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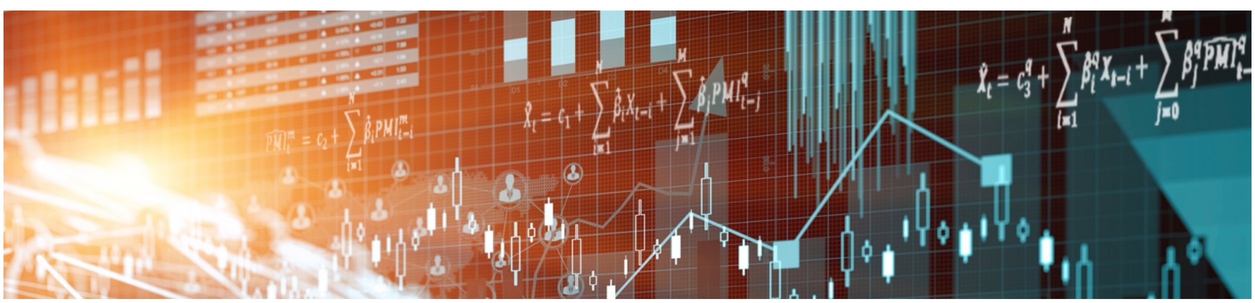
Government of Canada Securities in the Cash, Repo and Securities Lending Markets



by Narayan Bulusu and Sermin Gungor

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Abstract

This paper documents the properties of Government of Canada securities in cash, repo and securities lending transactions over their life cycle. By tracking every security from issuance to maturity, we are able to highlight inter-linkages between the markets for cash and for specific securities. Our results indicate that the interaction of search frictions with clientele effects may be key to producing the patterns of trade exhibited by bonds of different maturities.

Bank topics: Financial markets; Wholesale funding
JEL codes: G12, G21, G23

Résumé

Cette étude met en évidence les propriétés des titres du gouvernement du Canada dans les transactions du marché au comptant, les opérations de pension et les prêts de titres au fil de leur cycle de vie. En suivant tous les titres depuis leur émission jusqu'à leur échéance, nous sommes en mesure de faire ressortir les interrelations entre les marchés au comptant et les marchés de titres particuliers. Nos résultats indiquent que l'interaction des frictions de recherche et des effets de clientèle pourrait jouer un rôle essentiel dans l'apparition des profils de transactions affichés par les obligations assorties d'échéances différentes.

Sujets : Marchés financiers ; Financement de gros
Codes JEL : G12, G21, G23

1 Introduction

Financial market participants rely on access to low-cost funding and to specific securities for their operations. For example, borrowing bonds through repurchase agreements (repos) or in the securities lending markets is important for market makers seeking to fulfil client demand for a specific security, or for hedge funds wishing to sell a specific security short. Similarly, borrowing cash in the repo markets is crucial for primary dealers who wish to finance their inventory of securities allotted at auctions (Fontaine, Hately and Walton 2017). The interdependence between spot, repo and securities lending markets is captured in Figure 1, which shows that trading volumes in these three markets are highly correlated.[1] Core funding markets are thus pivotal for the efficient functioning and liquidity of financial markets, which in turn is important for an effective transmission of monetary policy — and, ultimately, supporting economic growth.

The main goal of this paper is to document the usage of Government of Canada (GoC) securities in three key markets for cash and specific securities — spot, repo and securities lending — over their life cycle. Tracking each bond from issuance to maturity in the different markets enables us to identify both patterns common to all bonds and those that differ by bond characteristics. Given that spot, repo and securities lending trades are all negotiated over the counter, it is not surprising that our results lend credence to the theoretical literature arguing for the importance of search frictions in explaining co-movements in these markets. For example, we observe that high volumes and liquidity in the spot market are coincident with high borrowing demand for the security, as in Vayanos and Weill (2008). However, as discussed in detail below, the preferred habitat of bond market clienteles (Culbertson 1957 and Modigliani and Sutch 1966) makes the trading patterns observed for shorter-term bonds markedly different from those of longer-term securities.

Unlike US Treasuries, bonds do not attain benchmark status upon issuance in Canada. As described in Gravelle (1999), the GoC staggers its primary issuance in a particular security

[1] For similar evidence in the United States, see Huh and Infante (2017).

over a period of time through repeated auctions of the same security.[2] In effect, the amount outstanding of a bond increases after its first issuance until reaching the target issuance level over successive "reopenings" of the bond, at which point it becomes the benchmark in its sector (maturity group).[3] This bond loses its benchmark status when a new bond in the same maturity group reaches its target issuance level. Thus, the life cycle of Canadian bonds can be broadly divided into the pre-benchmark, benchmark and post-benchmark phases. We show below that the usage of individual bonds varies over the life cycle, which could be explained by the interaction of clientele effects with the search frictions prevalent in the spot, repo and securities lending markets.

The literature beginning with Duffie, Gârleanu and Pedersen (2005) has highlighted the key role that search frictions play in over-the-counter (OTC) markets. In particular, Vayanos and Weill (2008) argue that short sellers prefer borrowing bonds that have high expected liquidity, in order to reduce search costs when closing out their short position. Banerjee and Graveline (2013) provide empirical evidence that short sellers are willing to pay the higher costs involved in borrowing more liquid securities to mitigate the difficulty of finding the bond at a later date. We find direct evidence consistent with these arguments: for all bonds, the benchmark period (analogous to the on-the-run phase of US Treasuries) has the best spot market liquidity, and the highest spot and borrowing volume, despite being, in general, more expensive to borrow. Liquidity and trading volume suffer a sharp drop as soon as the benchmark period ends.[4] This coordination of market participants on benchmark bonds is perhaps made easier by the Bank of Canada's public announcements of its benchmark bonds, along with the predictability around its next benchmark bond.[5]

[2]Díaz, Merrick and Navarro 2006 note that Spain followed a similar issuance pattern until 2002, possibly anticipating a significant price impact from auctioning the total preferred outstanding when the bond is first issued. Unsurprisingly, that paper also categorizes the life of Spanish government securities as having three phases — pre-benchmark, benchmark and seasoned — and shows that a common pattern dominates the liquidity of bonds of all terms over their life cycle.

[3]The Bank of Canada publishes the current benchmark issues, their effective dates and daily yields on its website: http://www.bankofcanada.ca/rates/interest-rates/canadian-bonds/.

[4]The sharp fall in borrowing demand and spot trading is also observed in the United States (see Keane 1996).

[5]The Goverment of Canada announces the desired level outstanding in each bond in its annual Debt

Our data additionally allow us to track the activity of individual bonds in these markets. We find that while the life cycle of bonds within a maturity group exhibits similar patterns, that across sectors displays interesting differences. Investors in bond markets are commonly assumed to have strong preferences for maturity, with limited desire to substitute across maturity groups (e.g., Vayanos and Vila 2009). Further, investors in the longer-term assets, especially the smaller pension funds and insurance companies, may be less active in repo markets.[6] Such investors therefore tend to engage the services of securities lending agents — third parties that lend from the aggregate portfolios of their clients — to enhance the returns on their assets. Thus, search frictions in the repo market may play a smaller role in borrowing longer-term securities, since securities lending markets provide an alternative venue to find them. The pattern of trading activity in the 2-, 5-, 10- and 30-year sectors follows this expected pattern: the longer the duration, the greater (smaller) the volume in the securities lending (repo) markets.[7] This volume-based evidence complements existing studies such as D'Amico, Fan and Kitsul (2014), D'Amico and King (2013) and Greenwood and Vayanos (2010, 2014), which infer support for the preferred-habitat hypothesis using the reaction of bond prices to unexpected changes in the demand and supply of bonds across the term structure.

Our results also confirm patterns of bond liquidity that have previously been observed in other geographies. First, bonds experience their highest spot liquidity when they are on the run, which has been shown in the United States (e.g., Amihud and Mendelson 1991, Barclay, Hendershott and Kotz 2006 and Krishnamurthy 2002), in Japan (Boudoukh and Whitelaw

Management Strategy document. The Bank of Canada provides advance notice of auctions in every bond, which allows market participants to anticipate when the amount outstanding in a bond would reach its desired level, close to which it would become the benchmark.

[6]Bédard-Pagé et al. (2016) point out that all except the largest pension funds in Canada do not have the scale to justify the costs of being active in the repo market. The costs of operating a repo desk include personnel and technological investments involved in managing counterparty risk evaluation, collateral optimization and trade execution (Johal, Roberts, and Sim 2017). The portfolios of smaller longer-term investors tend not to be large enough to generate sufficient revenue through repos to cover the operating costs.

[7]Canada also issues bonds in the three-year sector. However, since these bonds are sometimes reclassified as two-year bonds, and subsequently achieve benchmark status in the two-year sector, their properties differ significantly from the other bonds analyzed in this paper. We also do not present the life cycle of instruments with less than one year to maturity, since such bills do not have a pre-benchmark or benchmark phase.

1991, 1993), and also in emerging markets such as India (Deuskar and Johnson 2016). Second, the reduction in trading volume and liquidity as a bond ages, attributed to the bond moving from the portfolio of more active to less active investors, has previously been highlighted by Amihud and Mendelson (1991), Díaz, Merrick and Navarro (2006) and Fleming (2003), among others. More surprisingly, we find that bonds could have relatively good liquidity even in the absence of much spot market trading. We see this phenomenon in the pre-benchmark period for all except the 30-year bond in Canada, for which trading volume is not significantly high in any but the general collateral (GC) repo market. The mechanism proposed by Pasquariello and Vega (2009) could possibly explain this seeming puzzle. In their model, liquidity improves in situations that alleviate counterparties' information asymmetry. Under such conditions, the counterparty is less fearful of trading against an informed participant and is more willing to offer better terms of trade. Thus, in the pre-benchmark period, when primary dealers in Canada seek to sell their allotment of bonds received at the auction to reduce inventory costs (or to relax the balance sheet capacity for other activities), other dealers are willing to offer better terms of trade. The certainty that the bond would have excellent liquidity is the other factor that mitigates the risk of dealing with informed traders in the pre-benchmark period. Since dealers expect to obtain excellent liquidity for the bonds in the upcoming benchmark period, they are willing to provide good liquidity to the pre-benchmark bond.

