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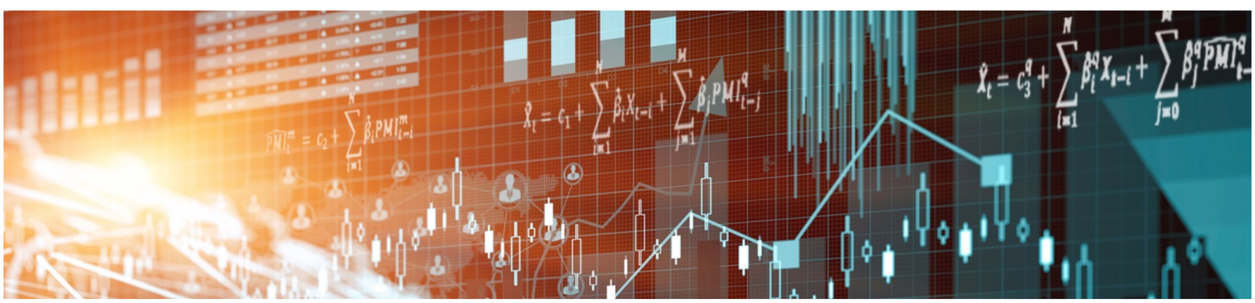
What Explains Month-End Funding Pressure in Canada?



by Christopher S. Sutherland

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Abstract

The Canadian overnight repo market persistently shows signs of latent funding pressure around month-end periods. Both the overnight repo rate and Bank of Canada liquidity provision tend to rise in these windows. This paper proposes three non-mutually exclusive hypotheses to explain this phenomenon. First, month-end funding pressure may be caused by search frictions. Market participants place a premium on liquidity around month-end periods because of the confluence of a generalized liquidity preference, heightened month-end forecast uncertainty, and resultant search frictions in the repo market. Second, this funding pressure could be attributed to spillovers from the US overnight repo market. Third, month-end funding pressure might be associated with large Canadian banks' end-of-month repo adjustments. By combining market, central-bank and payments data, this paper provides evidence that the first hypothesis explains the latent funding pressure observed on the first day of the month. Using market and non-public regulatory data, this paper further argues that the second and third hypotheses are much less plausible.

Bank topics: Interest rates; Financial markets; Monetary policy implementation; Monetary policy framework; Transmission of monetary policy

JEL codes: E41, E43, E52, E58, F36, G15, G14, G21

Résumé

Le marché canadien des pensions à un jour montre continuellement des signes que des pressions latentes en matière de liquidités de financement s'y exercent vers la fin du mois. Une hausse du taux des opérations de pension à un jour et une augmentation des liquidités octroyées par la Banque du Canada sont généralement observées durant cette période. Pour expliquer ce phénomène, nous proposons trois hypothèses non mutuellement exclusives. Premièrement, les pressions de fin de mois résulteraient de frictions de recherche. Les participants au marché des pensions attachent une importance particulière à la liquidité à la fin du mois et dans les jours suivants, ce qui s'expliquerait par l'effet conjugué de la préférence généralisée pour la liquidité, d'une incertitude accrue liée aux prévisions de trésorerie à ce moment-là et des frictions de recherche sur ce marché qui en découlent. Deuxièmement, ces pressions sur la liquidité de financement pourraient être imputables aux effets de contagion issus du marché américain des pensions à un jour. Troisièmement, elles pourraient être associées aux importants ajustements des soldes des opérations de pension des banques canadiennes à la fin de chaque mois. Les résultats de la présente étude, qui reposent à la fois sur des données de marché, de données recueillies par les banques centrales et des données sur les paiements, tendent à confirmer la première hypothèse comme explication des pressions latentes observées le premier du mois. À l’aide de données de marché et de données réglementaires non publiques, nous démontrons en outre que la deuxième et la troisième hypothèses sont beaucoup moins plausibles.

Sujets : Taux d’intérêt; Marchés financiers; Mise en œuvre de la politique monétaire; Cadre de la politique monétaire; Transmission de la politique monétaire

Codes JEL : E41, E43, E52, E58, F36, G15, G14, G21

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1 Introduction

The repo market is a core funding market in Canada and an important channel for the implementation of monetary policy, so its smooth operation is an essential consideration for both financial stability and the transmission of monetary policy. Despite its importance and liquidity, the Canadian repo market often shows signs of latent funding pressure around month-end periods. Although funding pressure is a healthy market mechanism, it is nonetheless important to identify its underlying causes to better understand this market.[1]

Month-end funding pressure is defined here as a persistent increase in the spread of a repo rate over the Bank of Canada target rate in the period just before, during and after month-end. Specifically, this paper documents recurring month-end funding pressure in the Canadian overnight general-collateral (GC) repo market.[2] The magnitude of this funding pressure is relatively small, at about one basis point on average, but it persistently coincides with increases in liquidity provision by the Bank of Canada. This strongly suggests that the true magnitude of the underlying funding pressure is greater than that suggested by market prices. To explain this phenomenon, we consider three non-mutually exclusive hypotheses.

First, month-end funding pressure may be caused by search frictions related to patterns in monthly payments. High volumes of payments and large payments are more frequent around month-end periods. As payments begin to recirculate, the destinations of cash flows become increasingly uncertain. High

[1] Funding pressure (an increase in the price of funding) provides the incentives needed to match the supply and demand of settlement balances (akin to bank reserves) in the large-value payment system.
[2] GC refers to a list of acceptable securities to be used for collateral, which include, *inter alia*, Government of Canada securities and mortgage-backed securities.

volumes and large payments exacerbate this uncertainty. This makes it not only more difficult for market participants to forecast their own cash inflows and outflows, but also more difficult to locate liquidity. Both consequences increase the potential for cash shortfalls. In general, repo-market participants prefer to maintain a liquidity buffer whenever possible, so the uncertainty surrounding both payment flows and liquidity supply may cause them to demand more liquidity and/or become more reluctant to supply liquidity. Either response will, *ceteris paribus*, tend to increase the repo rate.[3]

Canadian repo-market participants tend to trade with a relatively small number of counterparties, so base-level search frictions are fairly low. The increase in the generalized liquidity preference around month-end periods, however, makes it more difficult to find counterparties with whom to trade. This may compel repo-market participants to look elsewhere for liquidity, thereby increasing search frictions. Greater search frictions, and indeed the *expectation thereof*, cause repo-market participants to place a higher liquidity premium on short-term funding, which may lead to the month-end funding pressure documented in this paper.[4]

Second, Canadian month-end funding pressure could be imported from the US repo market. Theoretically, a US overnight GC repo paired with a currency swap can be a substitute for Canadian overnight GC repos. Further, Ehrmann, Fratzscher and Rigobon (2011) provide evidence of spillovers

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[3] In his seminal study of US commercial bank reserve management, Poole (1968, 776) observes that, “While the volume of Federal funds trading appears to be a relatively useless piece of information, the level of the Federal funds rate may provide useful information for policy-makers in an uncertain world. A relatively high Federal funds rate suggests that banks in general are short of reserves, or are expecting to be short by the close of business.”

[4] Hamilton (1998, 42) offers another useful parallel from the United States when he notes that, “The marginal benefit of excess reserves is much higher on settlement days or the end of a quarter. If the Fed drains reserves on these days, banks will replace some of the lost reserves with discount window borrowing and the movement in the federal funds rate needed to restore equilibrium will be substantially bigger.”

from the US money market to the euro-area money market. Hence, it seems reasonable to postulate spillovers from the US repo market to the Canadian repo market.

Third, Canadian banks adjust their repo balances around month-ends, which might lead to month-end funding pressure. This paper provides evidence that large Canadian banks systematically adjust their repo and reverse-repo balances at the end of the month. These adjustments could be endogenous (undertaken by the bank), exogenous (resulting from client actions), or both (Allen and Saunders 1992; Kotomin and Winters 2006). Endogenous adjustments could be undertaken for, *inter alia*, regulatory reasons (e.g., to improve the leverage ratio) or accounting reasons (e.g., to net repo and reverse-repo balances). Exogenous adjustments could result from clients' payment patterns around month-ends, for example. Munyan (2015) provides evidence of endogenous (regulatory-driven) adjustments, while Owens and Wu (2015) provide evidence for both.

Canadian banks' repo adjustments could lead to funding pressure for a number of reasons. First, reductions in reverse-repo balances may indicate negative supply shocks. Second, simultaneous reductions in repo and reverse repo may indicate increased efforts by repo-market participants to net repo and reverse-repo contracts off their balance sheets. This netting could also introduce search frictions should repo-market participants develop a strong preference for very specific repo contracts (i.e., maturity, counterparty, settlement system) over others—a preference also akin to a negative supply shock to some parts of the market.

To test the three hypotheses, we consolidate numerous data sources. Month-end funding pressure is measured by analyzing Canadian repo rates' deviations from the Bank of Canada target. Bank of Canada intervention is measured by the amounts of liquidity-providing repos and adjustments in settlement balances. Government of Canada bond payments are used as a proxy for large payments. Daily volumes in the Large Value Transfer System (LVTS) are used as a proxy for high payment volumes. US GC overnight repo rates are used to detect spillovers. Finally, regulatory data from Canadian banks are used to detect the effect of repo-balance adjustments on repo rates.

In conjunction, the evidence provided in this paper suggests that funding pressure in the Canadian overnight GC repo market is more attributable to patterns in month-end payments and the resulting search frictions than to either Canadian bank behaviour or US repo-market spillovers. These results are subjected to a battery of robustness checks, but they may nonetheless be subject to either some attenuation bias or simultaneous-equations bias. That some month-end funding pressure is as yet unaccounted for, particularly on the last day of the month, could ultimately be attributable to such bias.

Numerous studies have documented calendar effects in US money markets (e.g., Spindt and Hoffmeister 1988; Hamilton 1996; Musto 1997; Griffiths and Winters 1995, 1997, 2005; Carpenter and Demiralp 2006; Kotomin and Winters 2006) and international money markets (e.g., Kotomin, Smith and Winters 2008; Griffiths, Kotomin and Winters 2009). The evidence presented in this paper contributes to this literature and to the debate on the reasons for calendar effects in money markets.

Musto (1997) attributes price shifts in commercial paper around year-end to risk-related window dressing. By contrast, numerous studies attribute calendar-based price effects to a preferred habitat for liquidity (Ogden 1987; Griffiths and Winters 1997, 2005; Kotomin and Winters 2006; Kotomin, Smith and Winters 2008; Griffiths, Kotomin and Winters 2009), which is more consistent with the argument in this paper that banks' preference to create a liquidity buffer ultimately leads to funding pressure. The argument that banks prefer to build a liquidity buffer amidst cash-flow uncertainty is also consistent with Poole (1968), who suggests that when banks face payment-flow uncertainty, they may develop a preference for scarce central-bank reserves that is not strictly profit-maximizing.

To the best of our knowledge, this paper is the first to jointly test for the most commonly cited sources of seasonal effects in money markets—payment patterns, spillovers and bank window dressing (Klee, Senyuz and Yoldas 2016 and Munyan 2015 conduct related studies). It also combines market and central-bank data to make inferences about the underlying level of month-end funding pressure (Hamilton 1997, 1998, Carpenter and Demiralp 2006, Judson and Klee 2010, and Klee, Senyuz and Yoldas 2016 each provide related analysis for the United States). This contribution is enabled by a unique amalgam of data sourced from the national central bank (the Bank of Canada), the payment system (Payments Canada), and the bank regulator (the Office of the Superintendent of Financial Institutions).

The rest of the paper is structured as follows: Section 2 documents month-end effects in both the repo market and central-bank intervention. It then proposes three hypotheses to explain the observed underlying funding pressure. Section 3 outlines the data and methodology used for estimation. Section 4 presents the empirical results. Section 5 concludes.

2 Hypotheses

Overnight collateralized rates, namely, the Canadian Overnight Repo Rate Average (CORRA) and the Overnight Money Market Financing Rate (OMMFR), tend to rise around month-end periods (Figure 1, left-hand side). All else being equal, these higher overnight rates are likely an indicator of funding pressure. To alleviate funding pressure, the Bank of Canada occasionally injects intraday liquidity either by conducting repo operations—formerly known as special purchase and resale agreements (SPRAs) and now known as overnight repos (ORs)—or by increasing the level of settlement balances in the payments system (Figure 1, right-hand side).[5] Hence, the level of these Bank of Canada market interventions can also be an indicator of funding pressure. Figure 1 charts all four indicators to illustrate how they tend to rise around month-end periods. To gauge how funding pressure patterns differ around various month-end periods, the data are partitioned into three types of months as shown below.

Notation	**Interpretation**	**Months included in partition**
FQE	Fiscal quarter-end	January, April, July and October
FQE_{-1}	The month-end periods that precede FQE	March, June, September and December
FQE_{+1}	The month-end periods that follow FQE	February, May, August and November

Fiscal quarter-end (FQE) represents financial and regulatory reporting months for large Canadian banks. Theoretically, financial and regulatory reporting could create the incentives for bank behaviour that causes funding pressure (Hypothesis III below). The month-end periods that follow fiscal quarter-end (FQE_{+1}) are generally not financial and regulatory reporting months, but particularly large bond payments are frequently processed in FQE_{+1} month-end windows, which could also lead to funding pressure (Hypothesis I below). The month-end periods that precede fiscal quarter-end (FQE_{-1}) are generally financial reporting months for large US banks as well as other Canadian corporations. Perhaps, similar to Hypothesis III, calendar quarter-end behaviour by these US institutions could lead to funding pressure in Canada. Indeed, if this were true for US banks, then it would support Hypothesis II. Hence, partitioning the data should provide us with insights into each hypothesis.

[5] "In subsequent years, the targeted level of settlement balances was often adjusted in anticipation of seasonal or temporary upward pressure on the overnight rate, such as around quarter-ends and the fiscal year-end of commercial banks" (Bank of Canada website).

Judging by the CORRA, similar patterns and magnitudes in funding pressure routinely emerge around all month-end periods; conversely, the OMMFR, which encompasses the majority of transactions in the Canadian overnight repo market, is rather stable and does not follow the same pattern as the CORRA (Figure 1, left-hand side). This implies that month-end effects manifest in the inter-dealer broker market, but much less so in the bilateral, over-the-counter market.[6]

[Insert Figure 1 here]

The right-hand side of Figure 1 shows that the Bank of Canada tends to make more liquidity-providing interventions in the overnight market around month-end periods. On average, the Bank of Canada conducts more SPRAs/ORs and increases the level of the LVTS settlement balances around month-end in an effort to mitigate funding pressure. These operations are intended to guide the overnight GC repo rate back towards the Bank of Canada target rate whenever it rises too far above target.[7]

[Insert Table 1 here]

Table 1 helps to quantify the magnitude of month-end funding pressure more precisely. On the last trading day of the month, spreads, SPRAs/ORs and settlement balances were 1.15 basis points, $160 million and $170 million higher on average, respectively. Similarly, on the first trading day of the month, spreads, SPRAs/ORs and settlement balances were 1.20 basis points, $170 million and

[6] See Appendix 3 for the relevant background on the Canadian repo market.
[7] The intuition behind these operations is illustrated by Bagehot (1873, 119) when he points out, “But though the value of money is not settled in an exceptional way, there is nevertheless a peculiarity about it as there is about many articles. It is a commodity subject to great fluctuations of value, and those fluctuations are easily produced by a slight excess or slight deficiency of quantity.”

