figure also displays OTR trading volumes in the special repo market (orange crosses). OTR deliveries into GC trades and special trading volumes for OTR bonds are comparable in size which reinforces the importance of the GC market compared to the special repo market activity.

In contrast to government bond auctions, which are a source of supply of collateral assets, central bank asset purchase programs have led to asset scarcity and a corresponding reduction in collateral availability. Figure 3d graphs the volume delivered against the time since the last auction, separately for QE eligible bonds (orange crosses) and bonds that are not eligible for QE purchases (blue circles). For the first 30 days after a government bond auction, delivery volumes are similar between eligible and noneligible bonds, which is in line with an initial blackout period for central bank purchases. However, for periods more than one month after the auction, bonds that are not eligible for QE are delivered about one-and-a-half times as often as QE eligible bonds. Those results are consistent with the idea that central banks target QE eligible bonds which leads to their scarcity. Among other things, this reduces their availability to serve as collateral in repo trades.

## 2.2 Opportunity cost

Collateral opportunity cost (*price*) is the second driver of collateral choice. Posting a bond in a GC repo which is in high demand in the special segment due to its convenience benefits is costly as rates on special repos that earmark the specific collateral are often lower than prevailing GC rates (Ballensiefen and Ranaldo, 2022). A bank, therefore, faces opportunity cost for the delivery of a special collateral bond into a GC repo.<sup>22</sup>

---

<sup>21</sup>I display the percentage of the OTR status remaining since government bonds with different tenors follow different auction cycles and thus serve as the OTR bond for different time periods.

<sup>22</sup>The opportunity cost relate to the utility a borrower forgoes during the time between the purchase and repurchase when he delivers a bond as collateral into a GC trade. A repo represents a sale and repurchase of the collateral asset, i.e., the lender becomes the legal owner of the collateral at the purchase date. Still, while the buyer of the collateral is the owner of the bond during the term of the repo, the borrower retains the risk

For my analysis, I compute two measures of collateral opportunity cost: Equation (1) computes the “CTP spread” as the difference in special repo rates between the CTP bond of a given GC basket and bond  $i$  which was delivered as collateral into that basket. The CTP spread measures the opportunity cost of delivering bond  $i$  as collateral into a GC repo. Equation (2) computes the “repo specialness” measure as the difference between the GC repo rate of the basket in which a security is posted as collateral and the special repo rate of the delivered bond  $i$ . This spread measures the opportunity cost of engaging in a GC trade as opposed to a special repo trade.<sup>23</sup>

$$CTP\ spread_{i,t} = reparate_{CTP,t}^{special} - reparate_{i,t}^{special} \quad (1)$$

$$Repo\ specialness_{i,t} = reparate_{basket,t}^{GC} - reparate_{i,t}^{special}. \quad (2)$$

The economic intuition behind both measures is the same; the opportunity cost of posting a bond into a GC repo is higher for bonds that carry larger convenience benefits and thus are more special.

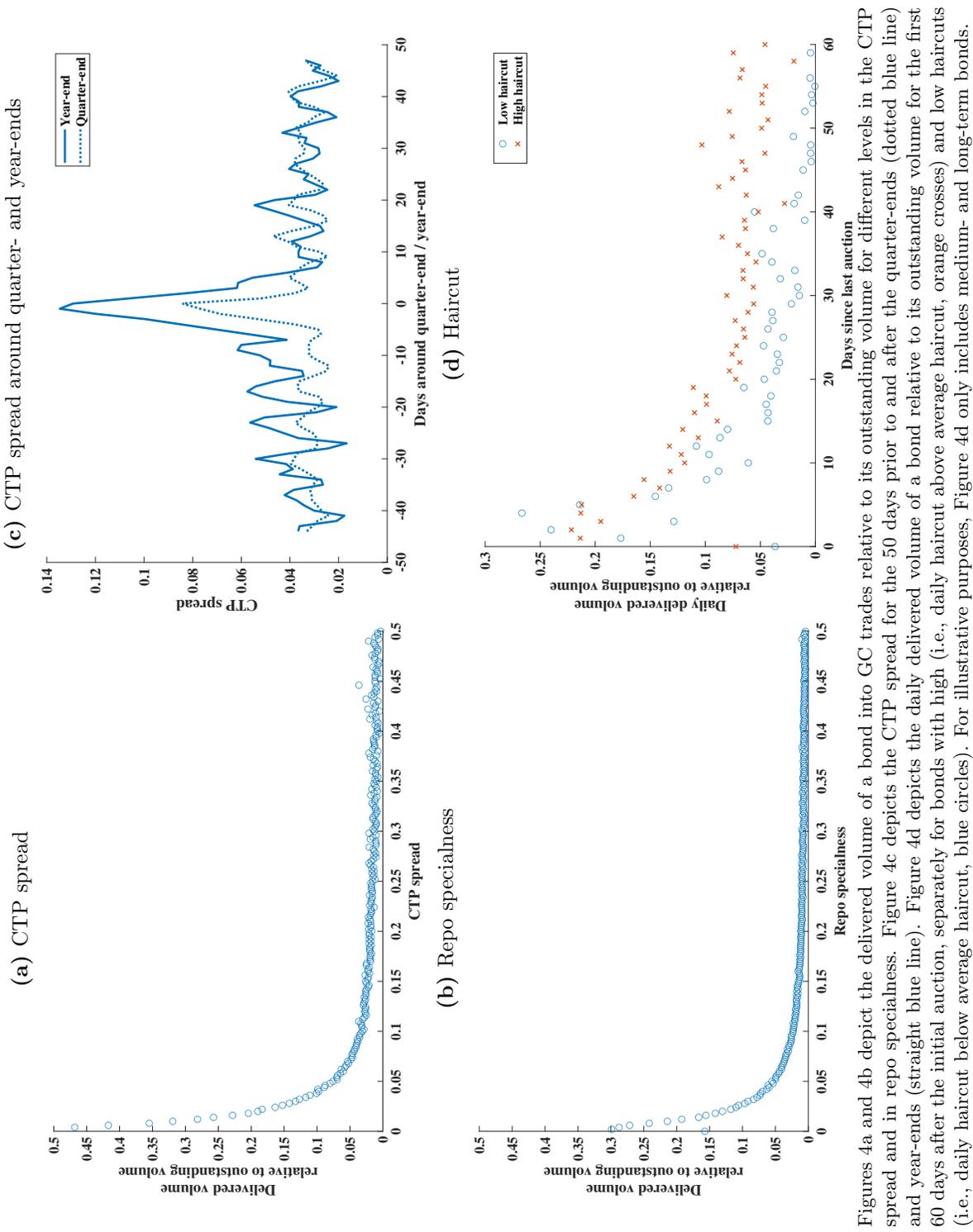
Figure 4 displays those aspects of collateral opportunity cost. Figure 4a plots the relative delivery volume of a bond into GC repos for different levels in the CTP spread. The delivery volume peaks for CTP spreads close to zero and almost monotonically decreases in the CTP spread as the collateral opportunity cost increase. For example, the delivery volume is up to 50% of the outstanding volume for CTP spreads close to zero; the volume drops to below 5% for CTP spreads larger than 10bps. Figure 4b presents consistent results for repo specialness as the alternative measure of collateral opportunity cost.

An interesting perspective is to look at the CTP spread on reporting dates. Rinaldo, Schaffner, and Vasios (2021) show that the introduction of the leverage ratio rules under the

---

of the bond as he has agreed to buy it back at the repurchase date. Any income arising from the bond during the term of the repo (e.g., coupon payments) is, therefore, transferred to the borrower. Hence, any foregone utility must stem from the collateral’s safety and liquidity attributes, also referred to as convenience benefits (Gorton, 2017).

<sup>23</sup>The decision to use a GC trade instead of a special repo trade involves subtle differences. In a GC trade, the borrower has the choice which bond he delivers as collateral until the first leg is settled. By contrast, a borrower already commits to deliver a specific collateral in a special trade at the trade date of the repo trade.



**Figure 4:** Aspects of collateral opportunity cost

Basel III framework disincentivizes the borrowing demand at quarter- and year-end periods when the leverage ratio is calculated.<sup>24</sup> Figure 4c illustrates the CTP spread for the 50 days prior to and after quarter-ends (dotted blue line) and year-ends (straight blue line). At quarter-ends, the CTP spread increases to about 8bps; at year-ends, the increase is even stronger to about 14bps. The spikes in the CTP spread on quarter- and year-end reporting days can be considered a measure of *collateral stress* as the opportunity cost of posting bonds into GC trades are higher on those dates.