Finally, turning to the life cycle of prices in the markets under consideration, we find considerable heterogeneity across bonds with different maturities. Therefore, we postpone this discussion to Section 4.

This paper is organized as follows. Section 2 describes the trading motives of investors in different markets. Section 3 presents the data in detail and shows some statistics summarizing key markets. Section 4 investigates the differences in the life cycle of GoC bonds of different maturities at issue, and suggests some hypotheses that may explain the observed heterogeneity. Section 5 concludes and discusses avenues for future research. An appendix provides details about data sources, modifications and applied filters.

2 Trading Motives of Participants in Funding Markets

Trades in the spot, repo and securities lending markets could be motivated by the "search for cash" or the "search for specific securities." For example, a security held by a market participant could be sold or used as collateral to obtain cash to fund inventories, finance leveraged positions, meet margin calls or other payment obligations, or purchase other desired securities. Market participants could also use reverse repos or securities lending to obtain temporary possession of particular securities that they wish to use for either hedging or speculation (or to close out existing hedging or speculative positions). Purchasing the security in the spot market could be a substitute for borrowing the security; however, such purchases could also be undertaken by investors desiring ownership of the security — whether for its cash flows or for other uses, e.g., to meet regulatory requirements.

Repos involve the sale of a security for cash combined with a promise to buy the security back at a later date. A repo is thus effectively a collateralized loan where the difference between the initial sale price and the repurchase price is the interest on the cash loaned out. Cash lenders, who value the collateral only for the protection it offers in the event of the counterparty's default, are usually indifferent to the specific security being pledged, as long as it belongs to a basket of "equivalent" securities. The interest rate on such GC repos is independent of the specific security being pledged. Since the lender of cash agreeing to a GC repo is, by definition, willing to accept any security that forms a part of the GC basket, the motive for such a trade is relatively straightforward — the search for cash by the borrower.

Other repo transactions are characterized by the desire to obtain specific collateral. If the desired security is scarce, the interest on the cash loan is lower, i.e., the repo rate of that bond is below the GC repo rate. These issues are referred to as being "on special." The spread between the GC and special repo rates (repo spread) is the interest foregone by the cash lender in exchange for obtaining the desired security and can be interpreted as the borrowing fee for that security. As a result, special repo is motivated by the search for specific securities by investors who put extra value on the particular collateral received.

Repo agreements can be negotiated for any maturity, but the majority are for one business day (overnight repos). Counterparties often choose to renew the overnight contracts by renegotiating the repo rate on a daily basis. Term repos are agreements to borrow cash for longer than one business day. In our analyses, we cannot identify the economic motive for term repos; therefore, we treat them as a separate category.

Securities lending involves the loan of a security against cash or other acceptable securities. Against cash collateral, they are economically indistinguishable from repos. Unlike repos, however, these trades are conducted between the borrower of the security and the securities lending agent (custodian bank), who intermediates between the owners of these securities and the borrowers.[8] Securities lending transactions collateralized by other securities are mainly motivated by the demand for a specific security rather than the demand for cash. As such, it can be inferred that GC repos and securities lending against cash collateral are driven by the search for cash, while the search for specific securities is satisfied by special repo and securities lending against non-cash collateral. In Canada, securities lending transactions are overwhelmingly conducted against the provision of non-cash collateral.[9] During the 2010–15 period, more than 85 per cent of securities lending was against other securities. Since cash is not exchanged in the vast majority of these loans, the economic motive for these transactions is driven by a desire to borrow specific securities.[10]

The spot market is an alternative venue for market participants to search for cash or specific securities. However, settlement delays affect spot trades, making them an imperfect

[8] The intermediation services offered by the lending agent include arranging trades, performing due diligence on prospective borrowers, reinvesting cash collateral and managing operational and administrative aspects of lending.

[9] See Dreff (2010) for details about the securities lending market in Canada.

[10] Aggarwal, Bai and Laeven (2016) suggest that securities lending is sometimes used to transform lower-quality collateral into higher-quality assets, which may in turn be used as collateral for repos. As a result, securities lending may occasionally be motivated by the search for a class of securities rather than for a particular security.

substitute for repo and securities lending. Settlement conventions guide the time elapsed between the initiation of a trade and its settlement. The repo and securities lending transactions settle on the same day that they are initiated; however, most bonds are settled between two and three days later in the spot market.[11] Thus, while cash or security needs that are fully anticipated can still be fulfilled by the spot market, unanticipated needs cannot. Moreover, investors may not always have a desire to take ownership of a security or bear the undesirable price risk that can be alleviated via the the pre-determined repurchase price in the repo and securities lending transactions. In this paper, the spot market is treated as a separate category due to lack of an identifier of whether a transaction was buyer- or seller-initiated.

Based on the above discussion, we rank trades in funding markets according to their economic motive. The ranking in decreasing intensity of the search for cash (and increasing intensity in the search for a particular security) is as follows: (i) GC repos, (ii) term repos, (iii) spot, (iv) securities lending and (v) special repos.

3 Canadian Funding Markets Data

We use several different data sources for the analyses in this paper. The primary transactions data for repo and spot markets are from Canada's securities settlement system (CDSX) and the central counterparty, the Canadian Derivatives Clearing Corporation (CDCC), from August 28, 2009, to July 31, 2015. These two sources provide comprehensive repo and spot transactions data, since almost all Canadian fixed-income trades settle through CDSX. Each reported transaction includes the trade type (repo or spot), the time stamp for the entry of trade into the settlement system, the trading price and volume and the International Securities Identification Number (ISIN). Repo transactions obtained by transforming these data additionally include information about the repo rate, tenor and haircut.

[11]Government bonds with three years or less to maturity settle two days after trade ("T+2 settlement"), while those with longer maturity settle on T+3. Only money market instruments, i.e., debt securities with less than one-year maturity, typically operate under the same-day settlement convention in Canada.

The data for securities lending are obtained from Markit Securities Finance and include the following information available at the daily frequency for each ISIN: total stock of securities available for lending and on loan, and the volume-weighted average fee on all open loans. In this section, we briefly outline the data cleaning and transformation process, provide summary statistics, and leave the remaining details to the Appendix. The reader uninterested in the data outline can skip to Section 3.4 without loss of continuity.

3.1 Repo market

Repos in Canada are largely arranged bilaterally, although some repos are traded on interdealer broker (IDB) operated electronic platforms open during pre-specified intervals during the day.[12] In 2012, CDCC began clearing repos. Trades cleared by CDCC are first negotiated bilaterally, or through the IDB screens, and then routed to CDCC for novation and netting (across spot, futures and repo trades). All repo transactions, whether traded bilaterally or centrally cleared, settle through CDSX, the settlement system of the TMX Group (see Garriott and Gray 2016).

In Canada, repo transactions are actually sell/buyback agreements. These agreements differ slightly from the classic repo in that the securities are sold (first leg) and bought back (second leg) at different prices. The difference reflects the interest accrued on the sell/buyback and any cash flows (interim coupons of the underlying bond) that occur during the term of the agreement.

Accordingly, the sale and repurchase legs of a repo are settled in CDSX as two separate cash-for-security trades, with the first and second legs having different settlement dates. To recover the terms of the underlying repo agreement, i.e., repo rate, tenor, haircut, we employ an algorithm to match the first and second legs of a trade. In essence, the matching algorithm

[12]As described by Garriott and Gray (2016), who provide a detailed description of the infrastructure and participants in the Canadian repo market, IDB repos are characterized by anonymity of the counterparties involved before execution. The IDBs may reveal the counterparties to each other before executing the trade. In some cases, the counterparties may even choose to modify the terms of trade after their identities are revealed. Fontaine, Hately and Walton (2017) estimate that about one-quarter of monthly repo trading volume was traded through the IDBs in 2013.

takes advantage of the fact that both legs of a repo involve an exchange of an equal par value of the same security, that these two trades are entered into the CDSX system "not too far apart" in time, and that the first leg of the repo settles on a date prior to the second (see the Appendix for details). The final matched repo data capture about 60 per cent of total repo volume traded. The top panel in Figure 2 shows the time series of the matching rates over the entire six-year sample period. The non-matched trades may be because our algorithm is not designed to identify forward, open-term, evergreen or floating-rate repos (see Garriott and Gray 2016 for a description of such repos). There could also be omissions arising from the assumptions made in the matching algorithm (treated in detail in the Appendix). Since it is unlikely that the errors induced by our algorithm are systematically correlated with security characteristics, we believe that the data are representative of the Canadian repo market.

An important feature of the central counterparty, CDCC, is to provide netting service to its clients. A direct consequence of this service is the reduction in the volume of repo-tagged trades, since the data provided by CDSX are post-netting settlement instructions. To mitigate this reduction, we complement the repos identified in the CDSX data with pre-netting transactions obtained from CDCC by the application of the same algorithm. We achieve a near-100 per cent identification of repo-flagged trades in the CDCC data due to a unique alphanumeric repo code that identifies all tranches in both legs of a repo trade. The Appendix describes the procedure we use to combine the repos from these two sources. The output of the algorithm is a set of repos with information on the collateral, quantity, repo rate, tenor and time of entry.[13]

The repo data do not contain indicators of GC and special repos. To identify these trades, we use the concept of economic benefit — highlighted by the ability of holders of a particular collateral to borrow cash at a lower rate — used by, e.g., D'Avolio (2002) and

[13]Time of entry reflects the time-stamp that a trade is entered into the CDSX or the CDCC system, not the trade time.