$130 million higher on average, respectively.[8] The rise in repo rates would almost certainly have been higher absent these central-bank interventions. Hence, using spreads as an indicator of funding pressure is slightly problematic because it may understate the true extent of this funding pressure. Nonetheless, the CORRA is a good proxy for funding conditions in the Canadian GC repo market. Accordingly, we focus primarily on the CORRA in this paper, but later augment our analysis using SPRAs/ORs and settlement balances.

2.1 Hypothesis I: Month-end funding pressure is caused by search frictions

Canadian repo-market participants process their transaction payments in Canada's LVTS. The LVTS is a closed system, so in principle the net aggregate cash position for the entire LVTS should be zero. Should an LVTS participant, such as a Canadian bank, accumulate a deficit position in the LVTS, it has an incentive to locate a counterparty with a surplus position.[9] If it cannot do so, it must take an advance at a relatively punitive rate from the Bank of Canada, which is also a participant in the LVTS.[10]

This search process can lead to market frictions (Stigler 1961). These search frictions arise, for example, when a repo-market participant with a settlement balance deficit cannot locate a counterparty with a settlement balance surplus. To mitigate these search frictions, the Bank of Canada provides surplus settlement balances to LVTS participants and hence maintains a deficit position.

[8] "A relatively high rate also suggests that the banks are likely to be coming to the discount window for relatively large amounts of funds near the close of business" (Poole 1968).
[9] See de Guzman (2016, 18) for a more detailed discussion.
[10] Appendix 3 provides an explanation of the role of the LVTS.

Ordinarily, repo-market participants are able to exchange settlement balances by contacting a relatively small number of their usual counterparties, search frictions are small, and the market functions smoothly. This efficient exchange of settlement balances is predicated on these counterparties' ability to reliably forecast their supply and demand of settlement balances throughout the day. However, forecasting becomes more difficult around month-end periods, for many reasons.

First, market participants (or, rather, their institutions) need to process higher volumes of transactions around month-end periods. LVTS volumes tend to be higher around month-end periods (Figure 2).

[Insert Figure 2 here]

Payment volumes may be higher around month-end due to, *inter alia*, invoice payments, payroll transactions, mortgage payments or payments compressed into shorter windows around holiday periods, for example. Similar explanations have been provided in the literature. In particular, Ogden (1987) and Kotomin, Smith and Winters (2008) discuss the role of interest, dividend and wage payments.

Second, large bond (principal and coupon) payments are frequently processed around month-end periods, and in the case of coupon payments, particularly on the first day of the month (Figure 2).[11] Although the timing and total size of these cash disbursements to the entire market is predictable, it is much more difficult to forecast the sizes of the payments to various *individual* market participants. It is more difficult still to forecast what these participants will then do with the funds they receive. This uncertainty makes it challenging for a given market participant to forecast cash inflows and outflows, which increases the chance of large forecast errors at the end of the day. Hence, around month-end periods, repo-market

[11] For example, Government of Canada bonds, provincial bonds, *National Housing Act* mortgage-backed securities and Canada Mortgage Bonds.

participants may find themselves with a larger deficit or surplus of settlement balances in the LVTS than anticipated.

In general, Canadian repo-market participants prefer to maintain a liquidity surplus in uncertain times and are fairly averse to liquidity deficits.[12] Economically, this preference can be attributed to risk aversion. After all, the operating band, or interest-rate corridor, is symmetric.[13] When banks forecast cash flows ex ante, they should be equally averse to borrowing unnecessarily through the Standing Lending Facility ex post as to lending at low rates through the Standing Deposit Facility ex post. “Yet,” as Poole (1968, 769) emphasizes, “it is clear that the existence of excess reserves and borrowing from the central bank at a rate of interest above market rates cannot be understood in a certainty model.”

Additionally, this preference may be particularly acute at month-end due to stigma.[14] First, repo-market participants may not wish to declare in month-end reports to the Office of the Superintendent of Financial Institutions (OSFI), which are made public, that they sought an advance from the Bank of Canada from the Standing Lending Facility. Similarly, banks may not wish to rely excessively on other repo-market participants for funds, which may be comparatively scarce and expensive at month-end. Hence, market participants may prefer to build a liquidity buffer at month-end.

The combination of increased liquidity preference, small CORRA spreads due to Bank of Canada intervention (or the potential thereof), and increased search frictions may also help explain why persistent

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[12] It is possible to maintain this surplus because there is an excess amount of LVTS settlement balances.
[13] See Engert, Gravelle and Howard (2008) or de Guzman (2016) for more details.
[14] Armantier et al. (2015) provide evidence of stigma associated with the Federal Reserve's discount window during the financial crisis. Of course, stigma will also be much greater during periods of crisis. Winters (2012) argues that the Bank of England Discount Window Facility also suffers stigma issues. As Winters points out, the level of stigma varies by type of central-bank liquidity facility.

month-end funding pressure is not arbitraged away. The economic incentives may simply not be large enough to compensate for the transaction and opportunity costs necessary to undertake such activity.

To summarize, under Hypothesis I, repo-market participants place a premium on liquidity around month-end due to the confluence of a general liquidity preference, heightened month-end forecast uncertainty, and month-end search frictions in the repo market.

2.2 Hypothesis II: Month-end funding pressure is imported from the United States

Perhaps the Canadian repo market is sufficiently integrated with the US funding market that funding pressure in the United States could be imported to Canada. Theoretically, US repo-based funding and lending can be a substitute for Canadian repo-based funding and lending. For example, a Canadian borrower could provide collateral, such as a US Treasury bond, in exchange for US dollars (i.e., a repo) and then swap those US dollars back into Canadian dollars.[15] Economically, a Canadian repo and a US repo in conjunction with a matched swap are essentially equivalent. The US repo market is considerably larger than the Canadian market, however (Baklanova, Copeland and McCaughrin 2015; Garriott and Gray 2016), so if the two are substitutes, spillovers from the United States could follow.

Month-end and quarter-end funding pressure in the US money markets has been well documented in the literature (Musto 1997; Griffiths and Winters 1997, 2005; Kotomin and Winters 2006). Further, the effect of quarter-end window dressing on repo markets has also been documented in the United States (Munyan 2015; Owens and Wu 2015). Klee, Senyuz and Yoldas (2016) find slight upward pressure on money-

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[15] See Truno, Stolyarov, Auger and Assaf (2017) for an overview of the funding strategies of large Canadian banks, including details on foreign funding.

market (including repo) rates at month-end periods and conjecture that this could be attributed to payment flows as well as deleveraging related to financial reporting.

Finally, spillovers between money markets have been documented both generally (Ehrmann, Fratzscher and Rigobon 2011) and within the context of repo-based window dressing (Munyan 2015). Hence, insofar as Hypothesis II and Hypothesis III hold in the United States (i.e., repo-balance adjustments drive month-end funding pressure, *and* funding pressure can spill over from the United States to Canada), US banks' balance-sheet adjustments could theoretically explain month-end funding pressure in Canada.

Conversely, Canadian and US repo-based funding may be imperfect substitutes for a number of reasons. First, the securities acceptable as GC are not the same in the United States and Canada. Canadian repo-market participants may have different levels of inventories of US GC and Canadian GC. The two types of collateral may also not be equally accessible. For example, a Canadian bank may have to locate a US Treasury from its US subsidiary. Further, using US GC or Canadian GC in a repo or reverse-repo transaction may not have equal opportunity costs.

Second, the repo counterparties for US and Canadian funds may differ. For instance, there may not be as many of one as of the other. The two sets of counterparties' willingness to trade may differ due to various internal constraints (availability of security and funds, regulatory constraints, risk limits, etc.). In practice, repo-market participants also need to find counterparties with whom legal arrangements already exist (Baklanova, Copeland and McCaughrin 2015; Garriott and Gray 2016). Similar counterparty restrictions would also apply as the Canadian repo-market participant seeks out a swap counterparty for the swap leg of the transaction.

Third, substituting US repo for Canadian repo may not be economical. This substitution would imply additional transaction costs, search costs, back-office processing time and perhaps additional regulatory costs. Hence, the US GC repo or reverse repo would have to be offered at a sufficiently favourable rate to compensate for these costs.

2.3 Hypothesis III: Month-end funding pressure is associated with Canadian banks' balance-sheet adjustments

Recent studies have found evidence that banks operating in the United States reduce their repo balances before quarter-end financial reporting periods (Munyan 2015; Owens and Wu 2015). Owens and Wu (2015) suggest that these deviations from intra-quarter levels of repo balances reflect both endogenous (bank-initiated) window dressing and exogenous (customer-driven) factors. Munyan (2015) provides evidence that banks' repo adjustments are related to their capital ratios and that these adjustments affect market liquidity each quarter. This paper provides evidence that Canadian banks' repo balances also tend to fall from intra-quarter levels at quarter-end financial reporting periods. This leads to Hypothesis III: Canadian banks' month-end adjustments to their repo balances may explain some of the observed month-end funding pressure in the Canadian repo market.

Adjustments to banks' repo balances could create both supply and demand shocks in the repo market. As banks reduce their reverse-repo balances (i.e., banks lend less cash), other borrowers in the repo market, such as pension funds and insurance companies, for example, will find fewer lenders around month-end periods. This would represent a negative supply shock to the repo market, which would tend to increase rates. Conversely, as banks reduce their repo balances (i.e., banks borrow less cash), lenders will find fewer borrowers around month-end periods. This would represent a negative demand shock to the repo market, which would tend to decrease rates.

[Insert Figure 3 here]

Figure 3 (left-hand side) shows that the largest banks in Canada tend to curtail repo balances in fiscal quarter-end months. On average, repo and reverse-repo balances were 5.8 per cent and 4.4 per cent lower, respectively, at fiscal quarter-end relative to the month before. Figure 3 (right-hand side) shows that the repo decreases in particular were much larger for end-of-month balances than for average monthly balances. This suggests that most of the repo reductions took place towards the end of the month. Conversely, in the months following an FQE month, end-of-month repo outstanding tended to be higher than the average over that month, which suggests that repo activity increased over the month. The adjustments in Figure 3 are persistent across the sample period, but their magnitudes are smaller than those found in related studies of US repo markets (Owens and Wu 2015; Munyan 2015).

Figure 3 also raises an important question: why would banks tend to reduce their repo and reverse-repo balances at fiscal quarter-end? One reason could be that banks seek to reduce their leverage ratios at fiscal quarter-end. Repurchase agreements (repo) play an important role in bank leverage because they increase the size of the balance sheet, thereby increasing the exposure measure (the denominator in the leverage ratio), and, *ceteris paribus*, reduce (i.e., deteriorate) the leverage ratio. Reverse repurchase agreements, however, generally do not.

The leverage ratio provides insight into how risky a bank might be. The appeal of the leverage ratio is its simplicity: it is essentially a measure of total capital over total assets. As such, the leverage ratio becomes a focal point during quarter-end reporting periods. In Canada, the regulatory leverage ratio is calculated as of the last day of fiscal quarter-end and is reported soon afterwards.[16] Repos constitute a significant share of banks' balance sheets, and these short-term contracts can be adjusted relatively easily (i.e., as

[16] For more, see Appendix 4: Background on Repos and the Leverage Ratio in Canada.

compared with longer-term sources of funding). This makes repos a good mechanism for balance-sheet adjustments (Adrian and Shin 2010). This reporting structure could provide banks an incentive to make end-of-quarter repo adjustments to present a more favourable picture of their balance sheets to the public.[17]

Despite the existence of the incentive to do so, it is not necessarily desirable or even feasible for a bank to make such adjustments. The marginal benefits of making balance-sheet adjustments would need to be weighed carefully against the marginal costs. Banks may benefit from a lower leverage ratio by creating the perception of a safer bank, for example, but the material adjustment of a bank's balance sheet may have costly implications. For example, downward adjustments could force banks to refuse business from clients or introduce friction into operations. Balance-sheet adjustments would be made only if they were relatively costless.

A variety of other reasons could also explain these repo-balance adjustments. They could be an artefact of public reporting, as banks may wish to consolidate their repo and reverse-repo balances before quarter-end. Reducing repo balances in this manner could conceivably give the impression of a safer bank that is not overly reliant on short-term wholesale funding.[18] One of the ways this can be accomplished is by netting repo and reverse-repo contracts that are substantially similar (i.e., same counterparty, maturity

[17] OSFI requires that Canadian banks meet their leverage ratio requirements on a continuous basis, so this does *not* imply that banks have an incentive to oscillate between regulatory compliance and noncompliance as quarter-end comes and goes. Indeed, Canadian banks generally maintain a significant buffer between their leverage ratios and their corresponding regulatory minimums.

[18] Winters (2012) offers insight into why this would be desirable when he proposes some reasons why UK banks might seek to maintain extra liquidity buffers, including, *inter alia*, internal risk management, risk-weighted return analysis, signals to credit ratings and investors, low credit demand and risk aversion.

date, settlement system, etc.) for accounting purposes.[19] In such netting cases, repo and reverse repo would decrease simultaneously, as depicted in Figure 3.

Alternatively, the patterns observed in Figure 3 could be explained by exogenous (client-driven) payment patterns, trading strategies or funding strategies around month-end periods. Additionally, banks could endogenously undertake strategic adjustments to their funding portfolios around month-end periods.[20] Isolating the reason(s) for these repo and reverse-repo adjustments falls outside the scope of this paper, however. Further, in the absence of daily balance-sheet data, this question is very difficult to address empirically.

3 Data and Methodology

3.1 Tests of Hypotheses I and II

Hypotheses I and II are tested jointly. This is accomplished in three stages. First, we quantify the month-end funding pressure in the Canadian overnight GC repo market and examine whether this funding pressure differs by type of month-end period. Second, we test whether US overnight GC repo rates can explain the observed month-end funding pressure in Canada. Third, we investigate whether funding pressure is related to month-end patterns in the Canadian payments system.

All three stages are performed by estimating the following model:

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[19] Appendix 4: Background on Repos and the Leverage Ratio in Canada provides more details.