A bond's haircut is another aspect of collateral opportunity cost. The idea here is that bonds with higher haircuts have a lower fungibility and (re-)pledgeability, thus they are less special in the repo market and have lower collateral opportunity cost. Figure 4d graphs the daily volume delivered against the time since the last auction, separately for bonds with high (orange crosses) and low haircuts (blue circles).<sup>25</sup> The results confirm that intuition as the delivery volume tends to be higher for high-haircut bonds.

### 2.3 Combined effects

I also want to understand the interplay of collateral availability and opportunity cost. Figure 5 provides several illustrations of it. Figure 5a plots the delivery volume for different levels in the CTP spread, as we have seen before, but now separately for OTR government bonds (orange crosses) and their off-the-run counterparts (blue circles). We clearly see that if bonds with high CTP spreads are delivered, those are likely to be OTR securities. The CTP spreads for OTR securities are economically meaningful as they go up to 50bps; this means that borrowers are willing to accept significant opportunity cost to post OTR bonds into GC repos. Still, also for OTR securities, the delivery intensity declines in the opportunity cost. This nicely illustrates both aspects of collateral choice: the generally declining delivery volumes with a bond's repo specialness point towards the role of collateral opportunity cost, whereas the relatively higher delivery volumes of OTR securities for higher levels in the CTP

---

<sup>24</sup>The Basel III rules imply that borrowing cash through a repo expands the balance sheet of financial intermediaries and thus reduces the leverage ratio, whereas lending cash via a repo does not.

<sup>25</sup>At each point in time, I classify a newly issued security into a bond with a high (low) haircut depending on whether its haircut is above (below) the average haircut of newly issued securities.

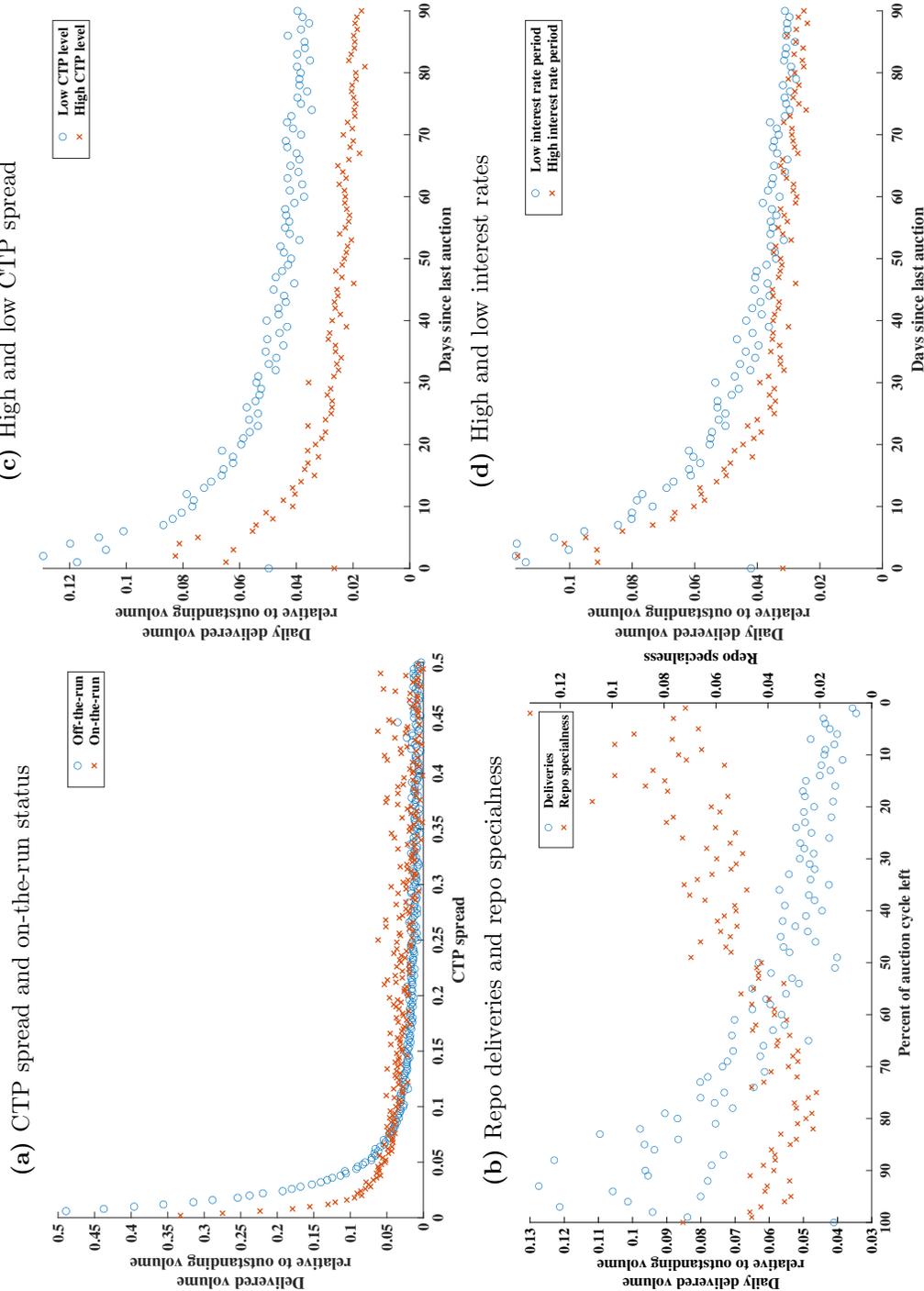


Figure 5a depicts the delivered volume of a bond into GC trades relative to its outstanding volume for different levels in the CTP spread, separately for on-the-run (orange crosses) and off-the-run securities (blue circles). Figure 5b depicts the daily delivered volume of a bond relative to its outstanding volume (blue circles) and the repo specialness of the delivered security (orange crosses) relative to the position in the auction cycle. Figures 5c and 5d depict the daily delivered volume of a bond relative to its outstanding volume for the first 90 days after the initial auction or reopening by differentiating between bonds with high (i.e., CTP spread above the average CTP spread over the sample period, orange crosses) and low levels of CTP spread (i.e., CTP spread below the average CTP spread over the sample period, blue circles), respectively during high (i.e., positive rate on the ECB's main refinancing operations (MRO), orange crosses) and low interest rate periods (i.e., non-positive rate on the ECB's MRO, blue circles).

**Figure 5:** Aspects of collateral opportunity cost

spread highlight the role of collateral availability.

Figure 5b is developed in a similar spirit, it shows the delivery volume of a bond into GC repos (blue circles) and its repo specialness (orange crosses) relative to the position in the auction cycle. In line with Keane (1996), clear cyclical patterns emerge as OTR bonds become increasingly special throughout the auction cycle. Repo deliveries reverse this pattern; they decline in the repo specialness of the delivered security. This means that borrowers have less incentive to post OTR bonds into GC repos when the opportunity cost of doing so increase.<sup>26</sup> Figure 5c complements this view by showing that OTR deliveries are lower during periods when CTP spreads are higher.

Inspired by the safe asset literature, I also consider the level of short-term interest rates. The borrower in a repo forgoes the convenience benefits of the bond which he posts as collateral. Nagel (2016) shows that the value of those convenience benefits depends on the level of short-term rates. His main finding is that the liquidity premium provided by near-money assets is more valuable in a high interest rate environment. The utility loss of posting OTR bonds, which carry the highest liquidity attributes, therefore, also depends on the level of short-term interest rates. Figure 5d shows the daily repo delivery volume during the first 90 days after the auction, separately for periods with high (orange crosses) and low interest rates (blue circles). Consistent with Nagel (2016), the delivery intensity of OTR bonds is lower in a high interest rate environment when the superior liquidity services of OTR bonds are more valuable.

## 2.4 Empirical estimation

For the empirical analysis, I formalize the graphical intuition in a set of panel regressions. The main variable of interest is the volume delivered of a bond into GC repos, which I measure as a bond's daily delivery volume over its outstanding volume ("Delivery volume"). I relate

---

<sup>26</sup>In a repo squeeze, banks post a substantial portion of their OTR bond holdings into GC trades at a higher GC rate instead of using the less expensive special rate. The goal of this trading strategy is to increase the specialness of the bond with the idea of profiting from it at a later point. However, in my data, I observe that OTR volumes in both segments, the GC and special segment, decline in the repo specialness, which counters this idea and alleviates any concerns around the concept of repo squeeze for my analysis.

the delivery volume to different aspects of collateral availability and collateral opportunity cost as depicted in Table 2. All regressions include basket-month-term fixed effects and standard errors clustered at the bond-level.