Duffie (1996).[14] We identify the special overnight repo transactions as those with a repo rate at least five per cent below the Canadian Overnight Repo Rate Average (CORRA).[15]

We estimate the haircut applied to the collateral by comparing the price at which the first leg of the repo was settled with the price of the spot trade closest in entry time in the same security. The estimated haircuts may suffer from estimation errors to the extent that the closest-in-time spot trade is not representative of the base price from which the haircut was calculated. This could be because the difference between entry times of the spot and repo transactions is sufficiently large for the base price to have changed. Alternatively, it could be because the price of the closest-in-time spot trade was not representative of the price at which the two counterparties would have traded the same security in the spot market, for example, because the spot trade was "too large or too small," or because it was conducted between parties of different credit risk or bargaining power. To account for possibly large errors, we set repos with estimated haircuts over 25 per cent or below -5 per cent to "missing." The bottom panel of Figure 2 plots the haircut against the time difference between the employed spot and repo trades. We observe no systematic patterns in the magnitude of haircuts with the time gap. The graph also highlights that haircuts are bi-modally distributed, with the largest density around 0 per cent, and a smaller concentration around 2 per cent. These features of haircuts are corroborated by market participants, providing confidence in our estimates.

3.2 Spot market

To identify spot trades, we use the trade type indicator provided in the CDSX data set. Then, we employ a filter that uses the settlement conventions for spot trades, to eliminate

[14]This categorization underestimates (reverse) repos driven by the search for a security to the extent that the supply of the security in repos is sufficiently large (or the demand is sufficiently small) so as not to allow for an economic advantage to accrue to holders of the collateral. This is the scenario illustrated in Figure 2 of Duffie (1996), and also in Figure 5 of Krishnamurthy (2002) — where the demand curve passes through the horizontal part of the supply curve.

[15]This paper uses the terms "GC repo" and "special repo" interchangeably with "overnight GC repo" and "overnight special repo," respectively. The CORRA is a measure of the average cost of overnight collateralized funding.

transactions that are potentially mixed with other types of settlement activity in fixed-income securities. Spot trades in all fixed-income securities up to (and including) one year to maturity settle on the same day (T+0). Government securities between one and three years to maturity settle on T+2; those with over three years to maturity settle on T+3.

To allow for the fact that spot trades are sometimes negotiated under special terms, we retain transactions involving bonds with one to three years (over three years) to maturity with settlement between one and three (two and four) days.[16] We treat all non-repo-flagged trades in government securities with up to one year to maturity with same-day settlement as spot trades.

Similar to its effect on the repo transactions, the netting activity of the central counterparty could potentially reduce the volume of spot trades. To alleviate this impact, we complement the CDSX data using the pre-netting spot trades novated by CDCC.

3.3 Securities lending market

Markit Securities Finance collects securities lending data on transactions and positions, estimated to account for about 90 per cent of such activity in Canada. To avoid double-counting caused by the trades that are reported by both entities involved in a transaction, Markit uses a proprietary algorithm. The "clean" transactions are then used to generate daily market-wide outstanding stock of each security available for lending and on loan. Other variables of interest in the data include the fraction of the stock on loan collateralized by cash, the volume-weighted average term of the loans outstanding, the volume-weighted fees and the number of transactions involving the security — the last two available for various time intervals (last 1, 3, 7, 30 days, and over the entire lifetime). In this study, we focus our attention on the total stock of a fixed-income security on loan and fees on all outstanding loans.[17]

[16] Discussions with market participants suggested that bonds with over one year to maturity are rarely — if ever — settled on the same day.

[17] Individual securities lending transactions reported by a small subset of data providers are also made available by Markit. However, we do not use this information in our analyses because of both the minuscule

3.4 Descriptive statistics

Table 1 summarizes the average monthly activity of GoC securities in each year of our sample. About Can$500 billion of repos are traded per month using GoC securities of all maturities (including bills), with the overwhelming majority being driven by the search for cash. In the last two years of the sample, we see a shift away from overnight GC repos and into term repos. The average volume of term repos has doubled from nearly $80 billion during 2009–13, to $160 billion during 2014–15, while GC repo volumes fell by about a third to $235 billion (compared with $343 billion on average in the preceding three years). Special repo volumes are rather volatile, reaching lows of $17 billion in the average month in 2011 and peaking at $158 billion in 2013. On average, they constitute less than 20 per cent of total repo volume. The size of the average GC repo is $120 million, the average term repo is $72 million, and the average special repo is $61 million.[18]

The volume of spot transactions is about two-thirds of that of repos traded in the average month. The monthly volume of spot trades averaged $260 billion up to 2012, and jumped to $480 billion during 2013–15. The average spot trade is small compared with transactions in the repo market, about $9 million.[19] While it is difficult to compare the stock of GoC securities on loan with the transaction volume in the spot and repo markets, it seems reasonable to suggest that securities lending of GoC instruments is highly significant in Canada, with over $1.2 trillion outstanding on average.

By definition, the term of our GC and special repos is one day (overnight). We see

size of trades (compared with those indicated by the more complete data) and also questions about the representativeness of the smaller sample.

[18]This ordering could perhaps be expected given the economic drivers of these trades. Special repos could have the highest price impact as they involve the search for an already scarce security. GC repos are likely to have a lower price impact, and consequently larger trade sizes, given competition between all the holders of cash looking for a short-term safe investment. Since not every lender of cash (or borrower of securities) may wish to tie up their funds (securities) for longer-term periods, term repo trades may be of lower size than GC repos.

[19]Small transaction sizes in the spot market could be the result of smaller traders operating in this market, or could stem from larger orders being deliberately split by participants wishing to minimize the price impact of their trades. Since our data do not include participant information, we are unable to distinguish between these two explanations.

that the average duration of term repos is less than a week. In contrast, securities lending contracts are open for an average of over five months. These differences point to potential diversity in the types of participants in each of these markets. Borrowers who anticipate the need to retain the security (e.g., short sellers who do not want to periodically return the security and search for it from another lender in order to keep their short positions open) may choose to transact in the lending market. Those searching for cash for a longer period (or perhaps searching for a security to satisfy unexpected demand) may use the term repo market instead.

Also by construction, the spread of GC repos is close to zero (recall that we define GC as those repos with rates sufficiently close to the CORRA). The special repo spread, however, exhibits substantial time variation. Special repos traded 21 basis points (bps) below the CORRA in 2013, during the time that special repo demand was the highest in our sample. In the last quarter of 2009, on the other hand, the average spread was 4 bps. This large variation in special repo volumes and rates is to be expected, given that special repos depend on time-varying security-specific demand and supply conditions. The spread on term repos lies between that of GC and specials. It is not clear, however, whether this indicates that at least some term repos are motivated by the search for securities. The difficulty in making inferences arises from the fact that the appropriate benchmark — repo rates for term trades driven by the search for financing — is not observed. Term repo rates incorporate expectations of future repo rates. A wide spread to the CORRA on the day the term repo was traded could be a result of decreasing expectations of the CORRA over the term of the repo. Further, as Buraschi and Menini (2002) point out, term repos also embed a term premium, which further complicates our ability to classify them by the motive for trade.

We conclude our discussion of the data with two further observations. First, only 10 per cent to 15 per cent of the stock of GoC instruments on loan is against cash. This is in contrast to the United States, where the majority of lending is against cash (see Baklanova, Copeland and McCaughrin 2015). This fact underlies our classification of lending activity as mainly security-driven. Second, we note that the estimated haircuts, on average, are less than 20 bps. GoCs are the safest asset class in Canada, which explains the low haircut that cash lenders are willing to accept when they are posted as collateral.

We now turn to the central results of our paper — the life-cycle analysis of the usage of GoC bonds in the spot, repo and securities lending markets.

4 Life-cycle Patterns of Bond Activity, Liquidity and Prices

The issuance practice of GoC bonds defines the different stages of their life cycle. Canada issues a limited set of maturities (2Y, 5Y, 10Y and 30Y) with common coupon payment dates on a regular basis.[20] In contrast to the issuance practice in the United States, large benchmark sizes in GoC bonds are achieved via consecutive reopenings after the initial auction.[21] Such staggered issuance is not unusual for smaller markets; for example, the Spanish Treasury followed a similar strategy until mid-2002 (see Díaz, Merrick and Navarro 2006). The outstanding amount in the newly issued GoC security in a sector grows at each reopening, and as it approaches the size of the old benchmark, market participants adopt the security as the new benchmark in that sector. This usually takes place close to the last reopening in a bond. Accordingly, the life of a typical GoC bond can be split into three phases: (i) *pre-benchmark*, the period from first issuance to the day prior to attaining the benchmark status; (ii) *benchmark*, the period between being designated as the benchmark and the day the next benchmark in the sector is announced; and (iii) *post-*

[20] There have been a few changes to the maturity structure during the sample period, such as the issuance of "ultra-long" bonds in the 50-year sector, and the discontinuation of new issues in the 3Y sector beginning in 2015. We do not include inflation-indexed bonds in our analysis, since they form a very small portion of government debt outstanding. Our analysis also excludes short-term zero-coupon GoC debt (3M, 6M and 1Y sectors), both because they are not much used in repo and securities lending markets and because bills do not experience any changes of status between issuance and maturity.

[21] See Gravelle (1999) for an in-depth explanation of the differences between the Canadian and the U.S. issuance practices, and their potential consequences.

benchmark, the period between loss of benchmark status and maturity. The pre-benchmark period is characterized by an increasing supply of the bond. Benchmark bonds are analogous to on-the-runs, and post-benchmarks are similar to off-the-runs in the United States.