[20] See Truno, Stolyarov, Auger and Assaf (2017) for a discussion of large Canadian banks' optimal funding strategies.

$$S_t = \alpha + \sum_{i=1}^{3} \beta_i S_{t-i} + \sum_{j=1}^{10} \gamma_j M_{jt} + \sum_{k=1}^{3} \delta_k P_{kt} + \theta Q_t + \sum_{m=1}^{30} \rho_m C_{mt} + \varepsilon_t \qquad [1]$$

All variables from equation 1 are described in more detail in Appendix 1 (Tables 2 and 3), and all data sources are included in Appendix 2. For the dependent variable, we use the spread of CORRA over the Bank of Canada target rate (S_t) to control for changes in the level of the target rate. For robustness, the model is also estimated using the OMMFR. The model is estimated using ordinary least squares (OLS) and includes three lags (S_{t-i}). As in Kotomin and Winters (2006), three lags are necessary to adequately address serial correlation. Newey-West standard errors are used to account for heteroskedasticity and any remaining serial correlation (Newey and West 1987).

A set of daily dummy variables (M_{jt}) is included to detect the presence of both month-end and quarter-end effects in repo rates. A set of payment variables (P_{kt}), which are described below, is included to test Hypothesis I. We test whether large-scale cash disbursements, which might increase cash-flow forecast uncertainty, might lead to funding pressure. Although data are not available for all such potential sources, we use as a proxy the aggregate of Government of Canada bond and bill payments as well as Canada Mortgage Bond payments made through the LVTS. We include daily LVTS payment volumes to test whether higher payment volumes, which could increase demand for funding, might lead to funding pressure. Finally, to test Hypothesis II, the average US overnight GC repo rate (Q_t) is included in equation 1.

Similar to Zhang (2012), we control for anomalous periods relevant to the Canadian payments system and repo market (C_{mt}). Dummy variables for three distinct periods of the financial crisis are tested: fixed announcement dates (FADs); pre-FAD periods; the period in which the target policy rate was at the effective lower bound; and calendar-based dummy variables, such as the day of the week, month and year.[21] Incidentally, only the day-of-the-week, month and year controls proved significant, so only they are included in the final regressions. These controls are suppressed for the sake of brevity.

To test Hypotheses I and II, we proceed in three stages. In specification 1, we estimate the model from equation 1 using only the month-end variables (M_{jt}) and calendar controls (C_{mt}) to demonstrate the magnitudes and patterns of these month-end (ME^{d+n}) and fiscal quarter-end (FQE^{d+n}) effects. In specification 2, we add LVTS payment volumes and large payments (as proxied by principal and coupon payments) to test Hypothesis I. Finally, in specification 3, we add the weighted-average US overnight GC repo rate (Q_t) to test Hypothesis II.

For these tests, we consider the period from 2001 to 2016, which follows a period of far more volatile repo rates. Rate volatility fell significantly following the introduction of the LVTS in February 1999 and FADs in December 2000 (Reid 2007). As such, this sample period is much more representative of prevailing Canadian money-market rate dynamics than the longer sample period from the Hypothesis III tests (1995 to 2016). All data in these tests have a daily frequency.

As discussed above, both SPRA/OR volumes and LVTS settlement balance levels may also be good proxies for month-end funding pressure (i.e., in addition to the CORRA).[22] Of course, a variable capturing a central bank's interventions in the overnight market cannot enter an equation for the overnight rate (equation 1) due to simultaneous-equations bias (Hamilton 1997). As such, we repeat the test

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[21] For background on the effective lower bound period in Canada, see Witmer and Yang (2015, 2016). See Zorn, Wilkins and Engert (2009) for an overview of the extraordinary liquidity operations conducted during the crisis.
[22] Hamilton (1997, 1998) studies supply and demand for Federal Reserve deposits and provides evidence that a reduction in reserves supply indeed leads to an increase in the overnight interest rate, particularly on settlement Wednesday and the last day of the quarter. Carpenter and Demiralp (2006) corroborate these results and argue that the effect is nonlinear since large changes in reserves supply more clearly affect liquidity than do small changes.

described above using daily SPRA/OR amounts and end-of-day LVTS settlement balances as dependent variables in equation 1. It is instructive to consider whether the estimates from these latter tests correspond well to the first test. Hence, we first re-estimate the model from equation 1 using LVTS settlement balances as the dependent variable. As above, this model is estimated using OLS and Newey-West standard errors.

Next, to re-estimate the model from equation 1 using the daily amount of SPRAs/ORs as the dependent variable (K_t), we take a slightly different approach because the SPRA/OR data are censored both from above and from below.[23] Historically, there has been a de facto upper limit on the amount of SPRAs that the Bank of Canada will engage in—both by counterparty and in total.[24] If the total SPRAs demanded by bank i at time t, $\sum_{i=1}^{6} D_{it}$, exceeds an upper limit, U_t, which varies over the sample period, then the data are censored from above at U_t.[25] If the demand for an SPRA by bank i at time t, D_{it}, exceeds the limit for an individual bank, U_{it}, then a sub-component of K_t is censored from above at U_{it}.

There is also a minimum threshold for market intervention. Generally, if the CORRA migrates away from the target policy rate only moderately, the Bank is unlikely to intervene. In such cases, $\sum_{i=1}^{6} D_{it}$ would tend to fall below some lower demand limit (floor) for intervention, L_t, which is a latent variable. As such, values of zero appear very frequently in the data, which indicates that the Bank of Canada did not conduct an SPRA. Accordingly, K_t is defined as follows:

[23] SRAs and term SPRAs are not included for a number of reasons: (i) they are relatively infrequent during large portions of the sample period; (ii) SRAs tend to coincide with periods of a surplus of funding, and we are more interested in periods of funding pressure; and (iii) brevity.
[24] The prevailing framework is available on the Bank of Canada's website, as are historical and current repo terms. Note that on rare occasions the Bank conducted numerous operations in one day.
[25] If the sum of SPRA tender amounts exceeds the amount available to allocate, tenders are allocated on a pro-rata basis and rounded to the nearest $1 million.

$$K_t = \begin{cases} 0 & \text{if } \sum_{i=1}^{6} D_{it} < L_t \\ \sum_{i=1}^{6} D_{it} \ \forall \ L_{it} \leq D_{it} \leq U_{it} \ + \sum_{i=1}^{6} U_{it} \ \forall \ D_{it} > U_{it} & \\ U_t & \text{if } \sum_{i=1}^{6} D_{it} \geq U_t \end{cases} \qquad [2]$$

To address the censored data issue from equation 2, we use the following Tobit model:

$$K_t = \alpha + \sum_{i=1}^{3} \beta_i \Delta S_{t-i} + \sum_{j=1}^{10} \gamma_j M_{jt} + \sum_{k=1}^{3} \delta_k P_{kt} + \theta Q_t + \sum_{m=1}^{30} \rho_m C_{mt} + \varepsilon_t \qquad [3]$$

The marginal effects from the Tobit model are then reported. The marginal effects for the month-end variables, M_{jt}, for example, are:

$$\frac{\partial E[K_t | M_{jt}]}{\partial M_{jt}} = \lambda \text{ x Prob}[\, L_t < K_t < U_t \,] \qquad [4]$$

These three series of tests (i.e., those using ΔS_t, LVTS settlement balances and K_t as dependent variables for equation 1) will allow us to test Hypotheses I and II, but those two hypotheses may not be sufficient to explain month-end funding pressure.[26]

3.2 Tests of Hypothesis III

Ideally, to test Hypothesis III, we would test for a relationship between daily repo-rate spreads and daily changes in the levels of Canadian banks' repo and reverse-repo balances; however, daily historical balance-sheet data for Canadian banks are not available. Instead, the difference between end-of-month repo and reverse-repo balances and the average balances over the same month can serve as a reasonable proxy for month-end fluctuations (hereafter known as $\text{Abnormal Repo}_{it}$ and $\text{Abnormal Reverse}_{it}$). Accordingly, to test Hypothesis III, we rely on two constructed variables, $\text{Abnormal Repo}_{it}$ and $\text{Abnormal Reverse}_{it}$, which are integrated into a modified version of the model from equation 1.

Canadian banks report balance-sheet repo data to OSFI on a monthly basis as part of their regulatory filings. For our purpose, the variables of interest are the end-of-month balances (the solid lines in Figure 3) and average-of-month balances (the dashed lines in Figure 3). These two series can be obtained from the OSFI M4 return (end-of-the-month, public data) and the L4 return (average-of-the-month, non-public data), respectively.[27] We consider the period from January 1995, when the full data set first becomes available, to August 2016.

[26] With three dependent variables and three stages of the test, there will be nine regressions in total.
[27] Please see Table 3: Summary Statistics and Appendix 2: Data Sources for more details.

The Canadian banking system is concentrated among the six Canadian banks studied in this paper; they are by far the largest counterparties in the Canadian repo market, so we focus on them.[28] This choice of sample group is also partly due to data restrictions because detailed data for smaller banks are available only sporadically at best. To determine whether systematic adjustments are made before regulatory reporting periods, we can compare end-of-month balances to intra-month balances by constructing the following measures, which will be the independent variables of interest in the Hypothesis III tests.

$$\text{Abnormal Repo}_{\text{t}} = \sum_{i=1}^{6} \text{Repo}_{\text{it}} - \overline{\text{Repo}_{\text{it}}} \qquad [5]$$

$$\text{Abnormal Reverse}_{\text{t}} = \sum_{i=1}^{6} \text{Reverse}_{\text{it}} - \overline{\text{Reverse}_{\text{it}}} \qquad [6]$$

Repo_{it} is the total of all repo balances for bank i at the end of month t, and $\overline{\text{Repo}_{\text{it}}}$ is the average of all repo balances for bank i over month t. Similarly, $\text{Reverse}_{\text{it}}$ is the reverse-repo balance for bank i at the end of month t, and $\overline{\text{Reverse}_{\text{it}}}$ is the average reverse-repo balance for bank i over month t. For example, a negative Abnormal Repo_{it} figure indicates that the end-of-month balances were less than the intra-month balances, and a positive number indicates the opposite. The measures are computed for Canadian-dollar repo and reverse-repo balances and are measured in billions of Canadian dollars.

[Insert Table 4 here]

[28] See Garriott and Gray (2016, 10–11) for details and figures. Alphabetically, the six banks studied are the Bank of Montréal, Bank of Nova Scotia, Canadian Imperial Bank of Commerce, National Bank of Canada, Royal Bank of Canada and Toronto Dominion Bank.

The estimates in Table 4 corroborate Figure 3. After accounting for fixed effects, we can see that, relative to D_{FQE-1} (by construction), Abnormal $Repo_{it}$ tends to be about 7 per cent lower in D_{FQE} months and about 4 per cent higher in D_{FQE+1} months.[29] This suggests that large Canadian banks scale down repo balances in D_{FQE} months and scale up repo balances in D_{FQE+1} months. A similar trend—albeit of a smaller magnitude—can be observed for Abnormal $Reverse_{it}$, and thus a similar inference can be made.

The following model is intended to test all three hypotheses simultaneously. We estimate the two models in equations 7 and 8 using both daily and monthly data. The variables and notation are explained in Table 2 below. In this section, we are particularly interested in the three φ coefficients (Hypothesis III) and expect the δ and θ coefficient estimates (Hypotheses I and II) to correspond closely to the estimates from Table 7.

$$S_t^d = \alpha^d + \beta^d S_{t-1}^d + \sum_{k=1}^{3} \delta_k^d P_{kt}^d + \theta^d Q_t^d + \varphi_0^d \text{Abnormal Repo}_t + \sum_{n=1}^{2} \varphi_n^d D_n \text{Abnormal Repo}_t + \varepsilon_t \qquad [7]$$

$$S_t^d = \alpha^d + \beta^d S_{t-1}^d + \sum_{k=1}^{3} \delta_k^d P_{kt}^d + \theta^d Q_t^d + \varphi_0^d \text{Abn. Reverse}_t + \sum_{n=1}^{2} \varphi_n^d D_n \text{Abn. Reverse}_t + \varepsilon_t \qquad [8]$$

The Abnormal $Repo_t$ and Abnormal $Reverse_t$ variables have a monthly frequency, so in these modified versions of equation 1, the t subscripts denote months rather than days. Accordingly, the focus of these models is month-end periods only. To elaborate, the d subscripts denote month-end period days: $d-1$ represents the day before month-end, d represents month-end, and $d+1$ represents the day after month-end. Consequently, we estimate each equation three times. A much more detailed description of each

[29] In Table 4, Abnormal $Repo_t$ and Abnormal $Reverse_t$ have been scaled by their respective intra-month averages and multiplied by 100 to present the changes as percentages. This version of the measure is thus more similar to the window-dressing measure used in Allen and Saunders (1992).

variable above is provided in Table 2. We estimate the model using OLS, include one lagged dependent variable to address serial correlation, and use Newey-West standard errors to adjust for heteroskedasticity and serial correlation.

As shown above, there are two separate models. The first is estimated with the Abnormal Repo_t variable and the second (otherwise identical model) with the $\text{Abnormal Reverse}_t$ variable. This approach avoids the multicollinearity issues that arise when estimating a model that uses two closely related independent variables.[30] D_n corresponds to two dummy variables: the first for FQE and the second for FQE_{+1}. These interaction terms allow for a test of the secondary aspect of Hypothesis III: do *regulatory-driven* repo and reverse repo balance-sheet adjustments cause month-end funding pressure?

It could be argued that estimating these models would essentially be equivalent to regressing price on a portion of the corresponding market volume, which could create an endogeneity issue due to simultaneity.[31] The dependent variable is a spread, or an interest rate, and so is essentially a price. The independent variables of interest, repo and reverse-repo balances (each a stock) are measured as changes and so are reasonable proxies for repo and reverse-repo volumes (each a flow), respectively. Hence, the spread and volume are determined in equilibrium (Roberts and Whited 2012). In other words, causality would be two-way rather than one-way. Accordingly, Abnormal Repo_t and $\text{Abnormal Reverse}_t$ would be considered stochastic, leading to biased and inconsistent estimates of the φ coefficients. Nonetheless, a

[30] With two equations and three different days to test, there will be six regressions in total.
[31] That is, Abnormal Repo_t, for example, could correspond to the portion of the Canadian overnight GC repo market volume that is attributable to large Canadian banks.

series of Durbin-Wu-Hausman tests do not reject the exogeneity of the regressors.[32] However, for robustness, we re-estimate the models using two-stage least squares.