Column (1) serves as the baseline. To capture collateral availability, I employ a bond's issuance volume at the preceding auction or reopening ("Auction size") and the time since the preceding auction or reopening ("Time since auction," measured in logs), both variables interacted with a dummy for initial auctions ( $D^{Initial}$ ); the dummy  $D^{OnTheRun}$  that is equal to one for OTR bonds; and the time for which a bond has been eligible for QE purchases ("Time since QE eligibility or TSE," measured in logs). To capture collateral opportunity cost, I add a dummy that equals one for the CTP bond ( $D^{CTP}$ ) and the CTP spread ("CTP spread").

**Collateral availability:** The delivery volume follows the auction cycle and is impacted by asset scarcity. Four patterns stand out: First, the delivery volume increases with the auction size; all else equal, a euro 10 billion increase in the auction size increases a bond's daily delivery volume (relative to its outstanding volume) by about 1.4%-points for initial auctions (0.3%-points for reopenings). Second, the delivery volume decreases in the time since the last auction. For example, an increase in the time since the initial auction by one percentage point relates to a decrease in the delivery volume by 4.1%-points; the effect is again stronger for initial auctions than for reopenings. Third, the delivery volume tends to be 0.7%-points higher for OTR bonds. And fourth, bonds eligible for central bank asset purchasing programs have a lower delivery volume. In economic terms, an increase in the time for which a bond is eligible for QE purchases by one percentage point is associated with a 0.7%-points lower delivery volume.

**Collateral opportunity cost:** The CTP bond has, all else equal, a 0.3%-points higher delivery volume. In addition, the delivery volume decreases in the CTP spread. If the CTP spread increases by one percentage point, the delivery volume decreases by 0.3%-points. This means that if the opportunity cost to post a bond increase (i.e., the bond's specialness increases), its delivery volume into GC repos decreases. Column (2) employs the repo

**Table 2:** Collateral availability and opportunity cost

	(1)	(2)	(3)	(4)	(5)
	Delivery	Delivery	Delivery	Delivery	Delivery
	volume	volume	volume	volume	volume
	b/t	b/t	b/t	b/t	b/t
Auction size	0.026	0.035*	0.029	0.027	0.041**
	(1.483)	(1.864)	(1.601)	(1.539)	(2.116)
Auction size $\cdot D^{Initial}$	0.144***	0.150***	0.144***	0.145***	0.154***
	(5.081)	(5.247)	(5.062)	(5.104)	(5.818)
Time since auction	-0.143***	-0.140***	-0.149***	-0.144***	-0.182***
	(-3.281)	(-3.121)	(-3.378)	(-3.288)	(-3.818)
Time since auction $\cdot D^{Initial}$	-4.100***	-4.262***	-4.112***	-4.118***	-4.036***
	(-14.034)	(-14.479)	(-13.919)	(-14.080)	(-12.905)
$D^{OnTheRun}$	0.708***	0.711***	0.868***	0.790***	0.946***
	(9.795)	(9.693)	(9.532)	(9.994)	(7.015)
Time since QE eligibility	-0.691***	-0.718***	-0.654***	-0.657***	-0.244***
	(-9.226)	(-9.475)	(-8.688)	(-8.924)	(-5.731)
$D^{CTP}$	0.265***	0.390***	0.245***	0.324***	0.388***
	(9.409)	(13.321)	(9.210)	(11.815)	(11.717)
CTP spread	-0.294***		-0.236***		
	(-15.978)		(-12.076)		
Repo specialness		-0.591***			
		(-10.990)			
$D^{OnTheRun} \cdot \text{CTP spread}$			-0.573***		
			(-10.373)		
$D^{HighCTP}$				-0.227***	
				(-14.026)	
$D^{OnTheRun} \cdot D^{HighCTP}$				0.237***	
				(3.620)	
$D^{HighInterest}$					-0.379***
					(-6.982)
$D^{OnTheRun} \cdot D^{HighInterest}$					0.282***
					(3.351)
$N$	611,444	611,444	611,444	611,444	613,392
$R^2$	0.256	0.252	0.258	0.258	0.190
FE	Yes	Yes	Yes	Yes	Yes

The table reports the results examining the impact of different aspects of collateral availability and opportunity cost on the delivery volume into GC repo trades. The dependent variable is a bond's daily delivery volume over its outstanding volume in percentage points. Auction size depicts a bond's issuance volume at the preceding auction or reopening in euro billion; time since auction denotes the time since the preceding auction or reopening in logs;  $D^{Initial}$  equals one for initial auctions;  $D^{OnTheRun}$  equals one if a bond is the OTR bond; time since QE eligibility refers to the time since QE eligibility in logs;  $D^{CTP}$  equals one if a bond is the CTP bond; CTP spread and repo specialness are the two measures of collateral opportunity cost;  $D^{HighCTP}$  equals one if the CTP spread is above the average CTP spread over the sample period; and  $D^{HighInterest}$  equals one for periods when the ECB's MRO rate is positive. \*\*\*, \*\*, and \* represent significance at a 1, 5, and 10% level, respectively;  $t$ -statistics are in parentheses. All regressions include basket-month-term fixed effects (regression (5) includes basket-term fixed effects) and standard errors clustered at the bond-level. Data include GC repo trades from January 2010–June 2020.

specialness measure (“Repo specialness”) instead of the CTP spread and confirms the results.

**Interaction:** Columns (3)–(5) provide different specifications of the baseline set-up to analyze the joint impact of collateral availability and opportunity cost. Column (3) interacts the CTP spread with the OTR dummy to analyze the different sensitivities of on-the-run and off-the-run bonds to changes in collateral opportunity cost. While, all else equal, OTR bonds have a higher delivery volume than their off-the-run counterparts, OTR bonds are also more sensitive to changes in the CTP spread. Column (4) illustrates this mechanism in more detail, it exchanges the CTP spread with a dummy that is equal to one for deliveries with high CTP spreads ( $D^{HighCTP}$ ) and also includes its interaction with the OTR dummy. The results confirm that delivery volumes in general and OTR deliveries in particular are lower when CTP spreads are higher. Column (5) extends the basic framework and additionally includes a dummy variable to capture high interest rate periods ( $D^{HighInterest}$ ); I also include the interaction of the interest rate dummy with the OTR dummy. In line with Nagel (2016), the results show that OTR deliveries are lower during high interest rate periods when the superior liquidity benefits provided by OTR bonds are more valuable.

To gain additional insights into borrowers’ collateral choices, Table 3 extends my analysis by looking at different *portfolio* aspects in more detail. Column (1) shows the baseline specification for reference. Column (2) exchanges the auction size variable with the ratio of the issuance volume over the total outstanding debt held by financial institutions. The idea here is that a larger auction size relative to the total outstanding debt held by financial institutions implies a greater need for banks to diversify their portfolio holdings. The results confirm this intuition; an increase in the relative auction size is accompanied by an increase in delivery volumes, the effect is more pronounced for initial auctions than for reopenings. Column (3) replaces the OTR dummy with the remaining time outstanding for which a bond serves as the OTR (“On-the-run remaining”). It shows that a 10% decrease in the remaining time for which a bond serves as the OTR is associated with a 0.2%-points lower delivery

**Table 3:** Aspects of collateral availability

	(1) Baseline b/t	(2) Relative auction size b/t	(3) OTR status b/t	(4) Securities lending b/t	(5) Low demand b/t
Auction size	0.026 (1.483)	0.173 (1.337)	0.035* (1.763)	0.032* (1.797)	0.011 (0.412)
Auction size $\cdot D^{Initial}$	0.144*** (5.081)	1.155*** (5.972)	0.069*** (2.600)	0.139*** (4.839)	0.123*** (3.140)
Time since auction	-0.143*** (-3.281)	-0.141*** (-3.275)	-0.108*** (-2.731)	-0.160*** (-3.573)	-0.123** (-2.527)
Time since auction $\cdot D^{Initial}$	-4.100*** (-14.034)	-4.106*** (-14.157)	-3.855*** (-14.066)	-4.115*** (-14.044)	-4.160*** (-15.510)
$D^{OnTheRun}$	0.708*** (9.795)	0.707*** (9.804)		0.699*** (9.724)	0.715*** (10.025)
On-the-run remaining			0.017*** (12.010)		
Time since QE eligibility	-0.691*** (-9.226)	-0.678*** (-9.133)	-0.647*** (-9.309)	-0.650*** (-8.052) -0.535** (-2.573)	-0.703*** (-8.893)
$D^{SecuritiesLending}$					
$D^{LowDemand}$					0.139*** (2.763)
$D^{CTP}$	0.265*** (9.409)	0.264*** (9.364)	0.236*** (8.813)	0.262*** (9.352)	0.274*** (8.807)
CTP spread	-0.294*** (-15.978)	-0.294*** (-15.922)	-0.309*** (-15.840)	-0.293*** (-16.192)	-0.298*** (-15.190)
$N$	611,444	611,444	611,444	611,444	539,726
$R^2$	0.256	0.257	0.276	0.258	0.254
FE	Yes	Yes	Yes	Yes	Yes