Our results are based on the 2Y, 5Y, 10Y and 30Y sectors.[22] Naturally, the duration of each phase is unequal for a given bond and varies across bonds of different maturities. Table 2 presents the average number of days spent by bonds of different terms in each phase of the life cycle. Given these differences, we use the following normalization scheme to obtain the activity of the "average GoC bond" in each sector and to compare activity across sectors. We divide the time spent by a bond in each phase of its life cycle into an equal number of sub-periods and take the average of each variable of interest for each bond per sub-period. The rest of this section begins with an analysis of transaction activity in each funding market, and follows it up by highlighting market liquidity and prices for the different sectors.

4.1 Trading activity

We measure trading activity of a bond by its turnover, which is defined as the dollar trading volume divided by the stock of its outstanding amount. Figure 3 presents the life cycle of turnover ordered according to the motive for trade. Panel A shows the results for transactions more closely resembling those driven by the search for financing, i.e., GC and term repo. Panel B highlights the life-cycle behaviour in the spot market. Panels C and D plot activity in markets likely driven by the search for particular securities — the stock on loan and the volume of specials, respectively.

Figure 3 shows that the pattern of usage over the life cycle is common to all sectors. Transactions motivated by the search for funding dominate in the pre-benchmark phase and

[22]Although Canada does not issue bonds in the 7Y sector, a suitably aged 10Y or 30Y bond is designated as the 7Y benchmark. In our analysis, we ignore this second benchmark period because unlike the 3Y bonds reopened as 2Y bonds, the 10Y (or 30Y) bonds do not undergo a change in sector. Thus, the period when a 10Y or 30Y bond is named the 7Y benchmark falls in the post-benchmark phase in our analysis. We also do not include the 3Y bonds due to their unique property. Select 3Y bonds in our sample were reopened as 2Y bonds and subsequently assigned benchmark status in the 2Y sector. The anticipated potential rebirth of 3Y bonds in their post-benchmark period could conceivably make their usage patterns quite different from those of bonds in the other sectors.

decline over the rest of their life. Spot trades, and those likely driven by the need to obtain particular securities, on the other hand, are concentrated in the benchmark period and show relatively little activity in the pre- and post-benchmark phases. Despite these commonalities, however, there is noticeable heterogeneity in the levels of activity across the different sectors.

First, Panel A reveals that an average of 10 per cent of the 2Y, 12 per cent of the 5Y and 10 per cent of the 10Y bond is used daily as collateral for GC repos in the pre-benchmark period. In the same period, 2 per cent, 3 per cent and 2 per cent, respectively, of the outstanding stock of these bonds collateralizes term repos on average in a day. The use of the 10Y bond for financing drops quite sharply shortly after it attains benchmark status, while the use of the 5Y bond for this purpose begins to fall toward the mid-benchmark period. The 2Y bonds continue to be used as collateral in GC and term repos and exhibit only a minor decline during the benchmark period. The difference in the rate of decline across sectors in their use for obtaining funding during the benchmark period is most starkly noted by comparing the 2Y and 10Y sectors. About 15 per cent (9 per cent) of the 2Y (10Y) bond is used as collateral for GC repos at the beginning of the benchmark period; this falls to 11 per cent (5 per cent) just before it loses its benchmark status.

Second, turning to trades whose motive is to mainly search for specific securities, we observe that shorter-term bonds (2Y and 5Y sectors) trade more in the cash and special repo markets, while longer-term bonds (10Y sector) are more active in the securities lending market. About 7 per cent of the outstanding 2Y and 5Y benchmarks is borrowed via special repos daily, in comparison with 2 per cent of the 10Y benchmark. About one-fifth of the shorter-duration benchmarks are traded in the spot market daily; however, only about one-tenth of the 10Y sector changes hands on the average day during its benchmark period. The relationship between duration and activity is reversed in the securities lending market: 25 per cent of the 10Y, 17 per cent of the 5Y and 13 per cent of the 2Y security is on loan during the benchmark period.

Finally, the use of 30Y securities is noticeably lower than that of other GoC securities across all markets. Only 3 per cent (2 per cent) of outstanding 30Y bonds is used daily to obtain funding through GC repos in the pre-benchmark (benchmark) period. Their daily turnover in the spot market is also relatively low at 2 per cent.

What could explain this heterogeneity? We argue that these usage patterns are consistent with the presence of clienteles with heterogeneous preferences for duration risk (see Culbertson 1957 and Modigliani and Sutch 1966 for an early discussion of the preferred-habitat hypothesis). Johal, Roberts and Sim (2017) identify typical lenders of securities in Canada as pension funds, mutual funds, university endowments and insurance companies. These longer-term investors prefer longer-maturity assets in order to match the duration of their liabilities (Greenwood and Vayanos 2010), and they are more likely to participate in the securities lending market through intermediaries such as securities lending agents. Long-term investors may be reluctant to lend out their securities in the repo market if their portfolio size or desired level of activity does not justify the investment in technology and expertise required to run their own repo desk. Further, these investors may not wish to be exposed to the reinvestment risk of cash collateral provided in repos. As a result, longer-maturity bonds are used more actively in the securities lending market than in the repo market. On the other hand, shorter-term investors (such as primary dealers, hedge funds) may hold the bulk of shorter-duration assets. These investors are also more likely to participate in the repo markets due to their active investment strategies that require short-term funding and/or temporary ownership of assets.[23]

The relatively stable and uniform fraction of bonds in all sectors used to search for cash in the pre-benchmark period can be explained by the holders' need to fund their inventories. The pre-benchmark phase is characterized by repeated auctions. During this phase, primary dealers carry inventory of bonds that they are unable to immediately sell forward and use this inventory as collateral for cash (see Bartolini et al. 2011). The choice of using overnight

[23]We are unable to explain the low utilization of the 30Y that is common to all markets. While clientele effects could help explain the low level of activity in the cash and repo markets, the fact that bonds in this sector are not recirculated by holders through the lending markets is a puzzle.

GC or term repos for funding depends on the flexibility desired by the borrower (to respond to unexpected changes in inventory) and by the lender (to react to unexpected changes in cash balances).

The drop in the use of GC and term repos throughout the benchmark period could reflect the transfer of bonds from primary dealers' inventories to the portfolio of the ultimate owners. Longer-horizon investors prefer longer-term assets to match the duration of their liabilities. Such investors value the cash flows provided by the bond, and they usually employ the services of lending intermediaries to enhance the returns on their portfolio holdings. Thus, we should expect to see a sharper decline in the use of longer-term assets as collateral for GC repos with time, as the fraction of the asset held by the ultimate owners grows. Lending further credence to this hypothesis is the fact that the fall in GC repo volume is accompanied by a contemporaneous rise in the fraction of the security on loan. In fact, the sharper the fall in GC repos in a sector, the larger the rise is in securities on loan in that sector. The shift in the venue through which these securities recirculate reinforces our suggestion of a possible clientele effect on ownership of the security.

Frictions in the OTC market have been used to explain the concentration of special repo and spot trades during the benchmark period. In Vayanos and Weill (2008), special repos are used by short sellers to borrow the security. Given the restriction that they have to return the same security to close out their position, short sellers prefer to borrow securities that they expect to be easy to find in the spot market. Graveline and McBrady (2011) provide empirical support for this mechanism, where short-sales are driven by market participants' hedging needs. Banerjee and Graveline (2013) recognize that short sellers pay for their preference for trading liquid assets.

The earlier discussion on the preferred-habitat hypothesis suggests that short sellers may find it easier to borrow longer-term bonds from securities lenders.[24] Thus, we should expect

[24]Market participants report a preference for borrowing securities in the lending market to support short sales. This is both because open term loans allow short sellers the flexibility to react to unexpected market opportunities, and also because of the anonymity of their trading positions assured by borrowing from lending intermediaries. Special (overnight) reverse repos are more frequently used to meet short-term needs for a

to see a tighter relationship between securities lending and spot market activity for longer-term bonds. For shorter-duration securities that are likely to be held by market participants active in the repo markets, the correlation between special repo and spot market volumes should be higher.

This is effectively what we see in the data. In the 10Y sector, a nearly constant 25 per cent of securities is on loan during the benchmark period, during which time 10 per cent of outstanding stock is traded every day in the spot market. Special repo activity in the 10Y bond is less than 1 per cent of outstanding stock soon after it attains the benchmark status, and it rises to an average 3 per cent in the latter half of the benchmark period. The turnover of 2Y bonds in the spot market rises through the benchmark period and reaches a peak of 33 per cent of outstanding stock just prior to losing benchmark status. The same pattern of increasing usage is observed in the special repo market, with the peak of 10 per cent of outstanding stock being traded at the end of the benchmark period. In contrast, about 13 per cent of outstanding stock is on loan throughout the benchmark period. This difference in patterns of activity across the term structure can be interpreted as further support for the preferred-habitat hypothesis.

4.2 Liquidity

The vast literature on the liquidity of financial assets has highlighted the multi-dimensional nature of this concept. The holder of an asset seeking to sell it (or a prospective buyer seeking to acquire it), *ceteris paribus*, prefers an asset with higher market liquidity. Market liquidity could manifest itself in terms of low price impact of trade, low transaction costs, greater immediacy or greater price resiliency (see Sarr and Lybek 2002 for a discussion). More recently, the ability of an asset to serve as collateral for quickly and cheaply raising funding to meet cash flow needs has also begun to receive attention. As Brunnermeier

security, such as those driven by closing a short position, or by unexpected non-receipt of the security from another participant. This could partially explain the spike in special repo and spot trading just prior to a bond losing its benchmark status.

and Pedersen (2009) and Kondor and Vayanos (2016) show, these two types of liquidity are mutually reinforcing. In this section, we focus on the life cycle of market liquidity for individual bonds.