To do so, we use a monthly proxy of Canadian banks' leverage ratio as an instrument for both Abnormal Repo_t and $\text{Abnormal Reverse}_t$ as the latter two are positively correlated ($\rho = 0.57$). Canadian banks report their regulatory leverage ratio on a quarterly basis, so leverage-ratio data are available only for FQE months. The regulatory leverage ratio is not reported for the other months (FQE_{-1} and FQE_{+1}); thus, to address this question, we construct a monthly proxy. Each month, Canadian banks report to OSFI data on the size and composition of their balance sheets.[33] To obtain a leverage ratio for each month, we construct a *balance-sheet leverage ratio* (BSLR):[34]

$$\text{BSLR}_t = \sum_{i=1}^{6} \frac{\text{Total Capital}_{it}}{\text{Total Assets}_{it}} \qquad [9]$$

The BSLR_t serves as a good instrument for Abnormal Repo_t and $\text{Abnormal Reverse}_t$ because it affects S_t only through the potentially endogenous regressors Abnormal Repo_t and $\text{Abnormal Reverse}_t$. First, there is a mechanical accounting relationship between Abnormal Repo_t and BSLR_t (*ceteris paribus*, as Abnormal Repo_t increases, BSLR_t decreases). Second, to the extent that Abnormal Repo_t represents repo volume, Abnormal Repo_t and S_t are determined in equilibrium. Conversely, it is not plausible that the aggregate leverage ratio of the large Canadian banks (BSLR_t) determines the Canadian overnight GC repo

[32] Note also that this endogeneity concern does not apply to bond payments or LVTS volumes since they are not driven by repo spreads.

[33] OSFI publishes a range of financial data, including consolidated and institution-level bank data. See Financial Data for Banks on the OSFI website for more details. These reports are published with a lag of about two to three months.

[34] Capital is calculated as the sum of subordinated debt, preferred shares, common shares, contributed surplus, retained earnings, non-controlling interests and accumulated other comprehensive income.

rate. Canadian banks' balance sheets are much larger than merely their repo balances, and so changes in banks' leverage ratios correspond to many other factors than those potentially affecting repo spreads, such as loan demand, for example.

Similarly, the positive correlation between Abnormal Repo_t and $\text{Abnormal Reverse}_t$ (see Figure 3) suggests that BSLR_t can also serve as an instrument for $\text{Abnormal Reverse}_t$. The validity of BSLR_t as an instrument for Abnormal Repo_t and $\text{Abnormal Reverse}_t$ is confirmed in the first stage of the two-stage least squares regressions (see Tables 5 and 6).

4 Empirical Results

4.1 Results for tests of Hypotheses I and II

The estimates from the models in equation 1 confirm the presence of month-end funding pressure in the Canadian overnight GC repo market (Table 7). The month-end and quarter-end coefficients (γ_j) from specification 1 offer two main insights.

First, funding pressure is greatest on the last day of the month and the first day of the month. Hence, we are primarily concerned with explaining funding pressure on these two days. The results from specification 1 show that the spread of CORRA over the Bank of Canada target tends to be about one basis point higher on the last day of the month and about three-quarters of a basis point higher on the first day of the month. In accordance with Figure 1 (left-hand side), the month-end (ME^{d}) coefficients from specification 1 show how funding pressure tends to rise and fall fairly symmetrically around a typical month-end period (i.e., from $\text{ME}^{\text{d}-2}$ to $\text{ME}^{\text{d}+2}$). When evaluating the economic significance of this result, it is crucial to consider that the Bank of Canada stands by prepared to conduct overnight liquidity operations to limit material deviations from the Bank of Canada target rate and frequently does so

(Figure 1, right-hand side). Therefore, the results in Table 7 suggest the presence of underlying funding pressure greater than the average realized funding pressure of just one basis point.

Second, the fiscal quarter-end coefficients (FQE^d) suggest that funding pressure is not significantly different at fiscal quarter-end compared with typical month-end periods (ME^d).[35] Again, this is consistent with Figure 1 (left-hand side) and provides *prima facie* evidence that Hypothesis III is less plausible.

[Insert Table 7 here]

The results from specification 2 in Table 7 provide evidence that Hypothesis I could explain funding pressure on the first day of the month but, interestingly, not the last day of the month. This suggests either that a confluence of factors drives month-end funding pressure or that there are two different regimes on the last day of the month and the first day of the month.

When the payment variables (P_{kt}) are added to specifications 2 and 3, the funding pressure originally detected on the first day of the month (ME^{d+1}) in specification 1 is no longer statistically significant; however, the funding pressure detected on the last day of the month falls only very moderately. The payment variable coefficients (δ_k) in specifications 2 and 3 are each statistically and economically significant.

The results in Table 7 suggest that for every Can$10 billion of bond principal payment made ($Principal_t$), we would expect an additional 0.6 basis points of funding pressure. For every Can$2 billion of bond coupon payment made ($Coupon_t$), we would expect an additional 0.25 basis points of funding pressure.

[35] Note that neither the FQE_{-1} (March, June, September, December), nor the FQE_{+1} (February, May, August, November), nor calendar year-end (December month-end) effects were significantly different than the baseline month-end effects.

For every additional Can$50 billion of LVTS volume ($LVTS_t^V$), we would expect an additional 0.25 basis points of funding pressure.[36] These would be quite common figures around month-end periods (see summary statistics in Table 3 for details). These results are also not surprising given that the first trading day of the month is among the most significant days for these principal and coupon payments.

Specification 3 in Table 7 allows us to address Hypothesis II (month-end funding pressure is imported from the US repo market) by adding the spread of the weighted average US overnight GC repo rate to the federal funds target (S_t^{USGC}). We can see that the coefficient on S_t^{USGC} enters the estimates as neither economically nor highly statistically significant. For instance, the results suggest that a one-standard-deviation increase in S_t^{USGC} of 20 basis points (Table 3) would tend to increase the CORRA by only about 0.08 basis points. Repeating this analysis with similar funding rates, such as LIBOR, yields similar results. All other coefficients are substantially unchanged when S_t^{USGC} is added, as is the R^2 (0.57). Taken together, these results suggest that Hypothesis II is not very plausible and that funding conditions in the Canadian overnight GC repo market are relatively distinct from those in the US overnight GC repo market.[37]

Next, it is instructive to consider two other proxies for funding pressure: the level of SPRAs/ORs conducted by the Bank of Canada (liquidity-providing repos) and the level of end-of-day LVTS settlement balances set by the Bank of Canada (liquidity-providing settlement balances). Using these two

[36] All three interpretations assume *ceteris paribus*.

[37] Note that when the regressions in Table 7 are repeated using the OMMFR as a dependent variable, the results are very similar, although the coefficients have smaller magnitudes, as the OMMFR exhibits substantially less variation than the CORRA.

series as dependent variables and repeating the analysis from Table 7, we are able to corroborate the results discussed above and detect the latent nature of month-end funding pressure.

[Insert Table 8 here]

First, using a Tobit model to account for the censored nature of the SPRA data (Table 8), we find that the Bank has conducted about the same amount of SPRAs/ORs in each type of month-end, as the (FQE_t^{d+n}) coefficients are, for the most part, not significant. For instance, the results from specification 1 suggest that the Bank of Canada has conducted an additional Can$63 million of SPRAs/ORs on the last day of the month on average.

Similar to the estimates for the CORRA (Table 7), the addition of the payment variables (P_{kt}) in specifications 2 and 3 (Table 8) seems to explain part of the month-end funding pressure observed on both the last day (ME^d) and the first day of the month (ME^{d+1}). Unlike the estimates for the CORRA, the addition of the payment variables does not appear to completely explain the first day of the month. Table 8 also emphasizes that bond principal payments (i.e., especially large payments relative to coupon payments) and high LVTS volume generally have more explanatory power than bond coupon payments. Once again, the addition of (S_t^{USGC}) in specification 3 leaves the results substantially unchanged and corroborates the inference that US repo market funding conditions do not appear to be a major driver of the CORRA.

Second, using OLS, we find that the Bank of Canada has tended to increase LVTS settlement balances by about the same amount around each type of month-end (Table 9). For instance, the results from specification 1 suggest that the Bank of Canada has added an additional Can$110 million of LVTS settlement balances on the last day of the month on average.

[Insert Table 9 here]

Similar to the estimates for the CORRA (Table 7), the addition of the payment variables (P_{kt}) in specifications 2 and 3 appear to explain increases in settlement balances on the first day of the month (ME^{d+1}), but not on the last day of the month (ME^{d}). Table 9 emphasizes that, once again, bond principal payments are associated with conditions consistent with funding pressure. For LVTS settlement balances in particular, however, coupon payments appear to be more important than high payment volumes. Again, the addition of (S_t^{USGC}) in specification 3 leaves the results substantially unchanged.

Taking the results from Tables 7 to 9 together, it appears that Hypothesis I may explain funding pressure on the first day of the month but not the last day of the month. Hypothesis II does not seem to play a role. So, despite the usefulness of the payment variables (P_{kt}) in explaining funding pressure, equation 1 cannot fully account for month-end funding pressure. We turn now to the results of the tests of Hypothesis III in an effort to explain this residual funding pressure.

4.2 Results for Tests of Hypothesis III

Do banks' end-of-month adjustments to their repo balances explain funding pressure on the last day of the month but not the first? A priori, this seems plausible. After all, banks' incentive to window dress should be highest on the last day of the month. Before investigating Hypothesis III empirically, however, we can make some preliminary inferences by comparing Figures 1 and 3.

The pattern in Figure 3 suggests that Hypothesis III is somewhat less plausible for at least two reasons. First, Figure 3 shows that reductions in repo balances are far more significant at fiscal quarter-end, yet Figure 1 shows that funding pressure is about as strong on average at all month-end periods, not just fiscal quarter-end periods. Second, as Figure 1 shows, rates tend to be higher around month-end periods, so by the reasoning above, the negative supply shocks to the market would need to dominate the negative demand shocks (i.e., banks' reductions in reverse repo would need to be larger than their reductions in repo balances). But to the contrary, Figure 3 shows that reductions in repo and reverse repo relative to intra-quarter levels are very similar. Further, the data show that the magnitude of these reductions tends to be similar on an absolute basis as well (i.e., the total amount of reduction in repo and reverse-repo balances). Nonetheless, we continue to investigate this hypothesis with more rigour.

[Insert Tables 10 and 11 here]

The results in Tables 10 and 11 suggest that the month-end balance-sheet adjustments captured by Abnormal Repo_t and $\text{Abnormal Reverse}_t$ do not explain month-end funding pressure—neither on the last day of the month nor the surrounding days. This also appears to be true regardless of the type of month-end (FQE versus FQE_{+1} versus FQE_{-1}) as indicated by the interaction terms (e.g., $\text{Abnormal Repo}_t \cdot \text{D}_{\text{FQE+1}}$). The results also corroborate the finding from Tables 7 to 9 that principal bond payments appear to be associated with month-end funding pressure.[38] Nevertheless, we cannot completely dismiss the possibility that large Canadian banks' balance-sheet adjustments can drive funding pressure, because this estimation approach may suffer from two limitations: endogeneity and measurement error.

The models from equations 7 and 8 may suffer from endogeneity issues. Estimating these models may be akin to regressing price on a portion of the corresponding market volume (i.e., large Canadian banks' share of that market volume), which could lead to simultaneous-equations bias. That is, the dependent variable is a spread, or an interest rate, and so is essentially a price. The independent variables of interest, repo and reverse-repo balances (each a stock) are measured as changes and are, to some extent, proxies

[38] Note that there are no results for the coupon variable on days d and $d-1$ because, in the sample data, no coupon payments are made on the last and second-to-last days of the month.

for repo and reverse-repo volume (each a flow), respectively. Hence, to the extent that we are truly measuring repo volume, spread and volume are determined in equilibrium, and we have an endogeneity issue. Whether Abnormal Repo_t and $\text{Abnormal Reverse}_t$ are truly proxies for volume in the Canadian overnight GC repo market is rather doubtful due to measurement error. This is elaborated upon in the limitations discussion below.

Nonetheless, we re-estimate the models from equations 7 and 8 using instrumental variables for robustness. As discussed in the previous section, ΔBSLR_t is used as an instrument for both Abnormal Repo_t and $\text{Abnormal Reverse}_t$ because of the negative correlation between each pair along with the absence of any plausible, direct causal relationship between ΔBSLR_t and S_t (CORRA). The first-stage regressions provide insight into the validity of this approach and are provided in Tables 5 and 6. The results from the two-stage least squares regressions in Tables 12 and 13 are very similar to those from Tables 10 and 11 and do not alter the conclusions.

[Insert Tables 12 and 13 here]

Further, the efficacy of the Abnormal Repo_t and $\text{Abnormal Reverse}_t$ measures suffers from measurement error for three reasons: maturity mismatch, collateral mismatch and frequency mismatch.

First, S_t^d is a spread for an *overnight* repo rate, but Abnormal Repo_t and $\text{Abnormal Reverse}_t$ are aggregates of repo and reverse-repo balances, respectively, across *all* maturities. The adjustments captured by the Abnormal Repo_t and $\text{Abnormal Reverse}_t$ measures, however, should tend to be shorter-term contracts. For instance, it is easier to allow a short-term repo contract to mature than to close out a long-term repo contract.

Second, S_t^d is a spread for a Canadian *general-collateral* repo rate, but Abnormal Repo_t and $\text{Abnormal Reverse}_t$ are aggregates of repo and reverse-repo balances, respectively, across *all* types of

Canadian collateral. Again, however, the adjustments captured by the Abnormal Repo_t and $\text{Abnormal Reverse}_t$ measures should tend to favour GC adjustments since GC contracts are easier to adjust at the margin due to their superior liquidity; indeed, it is common for repo-market participants to do so.

Third, Abnormal Repo_t and $\text{Abnormal Reverse}_t$ are measured on a *monthly* basis while all other values in equations 7 and 8 are measured on a *daily* basis. To the extent that adjustments to repo and reverse-repo balances are especially prevalent on the last days of the month, these proxy measures are particularly appropriate, but whether this is true is not observable given the aforementioned data restrictions (§3.2).

The measurement error in these regressors has likely introduced some attenuation bias, so *ceteris paribus*, the φ coefficients in the estimates for equations 7 and 8 found in Tables 10 to 13 will tend to be biased towards zero. Despite the endogeneity and measurement error (maturity mismatch, collateral mismatch and frequency mismatch) concerns with the Abnormal Repo_t and $\text{Abnormal Reverse}_t$ measures, these proxy variables likely offer the best chance of identifying any relationship between month-end funding pressure and large Canadian banks' repo adjustments given the available data. Nonetheless, it is possible that this data restriction precludes us from ascertaining the true role of balance-sheet adjustments in quarter-end funding pressure.

Finally, the approach to estimating month-end funding pressure in this paper does not consider the potential effect of repo-balance adjustments in the United States and other jurisdictions. Large Canadian banks have a large repo presence in the United States, so given the results from Munyan (2015) and Owens and Wu (2015), repo-balance reduction in the US market could theoretically affect supply and demand in the Canadian market.