The table reports the results examining the impact of different aspects of collateral availability on the delivery volume into GC repo trades. The dependent variable is a bond's daily delivery volume over its outstanding volume in percentage points. Auction size depicts a bond's issuance volume at the preceding auction or reopening in euro billion; in Column (2), auction size is defined as the ratio of a bond's issuance volume at the preceding auction or reopening over the total debt outstanding held by financial institutions; time since auction denotes the time since the preceding auction or reopening in logs;  $D^{Initial}$  equals one for initial auctions;  $D^{OnTheRun}$  equals one if a bond is the OTR bond and on-the-run remaining measures the remaining time outstanding for which a bond is the OTR bond; time since QE eligibility refers to the time since QE eligibility in logs;  $D^{SecuritiesLending}$  equals one if a bond is eligible for the Eurosystem's securities lending facility;  $D^{LowDemand}$  equals one for the lowest quartile in the bid-to-cover ratio at auctions and reopenings;  $D^{CTP}$  equals one if a bond is the CTP bond; and CTP spread refers to the measure of collateral opportunity cost. \*\*\*, \*\*, and \* represent significance at a 1, 5, and 10% level, respectively;  $t$ -statistics are in parentheses. All regressions include basket-month-term fixed effects and standard errors clustered at the bond-level. Data include GC repo trades from January 2010–June 2020.

volume.<sup>27</sup>

Column (4) introduces a dummy that is one for bonds that have been purchased by the ECB under the PSPP and have, afterwards, been made available for the Eurosystem’s securities lending facility ( $D^{SecuritiesLending}$ ). The goal of securities lending was to allow market participants to hold specific securities temporarily and to reduce the cost of acquiring good quality collateral. In the context of my analysis, bonds eligible for securities lending have, all else equal, a 0.5%-points lower delivery volume. Market participants need to hold lower inventories of bonds eligible for securities lending, hence, repo delivery volumes are lower as well. Lastly, inspired by Klingler and Sundaresan (2020), I introduce a dummy for low demand auctions ( $D^{LowDemand}$ ) in column (5). The dummy is equal to one for auctions and reopenings where the bid-to-cover ratio is in the lowest quartile. The idea here is that a lower bid-to-cover ratio indicates a lower demand for specific bonds. Market makers, therefore, need to hold those bonds for an extended period of time in their portfolios until, for example, they reallocate those bonds to secondary market investors. As a result, low-demand bonds have, all else equal, 0.1%-points higher delivery volume.

My results show that aspects of collateral availability and opportunity cost jointly play a role in explaining collateral choices. To analyze the *internal* robustness of my results, I replicate my analyses (i) by introducing different control variables,<sup>28</sup> (ii) by estimating the regression with the delivery volume in logs, (iii) by considering different fixed effect combinations and standard error clustering, and (iv) by employing a sample without quarter end and end of ECB maintenance period trading days. The effect of collateral availability

---

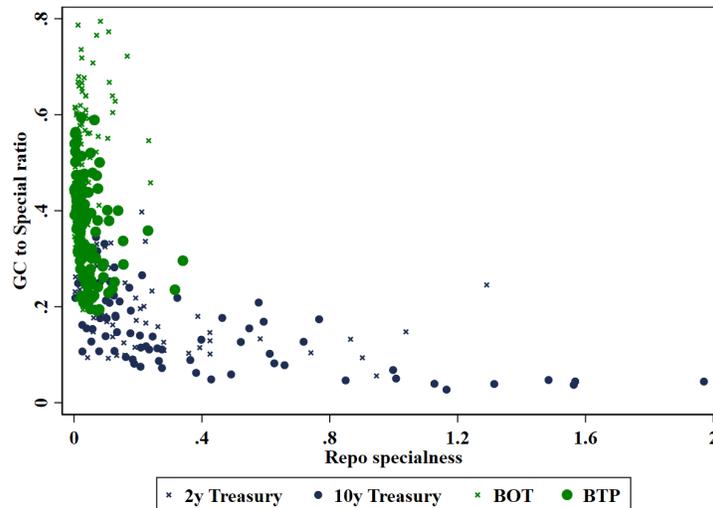
<sup>27</sup>The OTR dummy captures the, on average, higher delivery volume of OTR bonds during the entire OTR period, while the continuous variable capturing the remaining OTR time highlights that the delivery volume of OTR bonds tends to peak around auction days and decrease thereafter.

<sup>28</sup>I introduce the bond bid-ask spread and bond tenor as additional controls on the bond-level; I account for the cheapest-to-deliver bond in the futures market; I consider additional economic variables as controls. First, I employ the debt-to-GDP ratio to account for overall asset supply in line with Krishnamurthy and Vissing-Jorgensen (2012). Second, I include the price on 10-year CDS spreads as a measure of the overall sovereign risk level. More public debt creates uncertainty, which raises default risk premia (Liu, Schmid, and Yaron, 2019) so that collateral quality deteriorates with weak sovereign resources (He, Krishnamurthy, and Milbradt, 2019) and the government’s inability to back its borrowing with taxation (Krishnamurthy and Vissing-Jorgensen, 2015). When a sovereign bond bears a convenience premium that is uncertain and adversely affected by risk, it becomes a quasi-safe asset (Ballensiefen and Ranaldo, 2022). Finally, I consider the ECB’s purchases under the PSPP as those purchases reduced the overall supply of government debt in line with Arrata et al. (2020) and Corradin and Maddaloni (2020).

and opportunity cost on the delivery volume remains statistically and economically consistent across all specifications (results are reported in the Online Appendix).

## 2.5 External relevance

To highlight the *external* relevance of my results, I replicate my analysis for other euro area countries such as Germany and France. The results (reported in the Online Appendix) are fully consistent, which ensures that my analysis also speaks to other markets such as the German “safe haven” market which is the safe asset in the euro area. In line with the trade-off between collateral availability and opportunity cost, OTR bonds in Germany are also more likely to be posted as collateral into GC trades, this effect is, however, smaller than in my main sample as the opportunity cost in the German funding market are higher.



**Figure 6:** Repo financing shares in the U.S. vs the euro area

Building on this analysis, I complement my euro area sample with repo data for 2-year and 10-year OTR U.S. Treasury securities.<sup>29</sup> This allows me to calculate the ratio of OTR postings into GC trades relative to special trades for OTR bonds (“GC to Special ratio”).

<sup>29</sup>I use data from the FED’s Primary Government Securities Dealers Reports (Form FR 2004), which requires primary dealers in U.S. government bonds to report weekly repo activity in OTR U.S. Treasury securities. The U.S. primary dealer market is the U.S. repo market most closely assembling the euro area repo market set-up.

The same intuition as before applies; the dealer is more likely to post OTR bonds into GC trades when the collateral opportunity cost are lower. Figure 6 confirms this intuition, it graphs the GC to special ratio against the repo specialness measure for my main sample (green) and for U.S. Treasuries (blue). I observe that the share of GC financing is higher when the opportunity cost of doing so are lower. The U.S. Treasury bond is the world’s quintessential safe asset (e.g., He et al., 2019). As a result, repo specialness is highest in the U.S. market and the share of OTR postings into GC trades is smaller. Still, even for U.S. Treasuries, the intensity of OTR postings into GC trades increases as the opportunity cost get lower. This confirms that the economic intuition derived in this paper applies more generally to other money markets such as the U.S. Treasury market.