Figure 4 plots the Amihud (2002) measure of the price impact of spot trades (per million CAD) for the 2Y, 5Y, 10Y and 30Y sectors. On each day t, for each ISIN i, we estimate the price impact by $|R_t^i|/V_t^i$, where R represents the volume-weighted average return of all transactions on day t, and V is the spot trading volume.

Two results stand out. First, the price impact rises with the maturity of the security. The peak average daily price impact of a \$1 million spot trade in the 2Y, 5Y, 10Y and 30Y sectors is, respectively, 0.5 bps, 0.7 bps, 2.8 bps and 6.1 bps. The lower liquidity of longer-term securities could be the result of their lower availability owing to their being "locked-up" in the portfolios of longer-term investors, or because of their larger price (interest rate) risk, which translates into greater costs for dealers to make markets in such securities.

Second, with the exception of the 30Y sector, GoC bonds enjoy reasonably good liquidity in the pre-benchmark phase, become very liquid in the benchmark period, and suffer significant deterioration of liquidity after losing their benchmark status. For example, the average price impact of \$1 million spot trade on the average 10Y GoC bond is 0.1 bps, 0.0 bps and 1.1 bps in the three successive phases of its life cycle.[25]

The very high liquidity enjoyed by benchmarks is a well-known phenomenon that has been documented not just in the United States (e.g., Amihud and Mendelson 1991, Fleming 2003, Goldreich, Hanke and Nath 2005 and Krishnamurthy 2002), but also in other geographies (e.g., Boudoukh and Whitelaw 1991, 1993 in Japan; Díaz, Merrick and Navarro 2006 in Spain; and Deuskar and Johnson 2016 in India). This is not surprising given the elevated levels of activity in both the funding and the securities markets that we described in Section 4.1. As previously discussed, the sharp fall in liquidity in the post-benchmark period is also well known. This fall in liquidity with age is usually attributed to older bonds reaching

[25] Even the 30Y bond is most liquid in its benchmark period.

their ultimate owners, who may hold bonds for their cash flows and may not have motives to trade them regularly. The low level of activity as demonstrated in the previous section, particularly in the cash and repo markets, foreshadows this result.

The relatively good spot market liquidity enjoyed by pre-benchmark bonds, despite not trading actively in the spot market during this period, is not as well studied. Typically, it is intuitive to anticipate a positive relation between trading activity and liquidity. Therefore, the combination of low trading volume and high liquidity seemingly presents a puzzle. Looking at this relation over the time series, however, Chordia, Roll and Subrahmanyam (2001) and Fleming (2003) show that aggregate trading activity and market-wide liquidity are at best weakly correlated.

The fact that the stock of the bond allotted in auctions to primary dealers is growing in this period fits the theory of Brunnermeier and Pedersen (2009) that relates asset market liquidity to an asset's funding use. Although the spot market activity is low in the pre-benchmark period, the GC repo (funding) market experiences high activity. Given that all pre-benchmark bonds are future benchmarks — characterized by very high current funding and future market liquidity — market makers may indeed demand lower transaction costs in anticipation of the proximate desirability of the security. This is a topic that would benefit from further study.

4.3 Prices

A seminal contribution of Duffie (1996) is the formalization of the idea that the price of a security embeds the use value that it provides to market participants. This spurred a literature linking the various alternative uses (especially of safe assets) and their price in the spot market. Jordan and Jordan (1997) were among the first to empirically test the link between special repo rates and spot prices; subsequently, many other papers have confirmed this result (e.g., Fontaine and Garcia 2012 and Krishnamurthy 2002). Bartolini et al. (2011) show that the price advantage that certain asset classes deliver when used as collateral to obtain funding is capitalized in their spot price. More recently, Aggarwal, Bai and Laeven (2016) highlight that the securities lending market is used to transform low-quality assets into higher-quality collateral, the latter being used to obtain funding through repos. They show that the higher-quality collateral has higher lending fees (which, following the mechanism explained in D'Avolio 2002, should be reflected in a higher price of such securities). Apart from this literature establishing inter-linkages between the different markets, Goldreich, Hanke and Nath (2005) show that spot prices also capitalize expectations of the spot market liquidity of the asset over its lifetime.[26]

The dynamics of special repo rates, especially for U.S. Treasuries, has also received some attention. Keane (1996) shows that the special repo spread (defined as the difference between GC and special repo rates, and indicative of the funding advantage conferred to holders of the in-demand security) increases during the on-the-run period and peaks on the day prior to the security's becoming the first off the run. Moulton (2004) links this pattern to decreasing effective supply of the soon-to-be off-the-run security. Graveline and McBrady (2011) relate specialness to market participants' hedging demand. The behaviour of repo spreads of on-the-run securities is the exclusive focus of these studies. Missing from these analyses is the specialness of the off-the-run securities, and the dynamic behaviour of prices in the spot, repo and securities lending markets. We attempt to address these gaps.

Figure 5 plots the life cycle of prices in the three markets we study. Given the limitations of the trade-level securities lending data, we summarize the cost of borrowing a security by the weighted average fee for all outstanding loans. We report the volume-weighted special repo spread against the CORRA, which captures the degree of specialness of a security.[27] Finally, we also show the life cycle of the cash yield spread, calculated as the difference between the average yield of the spot trades in a bond and the yield for bonds of the same

[26] They argue that holders who need to sell the asset to meet liquidity shocks at a random time in the future would be willing to pay a higher price for assets with lower transaction costs over their entire lifetime, even after controlling for the alternative ways of raising funding using the asset, e.g., in the special repo market.

[27] As Duffie (1996) notes, OTC markets do not have a single market-clearing price. In our transaction-level data set, we even observe the same security collateralizing GC and special repos on the same day.

maturity obtained from the zero-coupon yield curve for the day.[28] A positive value indicates that the bond is trading at a premium to the yield curve.

We begin by noting that average lending fees and the special repo spread are nearly equal in the pre-benchmark period in all sectors (as before, we focus on the 2Y, 5Y and 10Y sectors). Since lending and repo markets are substitutes that cater to participants searching for particular securities, the difference in prices in these two markets is unlikely to be large. While they rise and fall in unison during the rest of their life cycle, lending fees react more slowly than the special repo spread. This observation does not contradict the previous statement, as pointed out by D'Avolio (2002). Since not all existing open contracts are repriced in response to, and only the new contracts are affected by, changes in repo rates, prices in the lending markets appear to be "sticky," just as we observe in the data.

The dominant message from Figure 5, however, is that the life cycle of bond prices displays considerable heterogeneity across sectors. We highlight two main facts. First, bonds in the 5Y and 10Y sectors become more special than those in the 2Y sector. The peak special spread is 23 bps and 21 bps for 5Y and 10Y bonds; the maximum for 2Y bonds is 15 bps. Second, longer-duration sectors experience peak specialness further into their life cycle than shorter-term sectors. The 2Y and 5Y bonds are most special towards the end of their benchmark period, while 10Y bonds reach peak specialness well after losing their benchmark status. While the average special repo spread of 2Y bonds drops back to 8 bps post-benchmark (close to its average pre-benchmark level of 7 bps), it remains elevated for 5Y bonds (15 bps, compared to the pre-benchmark average of 7 bps). The average special repo spread of 10Y bonds in the three phases is 6 bps, 10 bps and 17 bps.

The run-up in specialness towards the end of the benchmark period that we see in Figure 5 has also been observed in previous studies of repo specialness in on-the-run US Treasuries

[28] We use the daily zero-coupon yield curve in quarterly maturity increments made publicly available by the Bank of Canada (see Bolder, Johnson and Metzler 2004 for details). We use linear interpolation to obtain zero-coupon yields of intermediate maturities. To confirm robustness of our results, we also use the relative value measure developed by Fontaine and Nolin (2017) and find that it shares the salient patterns with the spot yield difference over the life cycle.

(see Keane and Moulton 2004). However, the post-benchmark behaviour has, to the best of our knowledge, neither been documented nor explained in the literature. The relatively elevated specialness post-benchmark is not driven by a large demand for the security. The fact that a small volume of special repos could trigger significant repo spreads once again suggests that the clientele effect may be in play. Our hypothesis is that longer-duration bonds begin to migrate to the portfolios of investors who are less inclined to actively trade in them. Thus, as time goes by, an increasing fraction of longer-term bonds becomes passively held, effectively reducing supply for those who wish to borrow them. The reduction in effective supply could be the reason why high prices can be sustained even with low demand. Market participants may choose to continue borrowing despite the elevated costs involved because they may lack good substitutes for these longer-term bonds, especially if borrowing is driven by a desire to hedge longer-duration risks.

The life-cycle behaviour of prices in these markets has received little attention in the literature. A significant exception is Duffie, Gârleanu and Pedersen (2002), who study the links between securities lending and spot market prices in a dynamic setting.[29] In their model, investors with lower valuation borrow a security in short supply from (optimistic) owners, and sell it to less optimistic investors (who are nevertheless not as pessimistic as the short sellers). Each asset owner capitalizes the expected fees from lending to short sellers in the price. Shorting increases the effective float, and decreases the price, since the security reaches investors with successively lower valuation. Thus, the price of the asset falls over time due to a decreasing rate of new shorting demand (and consequently lower expected lending fees), and also due to the decreasing valuation of the marginal investor. The, model suggests that a monotonically decreasing lending fee and spot price result.