Accordingly, we add a variable for repo-book reduction in the United States to test for this and estimate the model above. The variable measures the percentage change in repo and federal funds at the end of the quarter from the average over the quarter. These data are collected from the Federal Reserve Bank of Chicago and are available on a quarterly basis from 2002 to 2015 (see Appendix 2 for details). Neither the repo coefficient nor the reverse-repo coefficient is significant. The power of this test is much lower than the regression above because the observations are quarterly and begin in 2002 (N=55) rather than monthly and in 2001 (N=187). This approach also shifts the focus from all month-end types (FQE_{-1}, FQE, FQE_{+1}) to simply FQE_{-1} as this is when US quarter-end takes place, so the results are not generalizable in any case. Nonetheless, we do not find evidence to suggest that US market spillovers explain month-end funding pressure in Canada. This seems especially plausible given the results from the tests of Hypothesis II found in Tables 7 to 13.

These limitations imply that balance-sheet adjustments could contribute to quarter-end funding pressure to some extent. This may help to solve the puzzle from Tables 7 to 9 that funding pressure on the last day of the month remains largely unexplained. Nonetheless, the extent of any such contribution would necessarily be limited since funding pressure is about as strong around any given month-end.

Measurement error in the proxies for high payment volumes and large payment volumes also have the potential to explain funding pressure on the last day of the month. Ultimately, these variables are proxies for the interaction of forecast uncertainty, heightened liquidity preference and search frictions. Ideally, this mechanism would be more precisely measured with high-frequency bank data.

To disentangle the precise causal relationships, a number of granular time-series data sets would be useful: intraday fluctuations in each repo-market participant's cash-flow forecasts to better understand forecast uncertainty; realized intraday cash flows for each bank to better understand cash-flow shocks; detailed intraday funding-market (both secured and unsecured) transactions data to better understand liquidity preference and substitution effects; and, finally, data on repo-market participants' search processes, such as the number of bids and phone calls made by a particular repo trader, to draw conclusions about search frictions.

5 Conclusion

This paper asked what explains month-end funding pressure in a crucial Canadian funding market, the overnight GC repo market. It began by documenting the presence of month-end funding pressure. At about one basis point on average, the magnitude of this funding pressure is rather small, but it persistently coincides with increases in liquidity provision by the Bank of Canada. Hence, the true magnitude of the underlying funding pressure is almost certainly greater than that suggested by market prices. To explain this phenomenon, we considered three non-mutually exclusive hypotheses.

The first hypothesis postulated that this latent month-end funding pressure can be explained by search frictions in the repo market. Large payments and high payment volumes can make daily cash-flow forecasting more difficult for market participants. In such periods, market participants may demand larger liquidity buffers to protect against potential cash shortfalls. This can make overnight liquidity more difficult to locate. As search frictions (*and the expectation thereof*) are amplified, repo-market participants may place a higher liquidity premium on overnight funding. This hypothesis was supported by evidence that funding pressure is associated with both large payments (by using bond and coupon payments as a proxy) and high volumes in the payment system (LVTS). Interestingly, the search-frictions hypothesis appears to explain funding pressure on the first day of the month, but not the last day (and these are the two days in which funding pressure is the greatest). This left a puzzle that perhaps the second and third hypotheses could resolve.

The second hypothesis suggested that month-end funding pressure could be attributable to funding pressure imported from the US repo market. Theoretically, US repo-based funding and lending may be a substitute for Canadian repo-based funding and lending. However, numerous tests provide evidence that these two funding markets are not sufficiently integrated to support this hypothesis.

The third hypothesis proposed that month-end funding pressure might be caused by Canadian banks' adjustments to their repo balances at month-end periods, particularly fiscal quarter-ends. The evidence shows that large Canadian banks tend to reduce their repo and reverse-repo balances before fiscal quarter-end periods, but it does not suggest that these adjustments explain month-end funding pressure. Accordingly, the explanation for funding pressure on the last day of the month remains a puzzle.

We concede that either the first or third hypothesis could still account for this unexplained month-end funding pressure as the approach taken in this paper suffers from some limitations. The particular use of proxy variables in the empirical work could lead to both endogeneity and measurement error issues, which introduces the possibility of both simultaneous-equations bias and attenuation bias. On balance, this approach is likely the best available to account for Hypotheses I and III given current data restrictions. Nonetheless, intraday forecast and transactions data could ultimately reveal that Hypotheses I and III, either singly or together, resolve the puzzle put forth in this paper after all.

Of course, some other as yet unaccounted for hypothesis could explain this puzzle as well, but these three hypotheses appear to be the most plausible. As more daily data on the Canadian repo market become available, it may be possible to revisit this question, and so it is left for future research.

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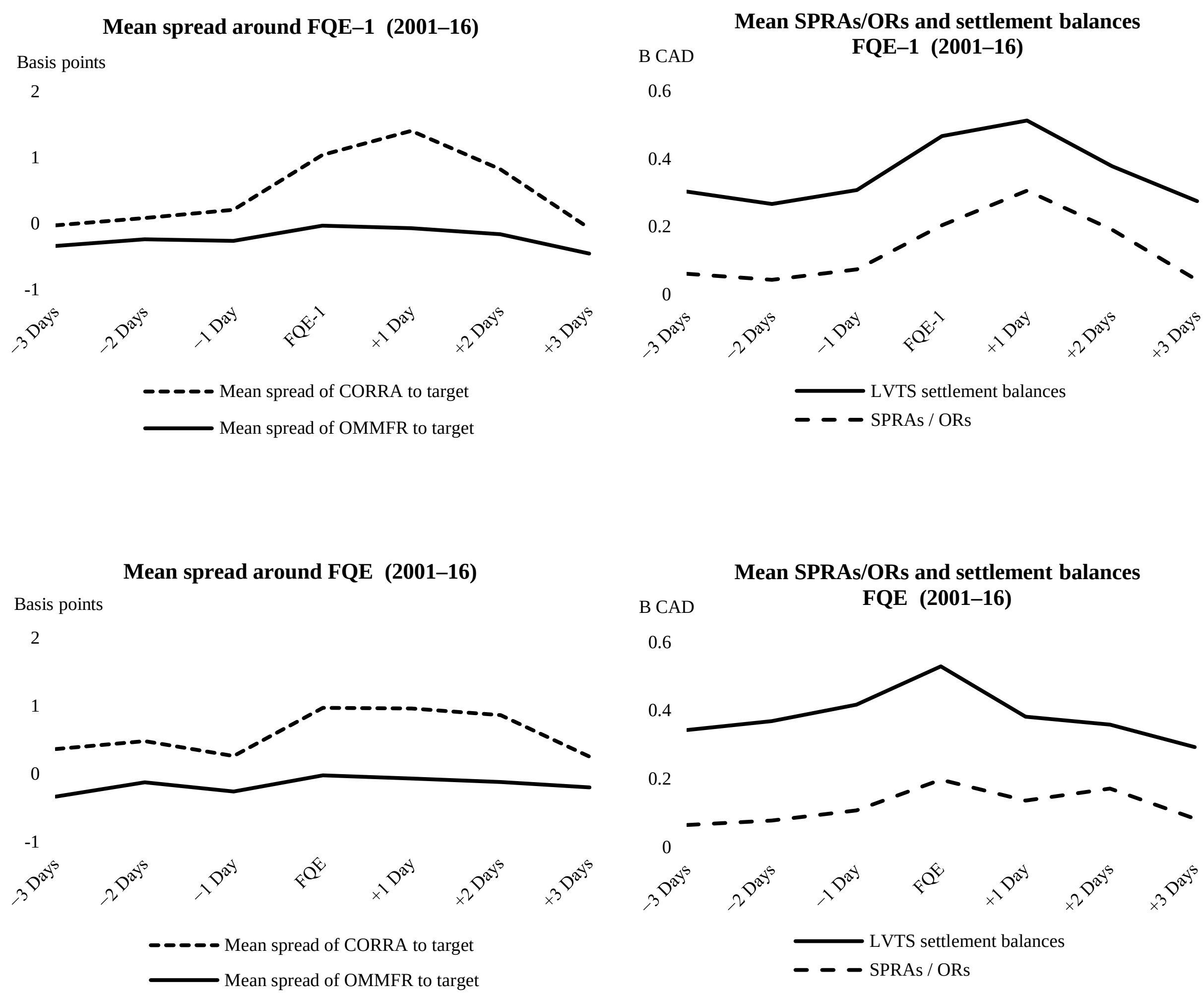
Appendix 1: Tables and Figures

Figure 1: Funding pressure emerges around each type of month-end period

The left-hand-side charts show mean spreads by type of month-end (FQE, FQE_{-1} and FQE_{+1}). The right-hand-side charts show the average levels of LVTS settlement balances and liquidity-injecting repo operations (SPRAs/ORs). The x-axes are measured in days from the last trading day of the month. The y-axes are measured either in basis points (left-hand side) or in billions of Canadian dollars (right-hand side). The sample period is 2001 to 2016.



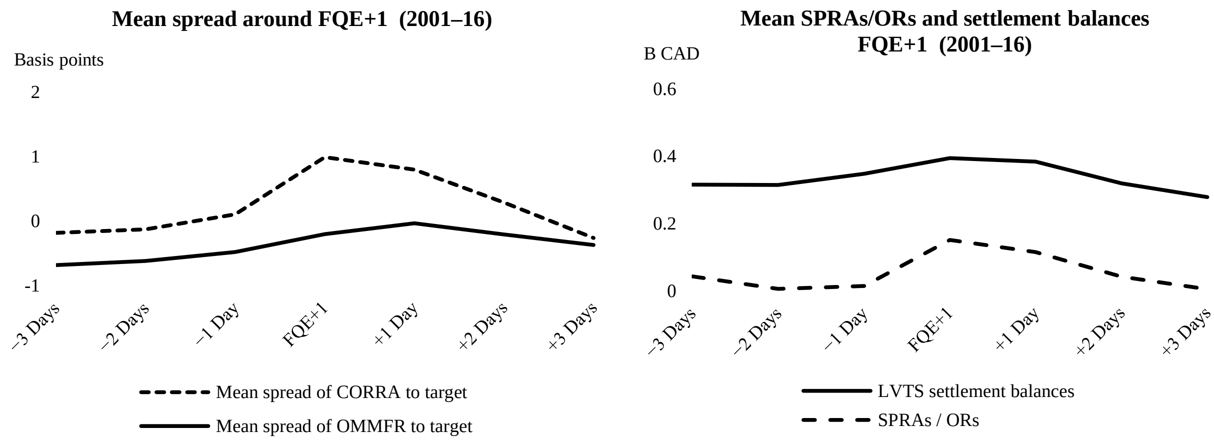


Figure 2: Average principal, coupon, and LVTS payments by day of the month

The chart shows average payments by the day of the month. The x-axis is measured in days from the last trading day of the month. The y-axes are measured in billions of Canadian dollars. The sample period is 2001 to 2016.

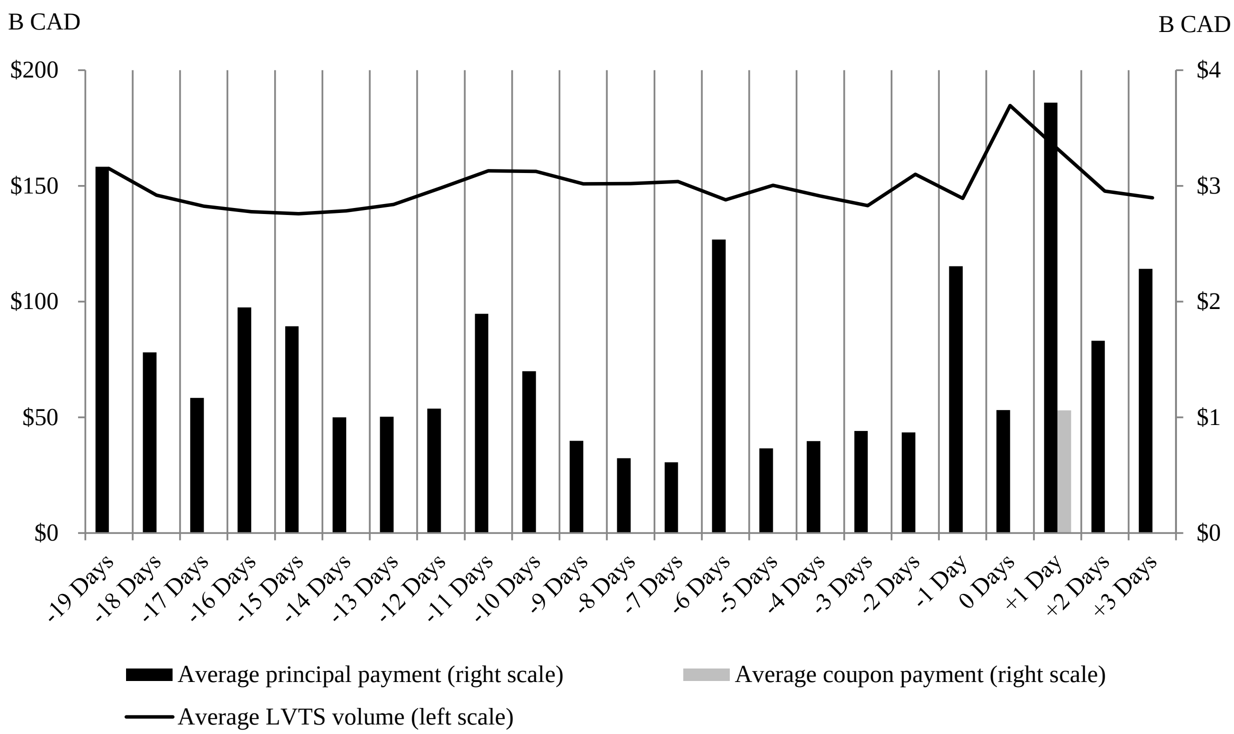


Figure 3: Repo and reverse-repo balances persistently decline at fiscal quarter-end

The charts show average changes in repo and reverse-repo balances. The y-axis is the percentage change in the average repo or reverse-repo balance relative to the average balance in FQE_{-1} months. The x-axis partitions observations into one of three month types: FQE, FQE_{-1} and FQE_{+1}. FQE corresponds to January, April, July and October; FQE_{-1} corresponds to March, June, September and December; FQE_{+1} corresponds to February, May, August and November. Each observation in the charts represents an average monthly balance from 1995 to 2016 (522 monthly observations aggregated across six banks per observation). An equal number of observations is included in each partition to avoid bias due to the upward trend in the data. Data are sourced from the OSFI M4 and L4 returns.