### 3. Theoretical implications

In the second part, I provide a theoretical framework related to market makers and their inventory holdings. My model is inventory-based (e.g., Stoll, 1978; Amihud and Mendelson, 1980; Ho and Stoll, 1981; Ho and Stoll, 1983),<sup>30</sup> it rationalizes borrowers’ collateral choices and links them to the underlying bond market for the collateral.<sup>31</sup>

#### 3.1 Intuition

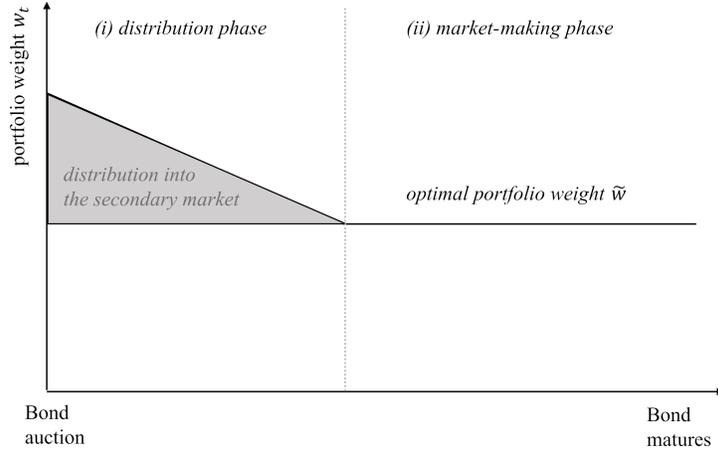
I consider a dealer for government bonds. This dealer participates in government bond auctions, the *primary* market for government debt, to establish a portfolio of newly issued, OTR securities. By participating in these auctions, the dealer builds up an inventory of bonds which allows him (i) to meet the demand of *secondary* market investors who are not

---

<sup>30</sup>Besides inventory cost, asymmetric information is the second, classic friction in the market microstructure literature to explain differences in intermediation cost (e.g., Glosten and Milgrom, 1985; Kyle, 1985). In my framework, I abstract from asymmetric information between the dealer and other market participants as government bonds are less prone to asymmetric information than, for example, equities.

<sup>31</sup>One important reference is Krishnamurthy (2002), who provides a framework that connects the repo market to the bond market for the collateral. In his set-up, the *lender* in special repos has a demand for a specific bond, which explains the higher repo specialness of newly issued, OTR U.S. Treasuries. Other related studies include, for example, Jordan and Jordan (1997), Buraschi and Menini (2002), D’Amico et al. (2018), and Corradin and Maddaloni (2020). Huh and Infante (2021) consider a cross-temporal perspective and arrive at the conclusion that bond market liquidity is lower when specialness is high due to the associated cost of intermediation.

able to participate in primary auctions (“distribution phase”) and (ii) to perform future market-making obligations (“market-making phase”).<sup>32</sup>



**Figure 7:** Illustration of optimal time-dependent portfolio weights

Figure 7 illustrates this mechanism, it shows the market maker’s portfolio weight in newly issued, OTR bonds over time relative to the optimal portfolio weight. The dealer has a time-independent, optimal portfolio share in OTR bonds ( $\tilde{w}$ ), which allows him to balance the investors’ regular order flow. However, during the distribution phase, the dealer’s actual portfolio share in OTR bonds ( $w_t$ ) is above the optimal level as he holds additional OTR bonds. The share declines over time as the dealer distributes part of his inventory into the secondary market; during the market-making phase, the optimal portfolio weight is reached. One can think of the dealer’s inventory as holding two portfolios: an optimal portfolio represented by the *optimal* portfolio weight  $\tilde{w}$  and an additional *trading* portfolio

<sup>32</sup>Dealers that are market makers have obligations for subscriptions in government bond auctions and trading volumes in the secondary market; thus, they are required to offer sufficient amounts to meet the demand of secondary market investors who are not able to participate in primary auctions. For example, in my case, the market makers’ obligations are more closely defined by evaluation criteria set by the Italian Treasury, which monitors that specialists participate in primary auctions, in secondary market trading, and in the repo market. An essential requirement for maintaining specialist status in government bonds is the allocation in primary auctions, which is evaluated via a “primary quantitative indicator.” In the calculation of this indicator, allotments of on-the-run bonds are weighted twice as much as those of off-the-run bonds (the full set of evaluation criteria, illustratively for 2020, can be found in Decree no. 111944 as of December 20, 2019, available at [http://www.dt.mef.gov.it/export/sites/sitodt/modules/documenti\\_en/debito\\_pubblico/specialisti\\_titoli\\_di\\_stato/Specialists\\_evaluation\\_criteria\\_-\\_year\\_2020.pdf](http://www.dt.mef.gov.it/export/sites/sitodt/modules/documenti_en/debito_pubblico/specialisti_titoli_di_stato/Specialists_evaluation_criteria_-_year_2020.pdf)).

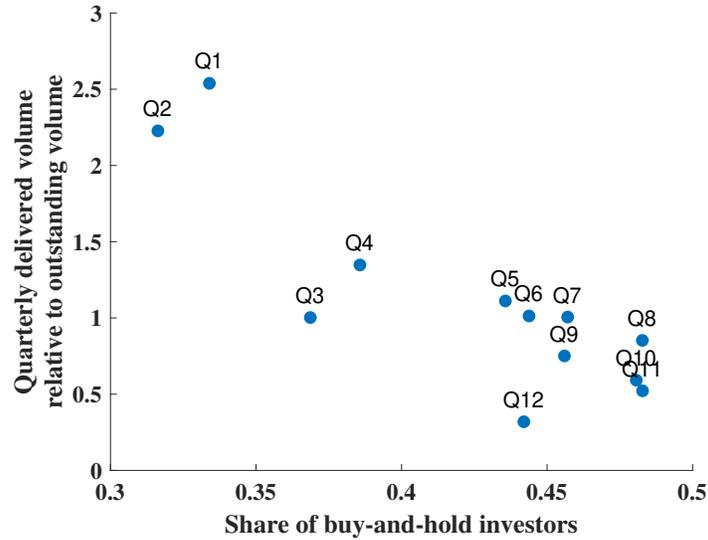


Figure 8 depicts the quarterly delivered volume of a bond into GC trades relative to the share of buy-and-hold investors; the figure illustratively includes data for ten-year government bonds.

**Figure 8:** Delivery volume and buy-and-hold investor share

of “excess” OTR bonds during the distribution phase.

This intuition is in line with, for example, Fleming and Rosenberg (2008), who estimate that primary dealers in U.S. Treasuries disseminate part of their auction purchases after the auction but also retain a substantial position until redemption. They argue that this mainly creates inventory risk since adverse selection risk is small. Building on this, Figure 8 depicts a bond’s GC repo delivery volume relative to the buy-and-hold investor share for the first 12 quarters following the initial auction. The results confirm that the share of buy-and-hold investors increases over time. For example, the share increases from about 30% in the first quarter after the auction to about 50% two years after the auction. A higher buy-and-hold investor share suggests lower holdings of that bond in the market maker’s portfolio; this is reflected in lower repo delivery volumes.<sup>33</sup>

<sup>33</sup>A different illustration of this is to look at trading volumes in the bond market. In the Online Appendix, I depict the trading volume in government bonds relative to the time since the last auction. The results confirm that trading volumes in the bond market are highest around auctions and decrease thereafter. This is in line with the idea of market makers distributing auction purchases to secondary market, buy-and-hold investors after the auction.

## 3.2 Model

My framework builds on Stoll (1978), who introduces an inventory model in which the representative agent is a dealer (market maker). The model introduced in Stoll (1978) is not specific to a certain asset class, while my application focuses on the bond market; this means that the dealer in my case is a market maker for government bonds. As a market maker, the dealer provides bond quotes to investors who are looking to sell a bond (at the market maker’s bid price) or buy a bond (at the market maker’s ask price). Following Stoll (1978), the dealer adjusts his quotes in response to an unexpected and uneven order flow. The spread between the bid and ask quote compensates the dealer for his cost  $C_i$ . Those cost are inventory cost which reflect, for example, cost for the dealer’s balance sheet and bank funding cost (e.g., Duffie, 2018).<sup>34</sup>

The dealer enters the period with wealth  $W_0$ . His optimal portfolio choice involves investing a share  $k$  into the optimal portfolio (yielding a return  $\tilde{R}_e$ ) and the remaining share  $(1 - k)$  into cash holdings (earning the risk-free rate  $r_f$ ).

Over time, the dealer participates in government bond auctions; based on the auction allotments, the dealer holds an additional trading portfolio in newly issued, OTR government bonds.<sup>35</sup> As the market maker needs to participate in government bond auctions to retain his market making status, he receives a certain allocation which I consider to be exogenous. The true value of these “excessive” OTR holdings in the trading portfolio is denoted with  $Q_{OTR}$ , the return of the OTR holdings is denoted with  $\tilde{R}_{OTR}$ .

### Repo market

The dealer needs to finance his portfolio. In my set-up, he does so via the repo market; this is different from Stoll (1978), in which the dealer refinances himself at the risk-free rate.<sup>36</sup> Repos are the most common vehicle for financing and rebalancing portfolios due to their

---

<sup>34</sup>One can think of the cost as charging the investor the bid-ask spread to cover the cost of holding a portfolio and constantly providing quotes.

<sup>35</sup>For expositional simplicity, I assume that the dealer only holds OTR securities in his trading portfolio.