The life cycle of prices observed in Canada suggests that some potential enhancements to the modelling environment may be necessary to better explain the data. Even ignoring the increasing stock of the security in the pre-benchmark period as being unique to Canada (and

[29] Also see Fisher (2002) in this context.

perhaps to other smaller jurisdictions), our earlier discussion suggests that two main features may need to be incorporated. The first is that the float of a security may decline over time, with the rate of decline a function of the security's maturity. As discussed earlier, longer-term bonds may increasingly be held up in passive investors' portfolios, driving up lending fees over time — even post loss of benchmark status — in the process. A second key element may be the inclusion of hedging as a motive for short sales. Hedging needs could depend on market participants' activity in other markets. This would help break the monotonically increasing shorting activity, which is key to achieving a monotonically decreasing spot price.

5 Conclusion

The life-cycle perspective of collateral use in spot, repo and securities lending markets reveals that the GoC markets can be described by the presence of clientele effects and search frictions. Our analysis yields three major findings. First, consistent with the clientele effect (preferred-habitat hypothesis), there are significant differences in the use of collateral with different maturities across the three funding markets. The shorter-term securities are actively traded in the repo market, while longer-term securities are traded more in the securities lending market. This divergence can be explained by the preferred habitat of the investor types, i.e., active short-term and passive long-term investors, and their participation choice in different funding markets. Second, bonds are more likely to be used as collateral in the GC repo market during the pre-benchmark and early benchmark periods, when search frictions are low. Third, as the bonds age towards the end of benchmark period and the post-benchmark period, the end users get hold of these bonds, reducing their effective supply and liquidity. This later phase of the life cycle is defined by high search frictions. During this period, investors search for shorter-term securities in the special repo market and for longer-term ones in the securities lending market.

The above findings prompt larger questions, for example, regarding sovereign debt issuance practices. The provision of an adequate level of safe assets that are used by financial intermediaries as collateral to quickly and cheaply meet their financing needs may have knock-on effects on financial stability.[30] The bond life-cycle analysis point out the importance of considering clientele effects while determining the issuance term structure. Moreover, sovereign issuers may wish to take into account that secondary-market outcomes and primary issuance are also related (as shown by Sundaresan 1994).

Finally, by providing a comprehensive picture of the dynamics of bond activity, prices and liquidity, our empirical evidence suggests the need for a more in-depth study of the relationship between investor preferences, market structure and secondary-market outcomes in sovereign bond markets.

[30]As Gorton and Metrick (2012) point out, the financial crisis of 2008–09 was characterized by a sudden shift from private to public safe assets to collateralized interbank loans.

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Appendix

A Canadian Depository for Securities Data

Each transaction in the Canadian Depository for Securities (CDS) contains the following fields: trade date (when the transaction is agreed to), business date (when the trade is entered into the CDSX system), settlement date, International Securities Identification Number (ISIN), price, trading volume, and an indicator of whether the trade formed part of a repo. For operational reasons, trades larger than $50 million are divided into tranches of $50 million prior to arriving at the CDS.[31] For example, a spot trade that involves an exchange of securities of par value $120 million for cash equivalent to the market value of these securities is split into three tranches: two of $50 million par value each, and one of $20 million. The cash exchanged for the security in each tranche is allocated proportionally to the par value of each tranche; in effect, the price of the security is equal across the tranches into which the trade is split.[32] Our algorithm has two phases: aggregating tranches so as to reconstruct the original trades, and finding the second leg that matches each possible first leg of a repo trade. Cash trades are processed through only the aggregation phase of the algorithm, while identifying repos requires both phases.

A.1 Aggregating split transactions

Tranches that share the ISIN, business date, trade date, settlement date and price are aggregated, taking into account that any aggregated trade can involve at most one tranche with less than $50 million par value of the security. (These restrictions are based on the idea that tranches that form a part of a transaction must share the terms of trade.) Further, to capture the intuition that automated tranching by CDSX implies that tranches of a transaction

[31] CDS requires the accounts of both counterparties to contain the requisite securities and cash to process a trade. The automated tranching system prevents the shortage of a small quantity of either cash or securities from impeding settlement of an entire large trade.

[32] For operational reasons, the price on the tranche with par value less than $50 million, if it exists, could differ from the price of the other tranches by 10^{-5} cents. The algorithm described below incorporates a tolerance for price differences up to this magnitude.

cannot be "too far apart" in time, we aggregate tranches that are less than 15 seconds apart, from the first tranche to the last.[33]

A.2 Matching opening and closing legs of a repo

Each repo involves two trades: an opening (first) and the closing (second) leg. In the first, party A receives cash for bonds (collateral) from counterparty B. In the closing leg, B returns the same quantity of bonds that it received in the opening leg, while A returns the cash, plus an interest determined by the repo rate. First, all aggregated repo-flagged CDSX trades with the trade date equal to the settlement date are categorized as potential first legs of repos. If it exists, a second leg with the same trade date, ISIN and quantity entered into CDSX in sufficiently close temporal proximity is matched with the first leg to obtain the repo trade.[34] The number of business days between the two legs is the repo term. For example, the second leg of an overnight repo written on a Friday settles on the following Monday (provided the latter does not fall on a trading holiday). The annualized repo rate is given by $(P_2/P_1 - 1) \times 365/D$, where P_2 and P_1 are the prices of the second and first legs, respectively, and D is the number of calendar days (including trading holidays) between the first and second legs.

Panel A of Figure 2 shows that about 60 per cent (by volume) of possible first legs are matched with a second leg in most of our sample. Since our algorithm is only designed to identify fixed-term repos, all first legs that belong to forward, open term, evergreen or floating-rate repos would not be paired with their second legs. While the fraction of such repo contracts traded in Canada is unknown, discussions with market participants indicate that they are unlikely to comprise 40 per cent of the total volume. It is also possible that the aggregation of tranches may result in incorrect identification of first legs. If two repo trades

[33] Using smaller aggregation windows — up to one second — does not alter the results in any significant way.

[34] We impose that the first and second legs may not be more than 15 seconds apart; this choice is not crucial to the data. If multiple second leg trades on the same trade date, in the same ISIN with the same quantity are found, the transaction closest in time to the first leg is matched.

in the same security were entered in a short interval, it would be likely that their first leg prices were exactly the same. This is because (assuming that the two trades have the same haircut), the first leg price is likely to be based on the same prevailing spot price, which may not have changed in the short time interval in which the two repos were negotiated. However, given the OTC nature of the market, it is likely that the repo rate of these two trades may be different (they could also have different terms). In such a situation, the aggregation algorithm would incorrectly combine the first legs of the two repos into one trade, while correctly identifying the two second legs separately. This would result in the first leg (which is actually a combination of two first legs) not finding a matching second leg. Another, perhaps less prevalent, scenario would be one in which operational delays (whether due to system or human error) could result in some tranches of one leg (but not the other) entering CDSX outside the permitted limits of the aggregation algorithm. This discussion raises the question of why the aggregation phase is necessary in the first place. We treat this issue next.

Combining the tranches to recover the original trade is crucial to estimate the number of trades, and the average trade size, for both spot and repo transactions. To identify repos, it would in theory be possible to run the matching phase without aggregating tranches first. However, this increases the possibility that first and second legs of different repos are matched, leading to erroneous estimates of repo rate and term.[35]

B Complementing CDS with Transaction Data from the Central Counterparty

Beginning in 2012, the data provided by CDSX are affected by netting across spot, repo and futures trades by CDCC. This is because CDSX replaces the original trades with netting trades returned by CDCC for settlement. Netting both reduces the volume of trades and

[35] Note that the average GC trade size is over \$100 million, which implies that a substantial portion of the non-aggregated trades have are of \$50 million. Especially for bonds with relatively large trading volume, this increases the possibility of incorrectly paired first and second legs.

jeopardizes the ability of the matching algorithm to identify repos. CDCC provided pre-netting data similar to CDSX — with an additional alphanumeric code for both repo and cash trades that makes both aggregation and matching trivial.[36] Every repo transaction has a unique repo code (which all tranches of both legs of the repo share). We aggregate trades sharing a repo code with the same business and settlement date to obtain the first leg. Similarly, aggregating trades with the same repo code, but with the settlement date after the business date, gives us the corresponding second leg. (We attain nearly 100 per cent matching of first and second legs in the CDCC data.) CDCC began clearing spot trades in Canadian fixed-income securities in 2014. We use the aggregation algorithm using the alphanumeric spot codes to recover underlying trades from the tranche-level data provided by CDCC. The haircut applied to the market value of the collateral is estimated for CDCC transactions using a procedure identical to that described for CDSX repos.

Trades that pass through CDCC unaffected by netting would be returned "as is" to CDSX. Such non-netted trades would therefore appear both in the CDSX and CDCC data. Since CDSX data do not indicate which trades were returned by CDCC for settlement, adding the transactions from these two data sets could potentially lead to overestimating the volumes and number of transactions. Given that participants use central counterparties in part to benefit from netting, we expect the number of such potential duplicates to be small. Nevertheless, we take the precaution of removing trades in CDSX that share the same characteristics (business date, ISIN, quantity, repo rate, term, first leg price) with a trade in CDCC to mitigate double-counting.

[36]CDCC also refrains from providing any information on the counterparties involved in a trade to protect client confidentiality.