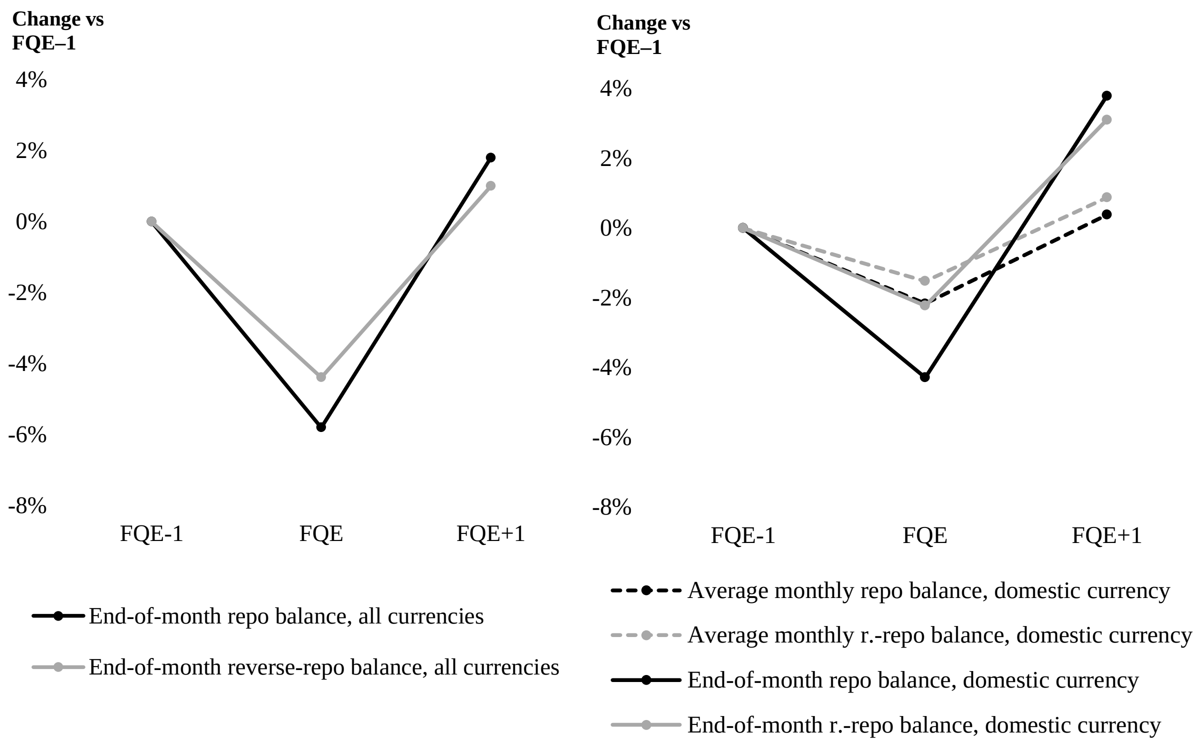


Table 1: Latent funding pressure and Bank of Canada intervention

This table presents summary statistics from OLS regressions. The three dependent variables are the spread between the CORRA and the Bank of Canada target (in basis points), liquidity-injecting repos (SPRAs/ORs, in billions of Canadian dollars), and LVTS settlement balances (in billions of Canadian dollars). To illustrate, $\mathrm{ME}^{\mathrm{d}-1}$ indicates the second-last trading day of the month. ME^{d} indicates the last trading day of the month. $\mathrm{ME}^{\mathrm{d}+1}$ indicates the first trading day of the month. The estimation is performed using Newey-West standard errors. Coefficients are shown in the left columns, and t-statistics (absolute value) are shown to the right of these columns. The regressions include calendar-based dummy variables for day of the week, month and year but are supressed here for brevity. *, ** and *** represent significance at the 10 per cent, 5 per cent and 1 per cent level, respectively.

	CORRA – Target (S_t)		**SPRAs/ORs**		**LVTS settlement balances**	
$\mathrm{ME}^{\mathrm{d}-2}$	0.39	2.72***	0.02	1.17	0.02	0.60
$\mathrm{ME}^{\mathrm{d}-1}$	0.31	2.11**	0.03	1.51	0.06	1.52
ME^{d}	1.15	6.11***	0.16	5.67***	0.17	3.62***
$\mathrm{ME}^{\mathrm{d}+1}$	1.20	8.23***	0.17	5.44***	0.13	2.78***
$\mathrm{ME}^{\mathrm{d}+2}$	0.87	6.68***	0.11	4.23***	0.05	1.08
Constant	1.71	8.43***	0.32	5.30***	0.52	8.12***
Adjusted R^2	0.29		0.15		0.48	
N	3924		3924		3924	

Table 2: Regression variables

This table provides a description of each of the variables included in equation 1 and Tables 7 to 9 as well as each of the variables included in equations 7 and 8, Tables 5 to 6, and Tables 10 to 13.

Notation		Interpretation
Eqn 1	Tables 1, 7–9	Dependent variables and lagged dependent variables (S_t) ; $i = \{1,2,3\}$
S_t	S_t	The spread of the CORRA to the Bank of Canada target rate on trading day t measured in basis points
S_{t-i}	S_{t-i}	A lagged dependent variable (the i^{th} period lag)
$LVTS_t^B$	$LVTS_t^B$	The level of end-of-day LVTS settlement balances measured in billions of Canadian dollars
$SPRA_t$	$SPRA_t$	The total value of all SPRA or OR operations conducted at time t measured in billions of Canadian dollars (see Appendix 3 for the details of these operations)
Eqn 1	Table 1, 7–9	Independent variables: Month-end effects (M_{jt}) ; $j = \{1,2,\ldots,10\}$
M_{1t} - M_{5t}	ME_t^{d+n}	A dummy variable that takes the value 1 when it is n trading days before (d − n) month-end (ME) or n trading days after (d + n) month-end and 0 otherwise. $n = \{-2,-1,0,1,2\}$
M_{6t} - M_{10t}	FQE_t^{d+n}	A dummy variable that takes the value 1 when it is n trading days before (d − n) a fiscal quarter-end (FQE) month or n trading days after (d + n) an FQE month and 0 otherwise. $n = \{-2,-1,0,1,2\}$
Eqn 1	Tables 1, 7–9	Independent variables: Payments (P_{kt}) ; $k = \{1,2,3\}$
P_{1t}	$Principal_t$	The value of principal payments for Government of Canada bonds and bills as well as Canada Mortgage Bonds measured in billions of Canadian dollars.
P_{2t}	$Coupon_t$	The value of coupon payments for Government of Canada bonds measured in billions of Canadian dollars.
P_{3t}	$LVTS_t^V$	The value of payments sent in the LVTS less the Principal and Coupon payments above measured in billions of Canadian dollars.
Eqn 1	Tables 1, 7–9	Independent variable: US repo rate (Q_t)
Q_t	S_t^{USGC}	The spread of the weighted average US overnight general-collateral (GC) repo rate to the federal funds target on trading day t measured in basis points
Eqn 1	Tables 1, 7–9	Independent variables: Calendar controls (C_{mt}) ; $m = \{1,2,\ldots,30\}$
$C_{1t} - C_{4t}$	Suppressed	Day-of-the-week dummy variables
$C_{5t} - C_{15t}$	Suppressed	Month dummy variables
$C_{16t} - C_{30t}$	Suppressed	Year dummy variables
Notation		**Interpretation**

Eqn 7–8	Tables 5–6, 10–13	Dependent variables and lagged dependent variables (S_t) ; i = {1,2,3}
S_t^d	S_t^d	S_t^d is the spread of the CORRA over the Bank of Canada target rate on day d of month-end period t. The d superscript denotes either the spread on the day before month-end t (S_t^{d-1}), the day of month-end t (S_t^d), or the day after month-end t (S_t^{d+1}). Hence, there are three separate dependent variables. The superscript applies in the same manner to several of the variables below. The spread is measured in basis points.
Eqn 7–8	Tables 5–6, 10–13	Independent variables: Payments (P_{kt}) ; k = {1,2,3}
P_{1t}^d	Principal_t^d	The value of principal payments for Government of Canada bonds and bills as well as Canada Mortgage Bonds on day d of month-end period t in billions of Canadian dollars.
P_{2t}^d	Coupon_t^d	The value of coupon payments for Government of Canada bonds on day d of month-end period t in billions of Canadian dollars.
P_{3t}^d	$\text{LVTS}_t^{V,d}$	The value of payments sent in the LVTS on day d of month-end period t in billions of Canadian dollars less Principal_t^d and Coupon_t^d.
Eqn 7–8	Tables 5–6, 10–13	Independent variable: US repo rate (Q_t)
Q_t^d	$S_t^{USGC,d}$	The spread of the weighted average US overnight general-collateral (GC) repo rate to the Fed Funds target on day d of month-end period t. The spread is measured in basis points.
Eqn 7–8	Tables 5–6, 10–13	Independent variables of interest for Hypothesis III
Abnormal Repo_t		The difference between repo at month-end t (Repo_t) and the average level of repo over month t ($\overline{\text{Repo}_t}$) measured in billions of Canadian dollars. See equation 5 for calculation.
$\text{Abnormal Reverse}_t$		The difference between repo at month-end t (Reverse_t) and the average level of repo over month t ($\overline{\text{Reverse}_t}$) in billions of Canadian dollars. See equation 6 for calculation.

Table 3: Summary statistics

This table provides summary statistics for each of the variables included in equations 1 and 5 to 9. The table can be used in reference to all other tables in this appendix.

	N	$\bar{x}$	σ	**Min**	**Max**
Tables 1, 7–9					
S_t	3924	0.01	2.15	-28.3	16.2
$SPRA_t \mid SPRA_t > 0$	372	0.77	0.45	0.65	2.83
$LVTS_t^B$	3924	0.33	0.76	-0.89	4.28
$Principal_t \| Principal_t > 0$	763	7.43	5.47	0.00	23.82
$Coupon_t \| Coupon_t > 0$	122	1.65	2.34	0.00	7.14
$LVTS_t^V$	3924	150.13	31.36	14.15	276.98
S_t^{USGC}	3924	-8.29	19.37	-290	50
Tables 5–6, 10–13					
S_t^{d-1}	187	0.20	2.12	-10.10	9.49
S_t^{d}	187	1.00	2.71	-9.10	10.76
S_t^{d+1}	187	1.03	2.24	-9.35	12.87
Abnormal Repo_t	187	-0.74	5.47	-16.01	20.01
$\text{Abnormal Repo}_t \cdot D_{FQE}$	187	-1.01	3.22	-16.01	7.02
$\text{Abnormal Repo}_t \cdot D_{FQE+1}$	187	0.56	3.31	-9.99	20.01
$\text{Abnormal Reverse}_t$	187	-0.99	4.40	-15.07	15.08
$\text{Abnormal Reverse}_t \cdot D_{FQE}$	187	-0.79	3.06	-15.07	6.24
$\text{Abnormal Reverse}_t \cdot D_{FQE+1}$	187	0.18	2.43	-11.54	15.08
$\Delta BSLR_t$	187	0.00	0.19	-1.04	0.67
$Principal_t^{d-1}$	187	2.32	4.84	0	17.9
$Principal_t^{d}$	187	1.07	3.44	0	16.8
$Principal_t^{d+1}$	187	3.71	4.84	0	23.8
$Coupon_t^{d-1}$	187	0	0	0	0
$Coupon_t^{d}$	187	0	0	0	0
$Coupon_t^{d+1}$	187	1.07	2.06	0	7.14
$LVTS_t^{V,d-1}$	187	144.67	30.57	38.01	255.43
$LVTS_t^{V,d}$	187	185.69	34.92	59.76	266.14
$LVTS_t^{V,d+1}$	187	167.29	32.99	73.31	260.52
$S_t^{USGC,d-1}$	187	-8.48	19.14	-130	25
$S_t^{USGC,d}$	187	-7.56	29.19	-270	48
$S_t^{USGC,d+1}$	187	-3.68	15.57	-98	41
Table 4					
$\text{Abnormal Repo}_{it}$ (Δ%)	1554	0.20	18.76	-65.81	124.83
$\text{Abnormal Reverse}_{it}$ (Δ%)	1554	-0.30	14.63	-43.74	65.79

Table 4: Banks tend to reduce repo balances in fiscal quarter-end months

The table presents summary statistics from panel regressions of (i) $\text{Abnormal Repo}_{it}$ and (ii) $\text{Abnormal Reverse}_{it}$ (see equations 5 and 6 above) on dummy variables indicating fiscal quarter-end months (D_{FQE}) and months following fiscal quarter-end (D_{FQE+1}). $\text{Abnormal Repo}_{it}$ and $\text{Abnormal Reverse}_{it}$ are each expressed as a percentage-point change (Δ%) relative to the average balance over that month (as in Table 3 above). Each variable has been winsorized at the 1 per cent and 99 per cent level due to what appear to be data entry errors in the bank returns. The regressions include bank, month and year fixed effects, which have been suppressed for brevity. The estimation is performed using Driscoll-Kraay standard errors (Hoechle 2007). Coefficients are shown in the left columns, and t-statistics are shown to the right of these columns. *, ** and *** represent significance at the 10 per cent, 5 per cent and 1 per cent level, respectively.

	$\text{Abnormal Repo}_{it}$		$\text{Abnormal Reverse}_{it}$	
D_{FQE}	-6.69	2.95**	-4.21	3.12**
D_{FQE+1}	3.63	2.33*	3.04	2.68**
Constant	-9.33	3.89**	-7.46	4.50***
R^2	0.12		0.08	
N	1554		1554	

Table 5: The validity of $\Delta BSLR_t$ as an instrument for Abnormal $Repo_t$

The table presents summary statistics from the first stage of the two-stage least squares regressions below. The dependent variable is Abnormal $Repo_t$ in all three specifications and is measured in billions of Canadian dollars. The d superscript denotes that the data used correspond to the day before month-end t ($d-1$), the day of month-end t (d), or the day after month-end t ($d+1$). The results confirm the partial correlation between $BSLR_t$ and Abnormal $Repo_t$ (Roberts and Whited 2012). Coefficients are shown in the left columns, and t-statistics (absolute value) are shown to the right of these columns. *, ** and *** represent significance at the 10 per cent, 5 per cent and 1 per cent level, respectively.