<sup>36</sup>The repo market is the closest equivalent to a “true” risk-free rate and the primary market for portfolio reallocations.

short-term nature; dealers can stop rolling over overnight repos once they find a buyer for the bonds in the inventory (e.g., Bartolini et al., 2011; Eisl et al., 2019; Macchiavelli and Zhou, 2021). The dealer’s decision to post a bond as collateral into a repo trade is, however, costly as the dealer needs to pay the repo financing cost and forgoes the utility flows of the repo collateral (Ballensiefen and Ranaldo, 2022). The dealer, therefore, requires a compensation to engage in his market making activities in the bond market for the collateral.

The dealer has the option to place bonds into GC *or* special repos. I denote the share placed in the special segment by  $\theta_{Special}$  and the share posted in the GC segment by  $1 - \theta_{Special}$ . The financing cost for the dealer are lower when he posts bonds into special repos, where he can earn the repo specialness ( $R_{Special} < R_{GC}$ ). The repo specialness is a function of the demand from lenders for collateral assets and reflects search frictions for the dealer. However, the market maker faces cost for relying on special repo trades related to different settlement cycles between GC and special repo trades. ON repos trade in the GC segment, while the special repo market is more liquid for SN repos. If the market maker “excessively” uses special repo trades, he faces the risk of being locked into repo trades when unexpected liquidity needs or investor trading in the bond market arise.<sup>37</sup> The associated marginal cost increase in the share funded via special repos.

The market maker chooses his optimal repo funding shares in GC and special repos so that the repo specialness earned from using special repo trades equals the cost of being “inflexible” and locked in special trades.<sup>38</sup> The funding cost in the repo market, therefore, reads as:

$$R_F = \theta_{Special} R_{Special} + (1 - \theta_{Special}) R_{GC}. \quad (3)$$

---

<sup>37</sup>GC repo trades have the advantages of superior liquidity, high trading volumes, and low price impact compared to special repo trades. For reference, I depict the ratio in trading volumes between the GC segment and the special segment for OTR securities relative to the time since the initial auction in the Online Appendix. Overall, the GC trading volume surpasses that of special trades for OTR securities by about five times around auctions and by about ten times one month after the auction, thus highlighting that GC repos are the more liquid option.

<sup>38</sup>The derivation of the optimal repo funding shares is depicted in the Online Appendix.

By defining the opportunity cost  $OC_i$  as repo specialness (see Equation 2), it follows:

$$R_F = R_{GC} - \theta_{Special} OC_i. \quad (4)$$

## Equilibrium

The model is based on a one-period setting during which one trade occurs. The dealer's terminal wealth based on the initial portfolio is denoted with  $\tilde{W}^*$ , the terminal wealth after the trade with  $\tilde{W}$ . The dealer maximizes his expected utility. This implies that for the dealer to provide quotes and engage in a transaction, the compensation from the trade must offset the utility loss associated with the dealer deviating from his optimal portfolio. The expected utility of the terminal wealth based on the initial portfolio must, therefore, be the same as the expected utility of the terminal wealth of the new portfolio after the transaction, which is the initial portfolio altered by the trade.<sup>39</sup> More formally:

$$EU(\tilde{W}^*) = EU(\tilde{W}). \quad (5)$$

The dealer's end-of-period, terminal wealth from the initial portfolio (comprised of the optimal portfolio, the risk-free investment, and the OTR bonds in the trading portfolio) without any trade occurring reads as follows:

$$\tilde{W}^* = W_0 \left[ 1 + \underbrace{k\tilde{R}_e}_{\substack{\text{return} \\ \text{optimal} \\ \text{portfolio}}} + \underbrace{(1-k)r_f}_{\substack{\text{return} \\ \text{risk-free} \\ \text{investment}}} + \underbrace{\frac{Q_{OTR}}{W_0}(\tilde{R}_{OTR} - OC_i)}_{\substack{\text{return} \\ \text{trading} \\ \text{portfolio}}} - \underbrace{\frac{Q_{OTR}}{W_0}R_F}_{\substack{\text{financing} \\ \text{cost}}} \right]. \quad (6)$$

The dealer earns the return on his optimal portfolio investment, the cash return, and the return on the OTR bond holdings in the trading portfolio. However, since the dealer posts his excessive OTR bonds into repo trades, the return on his trading portfolio is reduced by the foregone convenience yield valued  $OC_i$ . In addition, the dealer needs to pay the repo financing cost.<sup>40</sup>

<sup>39</sup>Terminal in this case refers to the end of the one period during which a trade occurs.

<sup>40</sup>The returns on the optimal portfolio and on the OTR holdings in the trading portfolio are stochastic,

I define  $\tilde{W}^* = W_0[1 + \tilde{R}^*]$  in which  $\tilde{R}^*$  depicts the overall return on the dealer's initial portfolio.

The dealer's end-of-period, terminal wealth of the new portfolio after a trade (comprised of the initial portfolio, the change in the trading portfolio, and the financing cost of the new trade) reads as follows:

$$\tilde{W} = W_0(1 + \underbrace{\tilde{R}^*}_{\substack{\text{return} \\ \text{initial} \\ \text{portfolio}}}) + \underbrace{Q_i(1 + \tilde{R}_{OTR} - OC_i)}_{\substack{\text{change} \\ \text{return}}} - \underbrace{(Q_i - C_i)(1 + R_F)}_{\substack{\text{change} \\ \text{financing} \\ \text{cost}}}. \quad (7)$$

$Q_i$  indicates the value of the additional OTR bond in the trading portfolio (assuming the dealer buys an additional OTR bond).<sup>41</sup> The dealer earns the OTR return on this position but foregoes the convenience yield of the bond which he posts into a repo trade. In addition, the dealer needs to finance the value of the new bond less any cost  $C_i$  which he charges to the investor.  $C_i$  is endogenously determined in the model, the dealer sets  $C_i$  such that Equation 5 is fulfilled.

I assume that the dealer is subject to an exponential utility function with constant absolute risk aversion (CARA) of the following form:

$$U(W) = -e^{-aW}, \quad (8)$$

in which  $a$  denotes the coefficient of absolute risk aversion.<sup>42</sup> Under the assumption that  $W$  is normally distributed with  $\sim \mathcal{N}(\mu, \sigma^2)$ , we know that:

$$EU(W) = E(W) - \frac{1}{2}a\text{Var}(W). \quad (9)$$

Thus, from Equation (5) follows:

---

while the funding cost is deterministic as the GC rate and the opportunity cost are known at the beginning of the period.

<sup>41</sup>Positive values of  $Q_i$  indicate purchases by the dealer (from the investor), while negative values indicate sales to the investor.

<sup>42</sup>The Arrow-Pratt measure of relative risk aversion  $z$  is defined as  $z = a \cdot W_0$ .

$$E(\tilde{W}^*) - \frac{1}{2}a\text{Var}(\tilde{W}^*) = E(\tilde{W}) - \frac{1}{2}a\text{Var}(\tilde{W}) \quad (10)$$

The dealer’s cost function can be derived by inserting the specifications for the dealer’s terminal wealth from the initial portfolio and the new portfolio after the trade into Equation (10).<sup>43</sup> Solving for  $C_i$  leads to:

$$C_i = \frac{\frac{1}{2}aQ_i^2\text{Var}(\tilde{R}_{OTR}) + aQ_iQ_{OTR}\text{Var}(\tilde{R}_{OTR}) + Q_iOC_i(1 - \theta_{Special})}{(1 + R_{GC} - \theta_{Special}OC_i)}. \quad (11)$$

Equation (11) reflects the cost that the dealer charges to the investor for a trade in the bond market, it incorporates the aspects of collateral availability and collateral opportunity cost into the dealer’s decision problem. The model implies that the dealer’s cost of intermediation increases in the size of the trading portfolio  $Q_{OTR}$  (as his holdings deviate further from his optimal portfolio) and in the collateral opportunity cost of each bond  $i$  (due to the higher forgone utility of posting the bond into a repo trade).<sup>44</sup>

### 3.3 Bond market estimation

I use my repo and bond data to provide empirical support for the theoretical predictions. The main variable of interest is a bond’s relative bid-ask spread charged by the dealer. I employ the bid-ask spread at time  $t+1$  so that I can relate *today’s* repo collateral choices by the dealer to *tomorrow’s* bid-ask spread quoted in the bond market. To capture the dealer’s repo market activity, I employ delivery volumes into GC trades to mimic the size of the trading portfolio and the repo specialness measure to capture collateral opportunity cost.<sup>45</sup> As implied by the model, I also control for the variance of the bond return and the quoted depth difference.