	2009	2010	2011	2012	2013	2014	2015
Panel A: GC repos							
Volume (bn)	350.60	321.30	320.70	373.00	350.40	278.50	192.90
Num trans	1758.00	2251.75	2747.08	3441.67	3655.92	3142.42	2255.29
Spread vs CORRA (bps)	-0.70	-0.33	0.20	0.69	0.89	0.77	-0.18
Haircut (%)	0.01	0.06	0.14	0.14	0.18	0.31	0.30
Panel B: Term repos							
Volume (bn)	64.39	71.08	71.14	93.18	100.40	152.00	168.80
Num trans	891.75	999.58	1085.08	1287.42	1238.83	1917.00	2563.57
Spread vs CORRA (bps)	1.10	2.23	2.39	3.50	6.31	10.50	12.80
Haircut (%)	0.13	0.10	0.07	0.05	0.15	0.10	0.07
Term (days)	7.84	7.90	6.81	5.45	5.00	3.87	3.42
Panel C: Spot trades							
Volume (bn)	232.60	239.30	269.30	291.00	490.40	486.30	459.60
Num trans ('000)	27.59	29.55	33.79	34.88	50.82	52.60	53.81
Panel D: Securities lending							
Total on loan (bn)	791.50	1096.00	1046.00	1070.00	1190.00	1324.00	1410.00
On loan vs cash (bn)	174.60	157.10	119.80	122.80	123.00	92.09	102.50
Fees (bps)	3.53	4.12	4.20	4.37	5.27	6.22	7.22
Tenure (days)	147.80	165.41	178.85	174.67	147.91	132.39	143.55
Panel E: Special repos							
Volume (bn)	68.09	51.04	16.53	66.62	157.90	128.40	127.70
Num trans	822.50	773.33	346.25	1142.67	2434.83	2259.25	2387.57
Spread vs CORRA (bps)	3.65	9.54	10.12	13.00	21.39	18.95	16.30
Haircut (%)	0.35	0.18	0.06	0.19	0.16	0.20	0.35

Table 1: This table presents the average monthly volume, the number of transactions and the weighted-average of spread over CORRA, haircut and term for repos in each year of our sample, along with daily average volume and number of spot trades, and the daily average of the stock of outstanding bonds on loan and the securities lending fees. All volumes and stock are in CAD billion; spread, fees and rebates in basis points; haircut in percentage; and term in number of days.

	2-year	3-year	5-year	10-year	30-year
Pre-benchmark	54	107	108	257	1378
	(23, 98)	(46, 148)	(73, 129)	(234, 290)	(984, 1772)
Benchmark	92	171	178	346	5020
	(48, 157)	(69, 264)	(126, 223)	(329, 369)	(4815, 5225)
Post-benchmark	681	313	1686	3356	6199
	(624, 715)	(21, 989)	(1645, 1791)	(3361, 3415)	(6016, 6381)

Table 2: This table presents the average number of days spent by bonds of different terms in each life-cycle phase. The numbers in parentheses indicate the minimum and maximum number of days, respectively.

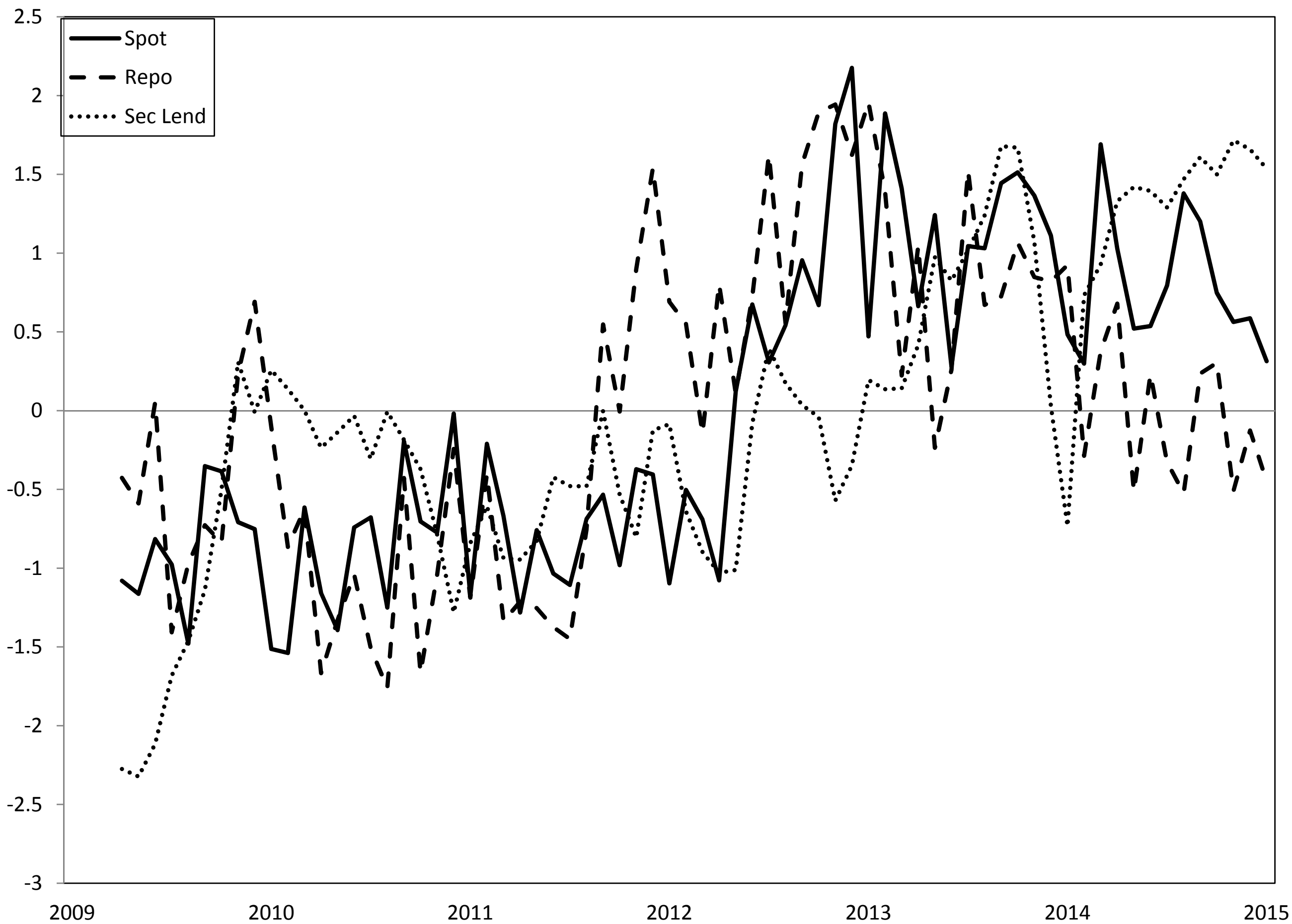

Figure 1: **Trading volume in spot, repo, and securities lending markets.** This figure shows the standardized trading volume in repo and spot markets, and the stock on loan in the securities lending market across all Government of Canada bonds.

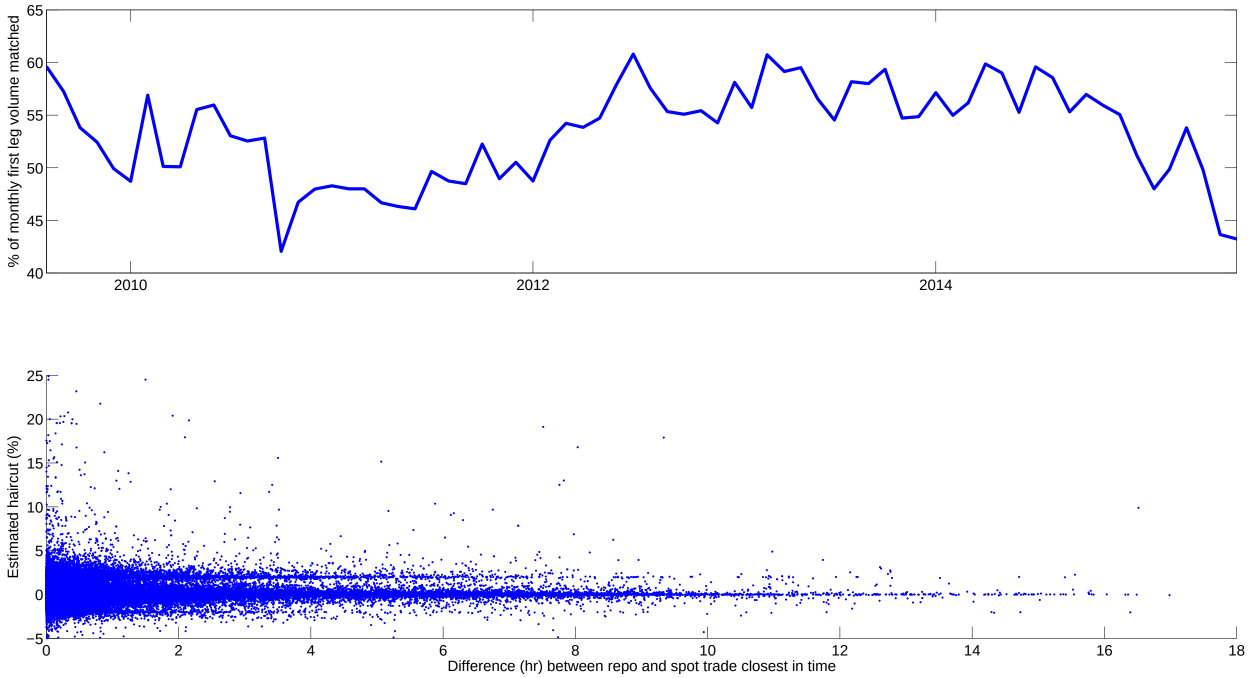

Figure 2: The graph on top shows the percentage (by volume) of possible first legs of GoC repos for which matching second legs are found. The lower graph plots the estimated haircut against the (absolute) difference in time (in hours) between the cash and repo trades used to estimate the haircut for all GoC repo trades in the sample. Note that haircuts estimated to be below -5 per cent and above 25 per cent are eliminated from the sample before plotting this graph. The data span the period August 28, 2015, to July 31, 2015.