	$d-1$		d		$d+1$	
$\Delta BSLR_t$	-10.56	5.52***	-10.33	5.66***	-9.84	4.56***
S_{t-1}^{d}	-0.12	0.68	-0.18	1.10	-0.21	1.51
$Principal_t^d$	-0.09	1.17	0.09	0.90	-0.03	0.30
$Coupon_t^d$					0.04	0.19
$LVTS_t^{V,d}$	0.02	1.25	0.01	0.61	0.02	1.56
$S_t^{USGC,d}$	-0.06	2.89**	-0.06	4.53***	-0.03	1.29
Constant	-3.23	1.79*	-2.45	1.24	-3.92	1.89*
Adjusted R^2	0.19		0.24		0.16	
N	187		187		187	

Table 6: The validity of the $\Delta BSLR_t$ as an instrument for Abnormal $Reverse_t$

The table presents summary statistics from the first stage of the two-stage least squares regressions below. The dependent variable is Abnormal $Reverse_t$ in all three specifications and is measured in billions of Canadian dollars. The d superscript denotes that the data used correspond to the day before month-end t ($d-1$), the day of month-end t (d), or the day after month-end t ($d+1$). The results confirm the partial correlation between $BSLR_t$ and Abnormal $Reverse_t$ (Roberts and Whited 2012). Coefficients are shown in the left columns, and t-statistics (absolute value) are shown to the right of these columns. *, ** and *** represent significance at the 10 per cent, 5 per cent and 1 per cent level, respectively.

	$d-1$		d		$d+1$	
$\Delta BSLR_t$	-6.87	4.19***	-6.64	4.16***	-6.17	3.37***
S_{t-1}^{d}	0.06	0.41	-0.01	0.04	-0.06	0.51
$Principal_t^d$	0.06	0.99	0.21	2.37**	0.04	0.58
$Coupon_t^d$					-0.02	0.12
$LVTS_t^{V,d}$	0.01	1.02	0.01	0.97	0.01	0.65
$S_t^{USGC,d}$	-0.01	0.55	-0.01	0.69	-0.01	0.57
Constant	-2.77	1.80*	-2.94	1.71	-2.28	1.30
Adjusted R^2	0.08		0.10		0.07	
N	187		187		187	

Table 7: Results from tests of Hypotheses I and II (CORRA)

This table presents summary statistics from OLS regressions of the spread between the CORRA and the Bank of Canada target on a series of variables intended to test Hypotheses I and II. Spreads are measured in basis points. Table 2 (above) describes each variable in detail. The estimation is performed using Newey-West standard errors. Coefficients are shown in the left columns, and t-statistics (absolute value) are shown to the right of these columns. The regressions include calendar-based dummy variables for day of the week, month and year but are supressed here for brevity. *, ** and *** represent significance at the 10 per cent, 5 per cent and 1 per cent level, respectively.

	(1)		**(2)**		**(3)**	
S_{t-1}	0.47	11.04***	0.47	10.96***	0.47	10.82***
S_{t-2}	0.15	6.35***	0.15	6.23***	0.15	6.25***
S_{t-3}	0.06	2.47**	0.07	2.63***	0.07	2.58***
ME^{d-2}	0.32	2.60***	0.30	2.52**	0.30	2.51**
ME^{d-1}	0.27	2.29**	0.31	2.68***	0.31	2.69***
ME^{d}	1.09	5.89***	0.92	4.96***	0.92	4.98***
ME^{d+1}	0.75	4.50***	0.25	1.47	0.23	1.30
ME^{d+2}	0.28	2.20**	0.24	1.85*	0.23	1.74*
FQE^{d-2}	0.01	0.07	-0.01	0.06	-0.01	0.06
FQE^{d-1}	-0.39	1.79*	-0.47	2.16**	-0.48	2.20**
FQE^{d}	-0.36	1.18	-0.39	1.28	-0.41	1.37
FQE^{d+1}	-0.36	1.16	-0.06	0.21	-0.05	0.17
FQE^{d+2}	-0.38	1.83*	-0.40	1.92*	-0.39	1.87*
$Principal_t$			0.06	7.87***	0.06	7.90***
$Coupon_t$			0.13	1.73*	0.13	1.74*
$LVTS_t^V$			0.005	3.93***	0.005	4.14***
S_t^{USGC}					0.004	1.90*
Constant	0.20	1.47	-0.70	2.87***	-0.70	2.90***
Adjusted R^2	0.56		0.57		0.57	
N	3924		3924		3924	

Table 8: Results from tests of Hypotheses I and II (SPRAs/ORs)

This table presents summary statistics from Tobit models of SPRAs/ORs on a series of variables intended to test Hypotheses I and II. SPRAs/ORs are measured in billions of Canadian dollars. Table 2 (above) describes each variable in detail. The *marginal effects* from a Tobit model are shown in the left columns, and test statistics (absolute value) are shown to the right of these columns. The estimation is performed using delta-method standard errors. The regressions include calendar-based dummy variables for day of the week, month and year but are supressed here for brevity. *, ** and *** represent significance at the 10 per cent, 5 per cent and 1 per cent level, respectively.

	(1)		**(2)**		**(3)**	
ME^{d-2}	0.003	0.33	0.002	0.21	0.002	0.13
ME^{d-1}	0.008	0.78	0.008	0.93	0.009	0.74
ME^{d}	0.063	7.23***	0.038	4.86***	0.038	3.26***
ME^{d+1}	0.057	7.38***	0.026	3.11**	0.025	2.19**
ME^{d+2}	0.050	6.71***	0.044	6.48***	0.044	3.98***
FQE^{d-2}	0.009	0.60	0.005	0.33	0.004	0.32
FQE^{d-1}	0.016	1.13	0.011	0.84	0.011	0.83
FQE^{d}	-0.002	0.16	-0.002	0.15	-0.002	0.21
FQE^{d+1}	-0.004	0.35	0.008	0.70	0.009	0.73
FQE^{d+2}	-0.034	2.20**	-0.034	2.35**	-0.034	2.33**
$Principal_t$			0.002	4.34***	0.002	4.35***
$Coupon_t$			0.003	1.12	0.003	1.14
$LVTS_t^V$			0.0005	5.85***	0.0005	5.86***
S_t^{USGC}					0.00006	0.79
N	3924		3924		3924	

Table 9: Results from tests of Hypotheses I and II (LVTS balances)

This table presents summary statistics from OLS regressions of end-of-day LVTS balances on a series of variables intended to test Hypotheses I and II. LVTS settlement balances are measured in billions of Canadian dollars. Table 2 (above) describes each variable in detail. The estimation is performed using Newey-West standard errors. Coefficients are shown in the left columns, and t-statistics (absolute value) are shown to the right of these columns. The regressions include calendar-based dummy variables for day of the week, month and year but are supressed here for brevity. *, ** and *** represent significance at the 10 per cent, 5 per cent and 1 per cent level, respectively.

	(1)		**(2)**		**(3)**	
$LVTS^{B}_{t-1}$	0.52	12.44***	0.52	12.55***	0.52	12.37***
$LVTS^{B}_{t-2}$	0.19	5.53***	0.19	5.59***	0.19	5.59***
$LVTS^{B}_{t-2}$	0.23	7.11***	0.23	7.03***	0.23	7.08***
ME^{d-2}	-0.01	0.49	-0.01	0.40	-0.01	0.41
ME^{d-1}	0.05	2.79***	0.05	2.96***	0.05	3.00***
ME^{d}	0.11	3.98***	0.11	3.82***	0.11	3.78***
ME^{d+1}	0.09	2.38**	0.03	0.57	0.02	0.47
ME^{d+2}	-0.05	1.30	-0.05	1.39	-0.05	1.46
FQE^{d-2}	0.06	2.12**	0.06	2.00**	0.06	1.99**
FQE^{d-1}	0.02	0.53	0.01	0.28	0.01	0.25
FQE^{d}	0.05	1.09	0.05	0.99	0.04	0.91
FQE^{d+1}	-0.19	3.74***	-0.14	2.49**	-0.14	2.46**
FQE^{d+2}	-0.04	0.91	-0.04	0.91	-0.04	0.88
$Principal_{t}$			0.005	2.99***	0.005	3.03***
$Coupon_{t}$			0.03	2.05**	0.03	2.06**
$LVTS^{V}_{t}$			0.0001	0.52	0.0002	0.70
S^{USGC}_{t}					0.0006	1.34
Constant	0.01	0.37	-0.02	0.38	-0.02	0.44
Adjusted R^2	0.92		0.92		0.92	
N	3924		3924		3924	

Table 10: Results from tests of Hypothesis III (repo adjustments)

Tables 10 and 11 present summary statistics from OLS regressions of the spread between the CORRA and the Bank of Canada target on Abnormal Repo_t and Abnormal $\mathrm{Reverse}_t$. Each table also includes interaction terms that isolate the effect of adjustments in repo balances by type of month (FQE and FQE_{+1}) on spreads. S_t^d is the spread of the CORRA over the Bank of Canada target rate on day d of month-end period t. The d superscript denotes either the spread on the day before month-end t (S_t^{d-1}), the day of month-end t (S_t^d), or the day after month-end t (S_t^{d+1}). All spreads are measured in basis points. All independent variables are measured in billions of Canadian dollars. Table 2 (above) presents each variable in detail. The estimation is performed using Newey-West standard errors. Coefficients are shown in the left columns, and t-statistics are shown to the right of these columns. *, ** and *** represent significance at the 10 per cent, 5 per cent and 1 per cent level, respectively.

	S_t^{d-1}		S_t^d		S_t^{d+1}	
S_{t-1}^d	0.750	8.55***	0.862	12.29***	0.446	5.91***
Abnormal Repo_t	-0.039	0.90	-0.004	0.10	-0.059	1.18
Abnormal $\mathrm{Repo}_t \cdot D_{FQE}$	0.068	1.74*	-0.038	0.60	0.020	0.43
Abnormal $\mathrm{Repo}_t \cdot D_{FQE+1}$	0.041	0.78	0.003	0.05	0.031	0.60
$\mathrm{Principal}_t^d$	0.054	2.73***	0.090	2.07**	0.124	3.62***
Coupon_t^d					0.056	0.72
$\mathrm{LVTS}_t^{V,d}$	0.002	0.55	0.001	0.30	0.006	0.98
$S_t^{USGC,d}$	0.005	0.62	0.009	1.26	-0.008	0.94
Constant	-0.312	0.53	0.488	0.43	-0.984	1.10
Adjusted R^2	0.58		0.48		0.33	
N	187		187		187	

Table 11: Results from tests of Hypothesis III (reverse-repo adjustments)

	S_t^{d-1}		S_t^d		S_t^{d+1}	
S_{t-1}^d	0.747	8.01***	0.873	12.28***	0.457	5.64***
Abnormal $\mathrm{Reverse}_t$	-0.022	0.59	-0.081	1.51	0.011	0.23
Abnormal $\mathrm{Reverse}_t \cdot D_{FQE}$	0.026	0.71	0.061	0.72	0.020	0.38
Abnormal $\mathrm{Reverse}_t \cdot D_{FQE+1}$	0.014	0.43	0.043	0.95	-0.035	0.81
$\mathrm{Principal}_t^d$	0.054	2.90***	0.100	2.32**	0.128	3.39***
Coupon_t^d					0.036	0.40
$\mathrm{LVTS}_t^{V,d}$	0.003	0.64	0.002	0.35	0.005	0.89
$S_t^{USGC,d}$	0.005	0.76	0.010	1.60	-0.007	0.74
Constant	-0.387	0.67	0.436	0.40	-0.838	0.96
Adjusted R^2	0.58		0.48		0.33	
N	187		187		187	

Table 12: Results from tests of Hypothesis III (repo adjustments, instrumented)

The table presents summary statistics from a two-stage least squares regression. The dependent variable is the spread between the CORRA and the Bank of Canada target. Here Abnormal Repo_t has been instrumented. The P superscript denotes the predicted variable based on the first-stage regression in which ΔBSLR_t is used as an instrument. The d superscript denotes either the spread on the day before month-end t (S_t^{d-1}), the day of month-end t (S_t^{d}), or the day after month-end t (S_t^{d+1}). All spreads are measured in basis points. All other independent variables are measured in billions of Canadian dollars. Coefficients are shown in the left columns, and t-statistics (absolute value) are shown to the right of these columns.

	S_t^{d-1}		S_t^{d}		S_t^{d+1}	
S_{t-1}^{d}	0.753	15.64***	0.880	12.54***	0.470	8.62***
Abnormal Repo_t^{P}	0.046	0.92	0.055	0.77	0.070	0.86
Principal_t^{d}	0.057	2.62***	0.085	2.00**	0.128	4.01***
Coupon_t^{d}					0.005	0.06
$\text{LVTS}_t^{V,d}$	0.002	0.64	0.001	0.24	0.004	0.71
$S_t^{USGC,d}$	0.008	1.23	0.013	1.89*	-0.004	0.37
Constant	-0.252	0.50	0.692	0.84	-0.486	0.56
Adjusted R^2	0.57		0.46		0.27	
N	187		187		187	

Table 13: Results from tests of Hypothesis III (reverse-repo adjustments, instrumented)

The table presents summary statistics from a two-stage least squares regression. The dependent variable is the spread between the CORRA and the Bank of Canada target. Here Abnormal Reverse_t has been instrumented. The P superscript denotes the predicted variable based on the first-stage regression in which ΔBSLR_t is used as an instrument. The d superscript denotes either the spread on the day before month-end t (S_t^{d-1}), the day of month-end t (S_t^{d}), or the day after month-end t (S_t^{d+1}). All spreads are measured in basis points. All other independent variables are measured in billions of Canadian dollars. Coefficients are shown in the left columns, and t-statistics (absolute value) are shown to the right of these columns.

	S_t^{d-1}		S_t^{d}		S_t^{d+1}	
S_{t-1}^{d}	0.743	15.66***	0.870	12.52***	0.462	8.95***
Abnormal Reverse_t^{P}	0.071	0.91	0.086	0.75	0.112	0.87
Principal_t^{d}	0.048	2.21**	0.072	1.47	0.121	3.81***
Coupon_t^{d}					0.011	0.13
$\text{LVTS}_t^{V,d}$	0.002	0.62	0.001	0.14	0.004	0.87
$S_t^{USGC,d}$	0.006	1.05	0.010	1.92*	-0.005	0.48
Constant	-0.205	0.39	0.811	0.92	-0.505	0.60
Adjusted R^2	0.56		0.44		0.29	
N	187		187		187	

Appendix 2: Data Sources

To preserve confidentiality, all data are reported at the aggregate level and never at the institutional level.