Table 4 reports the results of the panel regressions of the relative bid-ask spread (“Relative

---

<sup>43</sup>The model derivation is presented in the Online Appendix.

<sup>44</sup>The conclusions also hold for the relative bid-ask spread, the derivation is presented in the Online Appendix.

<sup>45</sup>I match the repo delivery volumes to the corresponding bond quotes depending on the settlement conventions.

**Table 4:** Bond market spread

	(1)	(2)	(3)	(4)	(5)
	Relative spread $t+1$ b/t	Relative spread $t+1$ b/t	Relative spread $t+1$ b/t	Relative spread $t+1$ b/t	Relative spread $t+1$ b/t
Delivery volume	1.010** (1.976)				0.879** (2.356)
Repo specialness		0.406*** (4.912)			0.252*** (5.003)
$Var(\tilde{R}_i)$			0.240*** (13.977)		0.224*** (13.604)
Quoted depth difference				2.877*** (3.426)	2.963*** (4.329)
$N$	253,521	256,944	289,034	289,073	253,521
$R^2$	0.633	0.633	0.715	0.594	0.736

The table reports the regression results examining the impact of different cost measures on the quoted relative spread in bond markets. The dependent variable is a bond's log of tomorrow's relative bid-ask spread at  $t+1$ . Delivery Volume denotes a bond's daily delivery volume into GC trades over its outstanding volume in percentage points; repo specialness refers to the measure of collateral opportunity cost;  $Var(\tilde{R}_i)$  denotes the variance of the bond's return; and quoted depth difference denotes the difference in the volume offered at the best ask minus the volume offered at the best bid. \*\*\*, \*\*, and \* represent significance at a 1, 5, and 10% level, respectively;  $t$ -statistics are in parentheses. All regressions include basket-month fixed effects and standard errors clustered at the bond-level. Data include repo transactions and bond quotes executed on the MTS platform for the period January 2010–June 2020.

spread”) on the delivery volume (“Delivery volume”) in column (1), on the repo specialness measure (“Repo specialness”) in column (2), on the variance of the bond return ( $Var(\tilde{R}_i)$ ) in column (3), on the quoted depth difference (“Quoted depth difference”) in column (4), and the combined effect in column (5).<sup>46</sup>

Column (1) confirms that a bond’s bid-ask spread at time  $t+1$  increases in *today’s* repo delivery volumes, the effect is almost one-to-one. Column (2) highlights that a bond’s bid-ask spread at time  $t+1$  also increases in *today’s* bond opportunity cost. If the repo specialness of a bond increases by one percentage point, the relative spread charged tomorrow increases by 0.4%-points. Columns (3) and (4) show that the bid-ask spread is higher for more volatile bonds (inventory risk) and for bonds with larger differences in the quoted depth (unbalanced portfolio). Finally, column (5) confirms the statistical significance and economic magnitude in the multivariate setting.

The results are in line with the idea that higher holdings of OTR bonds in the trading portfolio (which are posted into GC repo trades to finance and diversify the portfolio) and higher bond opportunity cost (which reflect the foregone utility due to the delivery of the bond into repo trades) are associated with higher bond market spreads.

### 3.4 Implications

The concept of liquidity is usually broadly defined and encompasses different aspects. Bond market liquidity is often measured via the bid-ask spread, other measures include, for example, the trading volume. Table 5 reports the relative bid-ask spread and the daily bond trading volume for the on-the-run bond and its off-the-run counterparts, separately for different bond types.

On average, the bid-ask spread is higher for OTR bonds, which reinforces the theoretical intuition. The difference in bid-ask spreads is statistically significant for medium- and longer-term bonds, while spreads are not statistically different for short-term bonds, which are less suitable for buy-and-hold investors and for which market makers are willing to hold

---

<sup>46</sup>All regressions include basket-month fixed effects and standard errors clustered at the bond-level.

**Table 5:** Liquidity measures for on-the-run and off-the-run bonds

	(1)	(2)	(3)	(4)	(5)
	Short-term	Medium-term	Medium-term floating	Long-term	Long-term inflation-linked
<hr/>					
Bid-ask spread					
On-the-run	0.45	0.33	0.14	0.54	0.78
Off-the-run	0.45	0.28	0.12	0.35	0.54
Difference	-0.00	-0.05***	-0.02***	-0.19***	-0.24***
	(-0.16)	(-24.11)	(-3.74)	(-36.07)	(-6.95)
<hr/>					
Daily bond trading quantity (mm)					
On-the-run	142.0	15.2	110.0	62.7	42.6
Off-the-run	61.9	14.2	51.7	28.9	28.3
Difference	-80.2***	-1.0***	-58.7***	-33.8***	-14.3***
	(-55.50)	(-3.48)	(-32.27)	(-73.97)	(-19.98)

The table reports the relative bid-ask spread in percentage points and the daily bond trading quantity in millions for on-the-run and off-the-run bonds for five different bond types: short-term bonds are Treasury bills, medium-term bonds are zero-coupon bonds, medium-term floating-rate bonds are Treasury certificates indexed to a floating benchmark, long-term bonds are Treasury bonds, and long-term inflation-indexed bonds are Treasury bonds linked to inflation. The difference is defined as the off-the-run less the on-the-run value.  $t$ -statistics are in parentheses. Data include bond quotes and trades executed on the MTS platform for the period January 2010–June 2020.

larger inventories (e.g., Naik and Yadav, 2003 and Fleming and Rosenberg, 2008). Huh and Infante (2021) analyze the relationship between repo market specialness and the bond market liquidity of the underlying collateral. They develop a theoretical model which suggests that over time (and for the same asset), a higher repo market specialness can lead to lower bond market liquidity as intermediaries face higher cost. Broadening their view, my focus is on the cross-section of assets; I show that higher GC repo delivery volumes and higher collateral opportunity cost lead to a higher bond bid-ask spread in the cross-section.

Still, while OTR bonds feature higher bid-ask spreads, they also have higher daily trading volumes. At first, it seems surprising that OTR bonds have higher bond market spreads in spite of higher trading volumes. At the same time, my results provide a *suggestive* explanation for it. Market participants are willing to pay a premium (in the form of higher bond

market spreads) to obtain certain assets, for example, the OTR bond, which features superior liquidity benefits in the form of larger trading volumes. Market makers, by contrast, need to hold inventories of OTR bonds to cater the needs of their clients, which creates cost for which they want to get compensated.

## 4. Conclusion

The novelty of my study is to analyze borrowers' refinancing behavior and collateral choices in the main short-term funding market. In GC repos, the borrower can choose which bond he posts as collateral out of a predefined list. I find that collateral availability and opportunity cost are the two main drivers of this collateral choice. In aggregate, OTR bonds are more likely to be delivered as collateral than CTP securities, which is surprising given that the former is more expensive. I incorporate the results into a theoretical framework that links the funding decision to the bond market for the collateral.

My results highlight the systematically important role of financial intermediaries in connecting short-term and long-term funding markets. Market makers subscribe to government bond auctions, allowing the government to finance long-term investments and manage its overall debt level. Market makers also reallocate auction allocations to secondary market investors, thus, enabling them to make efficient investment decisions and form optimal long-term portfolios. In doing so, market makers use their long-term government bond holdings as collateral in short-term funding transactions. My analysis, thereby, provides a novel link between the repo market and the underlying bond market for the collateral; my results suggest that repo collateral choices are one reason for the time-variation in bond market spreads. For the central bank, it is important to account for this intermediation behavior of market makers in its monetary policy implementation as the repo market is key for an efficient monetary policy transmission.

## References

- Adrian, T., N. Boyarchenko, and O. Shachar. 2017. Dealer balance sheets and bond liquidity provision. *Journal of Monetary Economics* 89:92–109.
- Amihud, Y., and H. Mendelson. 1980. Dealership market: Market-making with inventory. *Journal of Financial Economics* 8:31–53.
- Andersen, L., D. Duffie, and Y. Song. 2019. Funding value adjustments. *Journal of Finance* 74:145–192.
- Arrata, W., B. Nguyen, I. Rahmouni-Rousseau, and M. Vari. 2020. The scarcity effect of quantitative easing on repo rates: Evidence from the Euro area. *Journal of Financial Economics* 137:837–856.
- Ballensiefen, B., and A. Ranaldo. 2022. Safe asset carry trade. *Review of Asset Pricing Studies (forthcoming)* .
- Bank for International Settlements. 2017. Repo market functioning. *Committee on the Global Financial System (CGFS) Papers* No. 59. Available at <https://www.bis.org/publ/cgfs59.htm>.
- Bartolini, L., S. Hilton, S. Sundaresan, and C. Tonetti. 2011. Collateral values by asset class: Evidence from primary securities dealers. *Review of Financial Studies* 24:248–278.
- Beetsma, R., M. Giuliadori, F. De Jong, and D. Widijanto. 2016. Price effects of sovereign debt auctions in the euro-zone: The role of the crisis. *Journal of Financial Intermediation* 25:30–53.
- Beetsma, R., M. Giuliadori, J. Hanson, and F. de Jong. 2018. Bid-to-cover and yield changes around public debt auctions in the euro area. *Journal of Banking and Finance* 87:118–134.
- Boissel, C., F. Derrien, E. Ors, and D. Thesmar. 2017. Systemic risk in clearing houses: Evidence from the European repo market. *Journal of Financial Economics* 125:511–536.