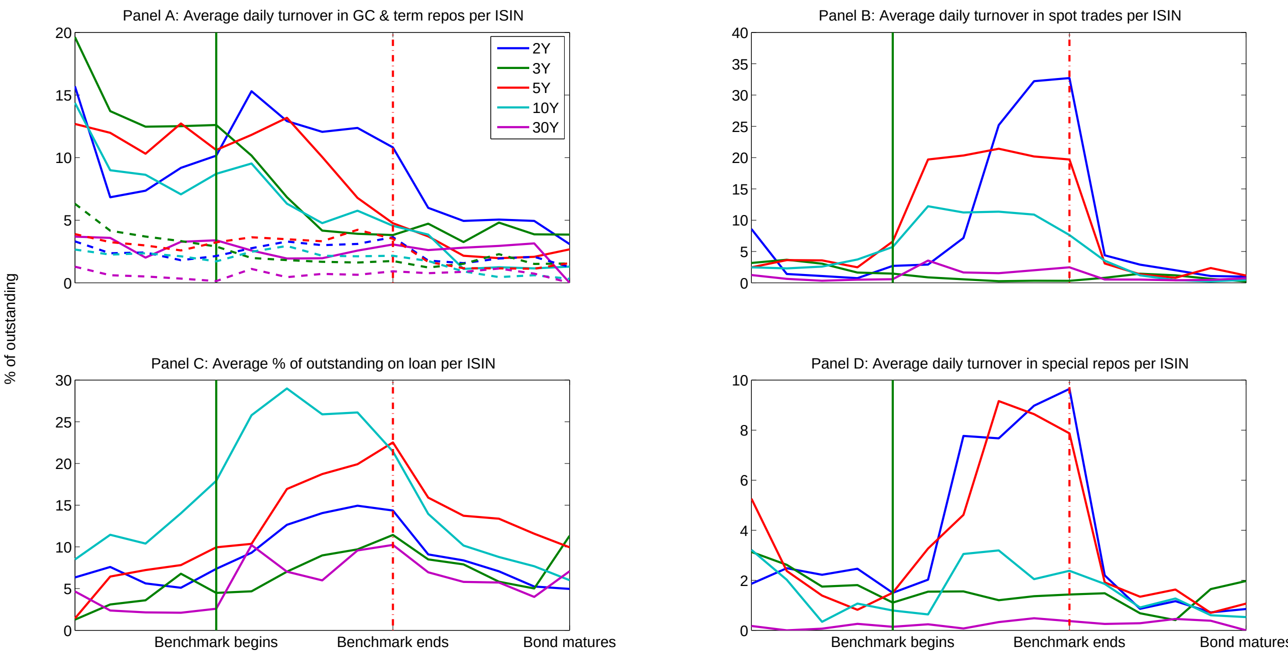

Figure 3: This figure plots the life cycle of average turnover of GoC bonds by sector. Panel A shows the search for cash activity, where the solid lines indicate GC repo and the dashed lines are for term repo. Panels B through D present the average turnover in the spot market, average daily stock on loan, and average turnover in the overnight special repos, respectively. Each phase of each bond is divided into five equal parts; average daily values are calculated for each bond in each part of each phase and, finally, averaged over all bonds in that sector. The sample is from August 28, 2009, to July 31, 2015.

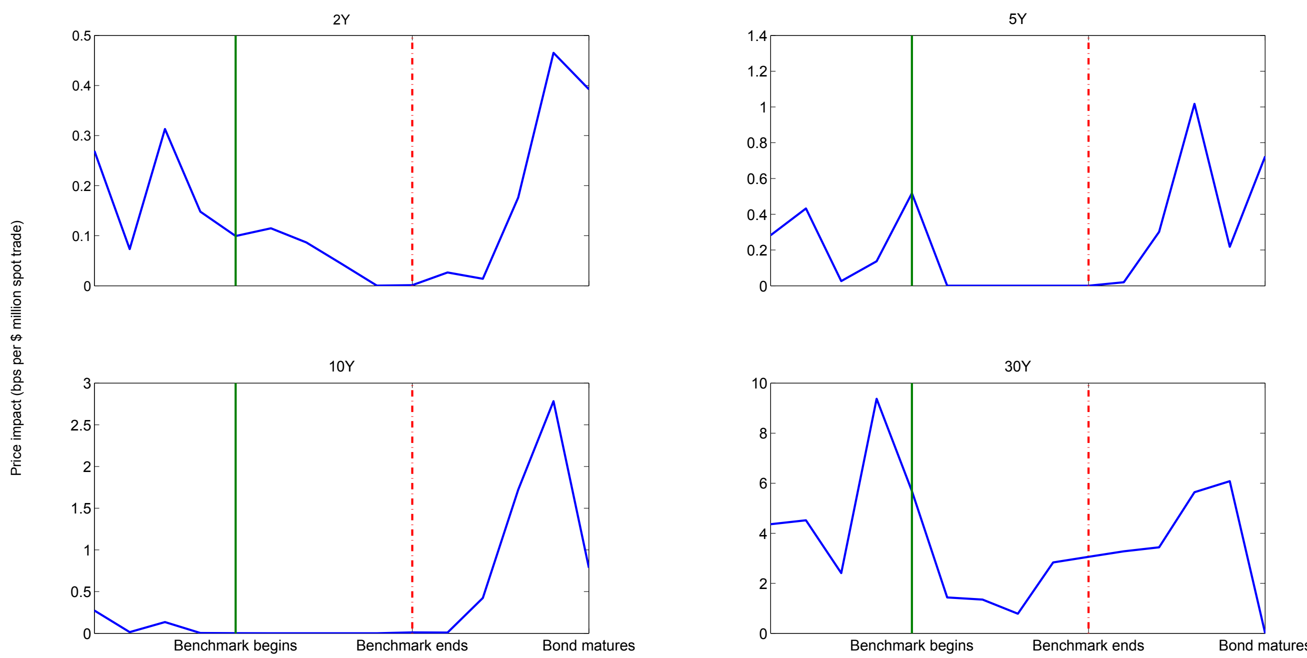

Figure 4: Each sub-plot of this figure shows the average daily Amihud price impact measure in the various phases of its life cycle, for the sector indicated in the title. Each phase of each bond is divided into five equal parts; average daily values are calculated for each bond in each part of each phase and, finally, averaged over all bonds in that sector. The sample is from August 28, 2009, to July 31, 2015.

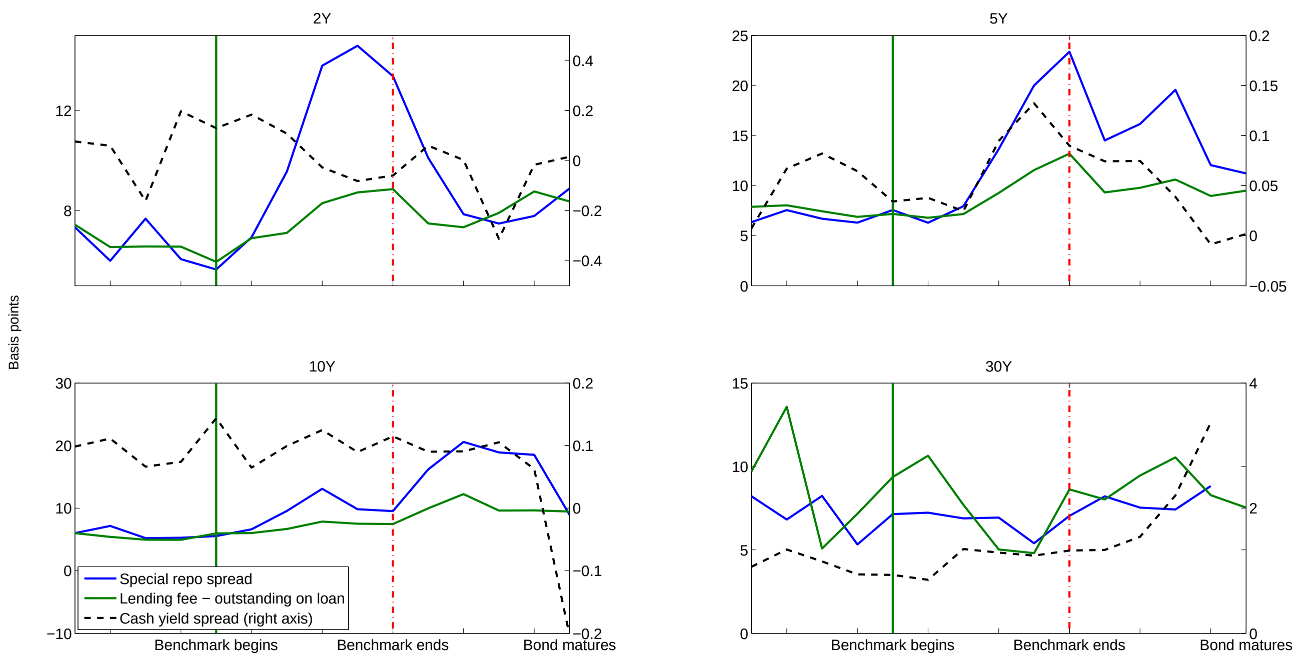

Figure 5: This figure shows the weighted average fees of all outstanding loans in the securities lending market along with measures of prices in the spot and repo markets over the life cycle of bonds in the 2Y, 5Y, 10Y and 30Y sectors. The dashed line (right axis) plots the difference in the weighted average yield of all spot market trades and the yield of corresponding maturity from the zero-coupon yield curve. The graph also includes the weighted average spread, against the CORRA, of special repos. Each phase of each bond is divided into five equal parts; average daily values are calculated for each bond in each part of each phase and, finally, averaged over all bonds in that sector. The sample is from August 28, 2009, to July 31, 2015.