Section	Data Source	Codes / Data Description	Availability
§2, §3, §4	Thomson Reuters Datastream	CN14309, CNCORRA, CNCOMMF, USORGCP, USFDTRG	Proprietary
§2, §3, §4	Bank of Canada internal database	SPRA, SRA, and TPRA auction sizes; LVTS volume and settlement balances	Public/ Non-public[39]
§2, §3, §4	OSFI: Balance Sheet Reporting Form (M4)	1045, 1065, 2355, 2357, 0503, 2225, 1202, 2212, 2604, 0633, 0634, 0665, 0666, 1059	Public
§2, §3, §4	OSFI: Monthly Average Return of Assets and Liabilities Reporting Form (L4)	0777, 0813, 0814	Non-public
§2, §3, §4	Bank of Canada website	Government of Canada bond and bill redemption data. These data were augmented with internal Bank of Canada data that updated the series for new issues and buybacks, which would not be reflected in the end-of-year reports on the Bank of Canada website.	Public
§4	Federal Reserve Bank of Chicago	End-of-quarter and average-of-quarter repo and federal funds data. BHCK3353, BHCK3365, BHCK2800, BHCK1350, BHCKB989, BHCKB995, BHDMB993, BHDMB987, BHCKA288	Public

[39] Some of these data are available on the Bank of Canada and Payments Canada websites, but the level of detail and historical data are not always available.

Appendix 3: Background on the Canadian Overnight Repo Market

The primary role of the Canadian repo market is to act as a funding market, facilitate market making and arbitrage, and allow investors to earn short-term return on their debt and equity securities (Garriott and Gray 2016).[40] The Bank of Canada also supports the implementation of monetary policy in the overnight general-collateral (GC)[41] repo market.[42] If the overnight GC repo rate quoted on inter-dealer broker screens significantly deviates from the Bank of Canada's target for the overnight rate, the Bank will intervene in the Canadian overnight repo market to reinforce the policy rate.[43] Specifically, if the rate is judged to be too high, the Bank will inject liquidity into the market by conducting repo operations, historically known as special purchase and resale agreements (SPRAs).[44] Conversely, if the rate is judged to be too low, the Bank will withdraw liquidity by undertaking reverse-repo operations, historically known as sale and repurchase agreements (SRAs).[45] When repo-market participants are unable to secure funding from their usual counterparties, they may resort to the inter-dealer broker market, where they are

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[40] See Fontaine, Selody and Wilkins (2009) for further discussion of the role of repo as a core funding market in Canada. See Fontaine, Garriott and Gray (2016) for a discussion of the role of repo in bond market liquidity.

[41] *General collateral* refers to a list of acceptable securities to be used for collateral, which include Government of Canada securities, mortgage-backed securities and others.

[42] See Engert, Gravelle and Howard (2008) for more on the implementation of monetary policy in Canada.

[43] See the section "Overnight repo and overnight reverse repo operations" in de Guzman (2016). For a discussion of the role of arbitrage activity in the implementation of monetary policy and the role played by the recent Basel III regulatory changes, see "Regulatory change and monetary policy," Committee on the Global Financial System and Market Committee (2015).

[44] On 1 October 2015, the Bank of Canada replaced SPRAs and SRAs with Overnight Repo (ORs) and Overnight Reverse Repos (ORRs), respectively. The key difference is that the operations changed from a fixed-price offering (SPRA/SRA) to a uniform-price auction (OR/ORR). The offering rate on SPRAs and SRAs was equal to the Bank of Canada target, but the rate on ORs/ORRs is an auction rate. For more details, see Overnight Repo and Overnight Reverse Repo Operations on the Bank of Canada website.

[45] These operations are typically conducted at 11:45 a.m. EST at the Bank's discretion, which encourages market participants to trade amongst themselves in the morning, but further operations can be conducted as needed. See Engert, Gravelle and Howard (2008) for more details. All Canadian Primary Dealers in Government of Canada securities are eligible, which includes the large Canadian banks. For more details, see SPRA/SRAs and Government of Canada Securities Auctions on the Bank of Canada website.

forced to pay higher rates for relatively scarce funds at month-end. Hence, this paper relies on the CORRA to estimate the level of funding pressure.

Despite the importance of repo for the implementation of monetary policy, the primary mechanism for such implementation is the Large Value Transfer System (LVTS), which is an electronic system that handles large-value payments. At the end of each day, LVTS participants settle their net obligations to each other through the transfer of settlement balances, which are held at accounts at the Bank of Canada. Should an LVTS participant face settlement balance shortfalls, the Bank of Canada can create settlement balances, which are claims on the Bank that provide overnight advances through the Standing Liquidity Facility.[46] Should an LVTS participant face a settlement balance surplus, the Bank of Canada will also hold those balances as interest-bearing deposits. The rate charged on the advances represents the upper limit of the 50-basis-point operating band for the overnight rate, and the rate paid on the positive settlement balances represents the lower limit. The target for the overnight rate, which is set at each fixed announcement date, is the midpoint of the operating band, and altogether this represents a corridor-type system for the implementation of monetary policy. [47]

The level of settlement balances in the LVTS is a tactical apparatus for monetary-policy implementation (SPRAs/ORs and SRAs/ORRs are another). Each day, the Bank of Canada decides on a target level of

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[46] See "Adjustments to the level of settlement balances" in de Guzman (2016).

[47] See Arjani and McVanel (2006) for a primer on the LVTS, and Engert, Gravelle and Howard (2008) for more details on the implementation of monetary policy by the Bank of Canada.

excess settlement balances to leave in the LVTS, thereby affecting the monetary base.[48] By adjusting the supply of settlement balances, the Bank of Canada can influence the overnight rate.[49]

The Bank also adjusts the level of settlement balances to neutralize the impact of government activity in the system. The Bank is the fiscal agent for the Government of Canada, so it also uses these auctions to earn short-term return on the government's excess short-term Canadian-dollar balances. This adjustment is accomplished through auctions of federal government balances to LVTS participants during a morning and afternoon auction known as the Receiver General (RG) auction.[50] The morning auction is fully collateralized and uses a broader pool of Canadian-dollar collateral than general collateral.[51] It is also typically far larger than the afternoon auction. The yield on the morning RG auction is communicated to market participants soon after the auction closes, so the results provide valuable early insight into market funding conditions for Canadian banks. The term on the auction varies, but it is very short-term in nature, typically ranging from one to eight days.

Historically, the Bank of Canada has published two measures of the overnight GC repo rate. The first measure is the Overnight Money Market Financing Rate (OMMFR), which is estimated using end-of-day survey data from the major participants in the Canadian overnight market (Reid 2007). It is calculated as the weighted average of each participant's submission, which is an estimate of the average rate at which

[48] The target LVTS settlement balances are posted each day on the Bank of Canada website.
[49] "The value of money is settled, like that of all of other commodities, by supply and demand, and only the form is essentially different" (Bagehot 1873).
[50] In 2002, other qualifying participants were also added to the list of eligible participants in the afternoon auction. See Reid (2007) for more details.
[51] For the list of acceptable collateral and further details of the RG auction, see "Terms and Conditions Governing the Morning Auction of Receiver General Cash Balances." Note also that, historically, the morning auction was occasionally only nearly fully collateralized.

they were able to transact in this market that day and their total volume for that day. Historically, this estimate included SPRAs and SRAs, which tended to move the OMMFR towards the target rate. The second measure is the Canadian Overnight Repo Rate Average (CORRA), which is the weighted average of overnight general-collateral repo trades that occurred through designated inter-dealer brokers between 06:00 and 16:00.[52] Approximately one-quarter of all Canadian-dollar-denominated repo transactions are intermediated by a broker (Fontaine, Hately and Walton 2017).

In general, large Canadian banks prefer to negotiate bilaterally because posting a bid or offer through an inter-dealer broker may reduce their bargaining power. The knowledge that a market participant was unable to conduct a trade bilaterally with one of the few major repo-market counterparties and was inclined to broadcast the intent to trade more broadly could be considered a tacit admission that funding is relatively scarce or that counterparties are less willing to trade. So although the OMMFR encompasses far more transactions than the CORRA and is a superior measure of the overnight GC repo rate, the CORRA is more volatile, and this variation in the data provides more information about underlying funding pressure.

For this paper, it is critical to understand the roles of and interactions between the CORRA, LVTS settlement balances and SPRAs/ORs. Carpenter and Demiralp (2008) stress the importance of understanding these institutional factors before drawing inferences about liquidity effects. They argue that by using inappropriate measures of balances (e.g., money supply, or in some cases, reserves), past studies

[52] Effective 30 March 2015, Thomson Reuters Benchmark Services Limited is the administrator, calculation agent and publication agent for the CORRA. See the Bank of Canada website for details.

have misrepresented the relationship between money and interest rates and thereby erroneously identified a liquidity puzzle. When the right relationships and variables are used, the puzzle vanishes.

Appendix 4: Background on Repos and the Leverage Ratio in Canada

Canadian banks have been subject to a leverage ratio since 1982 (Chen et al. 2012). The leverage constraint was first made more stringent in 1991 and then altered again in 2015 with the adoption of the Basel III leverage ratio.[53] In 2000, the Office of the Superintendent of Financial Institutions (OSFI) began to grant individual banks a moderate reduction in leverage limits on a discretionary basis (Bordeleau, Crawford and Graham 2009). Canadian banks report their capital ratios to regulators and investors at fiscal quarter-end.

This could create an incentive to present a more favourable snapshot of the bank on the final day of the quarter. [54] By contrast, US banks must report their leverage ratios on an average-of-quarter basis and have very little incentive to reduce repo activity at quarter-end, whereas non-US banks, which must report on an end-of-quarter basis, have significant incentives to do so. As Canadian banks report their capital ratios on an end-of-quarter basis, their incentives more closely resemble those of the latter group. Munyan (2015) added a novel and crucial nuance to the literature by separating US banks by their domicile, and thus their required reporting methodology. He finds that non-US banks operating in the United States (i.e., those that reported on an *end*-of-quarter basis) that have relatively low capital ratios seem to briefly

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[53] For details, see Leverage Requirements Guideline, OSFI, October 2014.

[54] This does not imply that banks have an incentive to oscillate between regulatory compliance and noncompliance as quarter-end comes and goes. OSFI requires that Canadian banks meet their leverage ratio requirements on a continuous basis.

remove an average of US$170 billion from the US tri-party repo market before quarter-end reporting periods to appear safer and less levered.

Canadian banks differ from their US counterparts because they follow an atypical fiscal calendar, so US and Canadian quarter-end reporting periods are not aligned. Canadian banks report their quarterly financial results, including regulatory ratios, at the end of January, April, July and October. This creates something of a natural experiment in that any leverage-ratio-driven deleveraging by Canadian banks should take place relatively independently of similar documented behaviour among US banks, which conduct financial and regulatory reporting on calendar quarter-end months (March, June, September and December).[55]

Repurchase agreements (repos) play an important role in bank leverage because they increase the size of the balance sheet, thereby increasing the exposure measure, and, *ceteris paribus*, reduce (i.e., deteriorate) the leverage ratio. Reverse repurchase agreements, however, do not.[56] Repos are deemed to be leverage creation in both economic and accounting terms, but reverse repos are regarded as collateralized lending. This treatment creates asymmetric incentives for banks between repos and reverse repos with respect to the leverage ratio.

Accordingly, if a bank sought to decrease the size of its balance sheet to improve its leverage ratio, repo would be an obvious candidate for doing so. First, the reduction of repos (bank borrowing) immediately

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[55] Most large Canadian banks also report regulatory data for their US operations, including leverage ratios, to the Board of Governors of the Federal Reserve System at FQE-1 month-ends on an average-of-quarter basis. See Form FR Y-9C for details.

[56] For a small portion of the sample (2015 to 2016), reverse repo *can* affect the leverage ratio due to regulatory add-ons for counterparty credit risk, but the effect on leverage is minor when compared with the effect of repo. See OSFI's Leverage Ratio Requirements for details.

reduces the size of the balance sheet. Second, as short-term wholesale funding, repo contracts can be scaled up and scaled down quickly compared with most other balance-sheet items.

Conversely, a bank cannot use reverse repos on their own to substantially reduce its leverage ratio.[57] The reduction of reverse-repo balances would merely result in a reclassification of balance-sheet assets, not a reduction. It is instructive then to observe that in Figure 3 repo balances are curtailed at fiscal quarter-end to a much greater degree than are reverse-repo balances.

Nonetheless, Figure 3 also shows that reverse-repo balances follow this same reduction pattern at fiscal quarter-end. First, this reduction in reverse repo may be a corollary of banks' reduction of repo and balance-sheet reductions more broadly. If funding becomes increasingly scarce around fiscal quarter-end periods, banks may become more reluctant to lend these balances. Second, a portion of these reductions may be merely an accounting construct rather than a true reduction in repo balances as repo and reverse repo can be netted for accounting purposes.

The current leverage-ratio requirement allows for limited netting between repos and reverse repos if certain strict criteria are met.[58] The repos and reverse repos must be with the same counterparty, have the same maturity date, settle through the same settlement system, have a legally enforceable right to set off the amounts, and intend either to settle on a net basis or to realize the asset and settle the liability simultaneously. Historically, some US banks have relied on this strategy to reduce the reported size of repo and reverse repo under Financial Accounting Standards Board Rule FIN 41. The rules under US

[57] One notable exception is the United Kingdom. The Bank of England's Financial Policy Committee (FPC) excludes central bank reserves from the exposure measure in the UK leverage ratio framework. Hence, in some cases, reverse repos could lead to a deterioration in the leverage ratio. See the following FPC statement for details.
[58] See Basel Committee on Banking Supervision (2014) and OSFI (2014) for a discussion of the restrictions, and Fender and Lewrick (2015) for further discussion.

generally accepted accounting principles and the International Financial Reporting Standards are different, but both allow for such netting. If Canadian banks are also able to net significant amounts of repo for accounting purposes, this could explain a portion of the reductions observed at quarter-end periods.

Finally, although not the focus of this paper, it should be acknowledged that Canadian banks' capital adequacy requirements may also create incentives to reduce repo and reverse repo at fiscal quarter-end. The ratios are defined by the ratio of a capital measure to a measure of risk-weighted assets. Banks must meet a minimum ratio of the former to the latter. This includes the total capital ratio, the tier-one capital ratio and, more recently, the common-equity tier-one capital ratio. This applies to the full sample period since minimum capital adequacy requirements were introduced in Canada in 1994 as part of the 1988 Basel I accord. The requirements were periodically raised and revised as part of the Basel II and Basel III agreements over the sample period (Chen et al. 2012).

Riskier activities at banks, such as capital-markets operations, tend to raise banks' risk-weighted assets. An increase in risk-weighted assets will, *ceteris paribus*, lower capital adequacy ratios. Further, repo and reverse repo conducted in conjunction with risky counterparties tend to raise risk-weighted assets. Repo is also occasionally used to fund riskier operations, and reverse repo may be used to bring assets onto banks' balance sheets to support shorting activity. If banks' capital adequacy ratios were to deteriorate, they could opt to curtail riskier operations in order to reduce risk-weighted assets. Accordingly, repos and reverse repos could be expected to fall commensurately. Internal risk limits such as value-at-risk limits, which are also monitored by regulators, could play a similar moderating role.