- Brandt, M. W., and K. A. Kavajecz. 2004. Price discovery in the US Treasury market: The impact of orderflow and liquidity on the yield curve. *Journal of Finance* 59:2623–2654.
- Brunnermeier, M. K., and L. H. Pedersen. 2009. Market liquidity and funding liquidity. *Review of Financial Studies* 22:2201–2238.
- Buraschi, A., and D. Menini. 2002. Liquidity risk and specialness. *Journal of Financial Economics* 64:243–284.
- Chen, H., Z. Chen, Z. He, J. Liu, and R. Xie. 2019. Pledgeability and asset prices: Evidence from the Chinese corporate bond markets. *University of Chicago Working Paper No. 2018-82*.
- Comerton-Forde, C., T. Hendershott, C. M. Jones, P. C. Moulton, and M. S. Seasholes. 2010. Time variation in liquidity: The role of market-maker inventories and revenues. *Journal of Finance* 65:295–331.
- Corradin, S., and A. Maddaloni. 2020. The importance of being special: Repo markets during the crisis. *Journal of Financial Economics* 137:392–429.
- Duffie, D. 1996. Special repo rates. *Journal of Finance* 51:493–526.
- Duffie, D. 2018. Post-Crisis Bank Regulations and Financial Market Liquidity: Baffi Lecture. Available at <https://www.darrellduffie.com/uploads/policy/DuffieBaffiLecture2018.pdf>.
- D’Amico, S., R. Fan, and Y. Kitsul. 2018. The scarcity value of Treasury collateral: Repo-market effects of security-specific supply and demand factors. *Journal of Financial and Quantitative Analysis* 53:2103–2129.
- D’Amico, S., and T. B. King. 2013. Flow and stock effects of large-scale treasury purchases: Evidence on the importance of local supply. *Journal of Financial Economics* 108:425–448.
- D’Amico, S., and N. A. Pancost. 2022. Special repo rates and the cross-section of bond prices: The role of the special collateral risk premium. *Review of Finance* 26:117–162.

- Eisl, A., C. Ochs, N. Osadchii, and M. G. Subrahmanyam. 2019. The Linkage between Primary and Secondary Markets for Eurozone Sovereign Debt: Free Flow or Bottleneck? *Working Paper* .
- European Central Bank. 2018. Euro money market survey, 2018. Available at [https://www.ecb.europa.eu/pub/euromoneymarket/html/ecb.euromoneymarket201909\\_study.en.html](https://www.ecb.europa.eu/pub/euromoneymarket/html/ecb.euromoneymarket201909_study.en.html).
- Fleming, M. J., and J. V. Rosenberg. 2008. How do Treasury dealers manage their positions? *FRB of New York Staff Report* .
- Fontaine, J.-S., and R. Garcia. 2012. Bond liquidity premia. *Review of Financial Studies* 25:1207–1254.
- Glosten, L. R., and P. R. Milgrom. 1985. Bid, ask and transaction prices in a specialist market with heterogeneously informed traders. *Journal of Financial Economics* 14:71–100.
- Goldstein, M. A., and E. S. Hotchkiss. 2020. Providing liquidity in an illiquid market: Dealer behavior in US corporate bonds. *Journal of Financial Economics* 135:16–40.
- Gorton, G. 2017. The history and economics of safe assets. *Annual Review of Economics* 9:547–586.
- He, Z., B. Kelly, and A. Manela. 2017. Intermediary asset pricing: New evidence from many asset classes. *Journal of Financial Economics* 126:1–35.
- He, Z., and A. Krishnamurthy. 2013. Intermediary asset pricing. *American Economic Review* 103:732–70.
- He, Z., A. Krishnamurthy, and K. Milbradt. 2019. A model of safe asset determination. *American Economic Review* 109:1230–1262.
- Ho, T., and H. R. Stoll. 1981. Optimal dealer pricing under transactions and return uncertainty. *Journal of Financial Economics* 9:47–73.

- Ho, T. S., and H. R. Stoll. 1983. The dynamics of dealer markets under competition. *Journal of Finance* 38:1053–1074.
- Huh, Y., and S. Infante. 2021. Bond market intermediation and the role of repo. *Journal of Banking and Finance* 122:105999.
- ICMA. 2021. European repo market survey. Available at <https://www.icmagroup.org/Regulatory-Policy-and-Market-Practice/repo-and-collateral-markets/icma-ercc-publications/repo-market-surveys/>.
- Infante, S. 2020. Private money creation with safe assets and term premia. *Journal of Financial Economics* 136:828–856.
- Jordan, B., and S. D. Jordan. 1997. Special repo rates: An empirical analysis. *Journal of Finance* 52:2051–2072.
- Keane, F. M. 1996. Repo patterns for new treasury notes. *Federal Reserve Bank of New York Current Issues in Economics and Finance* 2:1–6.
- Klingler, S., and S. M. Sundaresan. 2020. Diminishing Treasury Convenience Premiums: Effects of Dealers’ Excess Demand in Auctions. *Working Paper* .
- Krishnamurthy, A. 2002. The bond/old-bond spread. *Journal of Financial Economics* 66:463–506.
- Krishnamurthy, A., and A. Vissing-Jorgensen. 2012. The aggregate demand for Treasury debt. *Journal of Political Economy* 120:233–267.
- Krishnamurthy, A., and A. Vissing-Jorgensen. 2015. The impact of Treasury supply on financial sector lending and stability. *Journal of Financial Economics* 118:571–600.
- Kyle, A. 1985. Continuous auctions and insider trading. *Econometrica* pp. 1315–1335.
- Liu, Y., L. Schmid, and A. Yaron. 2019. The risks of safe assets. Working paper, Duke University.

- Longstaff, F. A. 2004. The flight-to-liquidity premium in U.S. Treasury bond prices. *Journal of Business* 77:511–526.
- Lou, D., H. Yan, and J. Zhang. 2013. Anticipated and repeated shocks in liquid markets. *Review of Financial Studies* 26:1891–1912.
- Macchiavelli, M., and X. Zhou. 2021. Funding liquidity and market liquidity: the broker-dealer perspective. *Management Science* 68:3378–3398.
- Mancini, L., A. Ranaldo, and J. Wrampelmeyer. 2016. The Euro interbank repo market. *Review of Financial Studies* 29:1747–1779.
- Nagel, S. 2016. The liquidity premium of near-money assets. *Quarterly Journal of Economics* 131:1927–1971.
- Naik, N. Y., and P. K. Yadav. 2003. Risk management with derivatives by dealers and market quality in government bond markets. *Journal of Finance* 58:1873–1904.
- Nyborg, K. G. 2016. *Collateral frameworks: The open secret of central banks*. Cambridge University Press, Cambridge, England.
- Pasquariello, P., and C. Vega. 2009. The on-the-run liquidity phenomenon. *Journal of Financial Economics* 92:1–24.
- Pelizzon, L., M. G. Subrahmanyam, D. Tomio, and J. Uno. 2016. Sovereign credit risk, liquidity, and European Central Bank intervention: Deus ex machina? *Journal of Financial Economics* 122:86–115.
- Ranaldo, A., P. Schaffner, and M. Vasios. 2021. Regulatory effects on short-term interest rates. *Journal of Financial Economics* 141:750–770.
- Rytchkov, O. 2014. Asset pricing with dynamic margin constraints. *Journal of Finance* 69:405–452.
- Sigaux, J.-D. 2018. Trading ahead of Treasury auctions. *ECB Working Paper No. 2208* .

- Song, Z., and H. Zhu. 2019. Mortgage dollar roll. *Review of Financial Studies* 32:2955–2996.
- Stoll, H. R. 1978. The supply of dealer services in securities markets. *Journal of Finance* 33:1133–1151.
- Vayanos, D., and P.-O. Weill. 2008. A search-based theory of the on-the-run phenomenon. *Journal of Finance* 63:1361–1398.