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Estimating the Appropriate Quantity of Settlement Balances in a Floor System

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Abstract

In April 2022, the Bank of Canada announced that it would continue to use a floor system to implement monetary policy by providing a sufficiently large quantity of settlement balances to enable the overnight repo rate to trade at close to the deposit rate. In contrast, the Bank's guiding principles of prudence, transparency and neutrality, which govern the management of its balance sheet, favour maintaining settlement balances as low as possible. In this context, this paper describes two complementary approaches to estimating the appropriate quantity of settlement balances needed to effectively maintain a floor system. The first is a regression-based analysis to estimate the quantity required to maintain the overnight repo rate close to the Bank's policy interest rate (which is equal to the deposit rate in a floor system). The second is an analysis of operational considerations in implementing a floor system in Canada. Both approaches highlight that considerable uncertainty exists in determining the demand for settlement balances. Such uncertainty emphasizes the need for the Bank to monitor money market conditions as it continues to normalize its balance sheet after undertaking quantitative easing operations related to the COVID-19 pandemic.

Topics: Financial institutions, Financial markets, Financial system regulation and policies, Monetary policy implementation, Payment clearing and settlement systems

JEL codes: E41, E42, E52, E58, G21, G28

Résumé

En avril 2022, la Banque du Canada a annoncé qu'elle continuerait de baser la mise en œuvre de la politique monétaire sur un système de valeurs plancher en offrant une quantité suffisante de soldes de règlement pour que le taux des opérations de pension à un jour se négocie aux alentours du taux de rémunération des dépôts. En revanche, les principes directeurs de la Banque – la prudence, la transparence et la neutralité –, qui régissent la gestion de son bilan, privilégient le maintien des soldes de règlement au niveau le plus bas possible. Dans ce contexte, nous proposons deux approches complémentaires afin d'estimer la quantité appropriée de soldes de règlement nécessaire au maintien efficace d'un système de valeurs plancher. La première approche consiste en une analyse de régression visant à estimer la quantité de soldes de règlement requise pour maintenir le taux des opérations de pension à un jour près du taux directeur de la Banque – qui, dans un système de valeurs plancher, correspond au taux de rémunération des dépôts. La seconde approche consiste en une analyse des considérations opérationnelles lors de la mise en œuvre d'un système de valeurs plancher au pays. Les deux approches mettent en lumière la forte incertitude qui règne lorsque l'on tente de déterminer la demande de soldes de règlement. Cette incertitude fait ressortir le besoin pour la Banque de surveiller les conditions sur le marché monétaire, alors qu'elle continue de normaliser son bilan après avoir effectué des opérations d'assouplissement quantitatif en réaction à la pandémie de COVID-19.

Sujets : Institutions financières; Marchés financiers; Réglementation et politiques relatives au système financier; Mise en œuvre de la politique monétaire; Systèmes de compensation et de règlement des paiements

Codes JEL : E41, E42, E52, E58, G21, G28

1. Introduction

In April 2022, the Bank of Canada announced that it would continue to use a floor system to implement monetary policy for the foreseeable future.[1] It further stated that the "longer-run level of settlement balances is yet to be determined, but it is far lower than the current level [around $230 billion at the time]." Several factors contributed to the decision to remain in a floor system, rather than revert to a corridor system for monetary policy implementation. These factors include an increase in the demand for safe assets; changes to payment, clearing and settlement systems in Canada; and the impact of quantitative easing on how the Bank implements monetary policy (see Gravelle, Morrow and Witmer 2023).

While a corridor system can be operated with a near-zero level of settlement balances, a floor system requires a larger quantity of settlement balances to promote trading near the deposit rate.[2] The Bank currently implements a floor system with between $160 billion and $180 billion in settlement balances. As the Bank continues to normalize its balance sheet after undertaking quantitative easing operations related to the COVID-19 pandemic, the amount of settlement balances will naturally decline. This decline can continue as long as the Bank assesses that it can effectively operate a floor system where the overnight repurchase agreement (repo) rate trades close to the deposit rate, which is also the Bank's target for the overnight repo rate (the target or policy rate).

This staff discussion paper sets out two complementary approaches to estimating the quantity of settlement balances needed from the perspective of effectively operating a floor system in Canada. On the one hand, if the Bank sets the quantity of settlement balances too low, the overnight rate could significantly and persistently deviate above its target. On the other hand, if the quantity is too high in non-stressed periods, the Bank may have a larger balance sheet and fixed-income-market footprint than intended by the three key principles of prudence, transparency and neutrality that govern the management of the Bank's balance sheet.

We first discuss a conceptual framework for determining the optimal level of settlement balances. This framework trades off some of the benefits and costs of a larger quantity of settlement balances and shows how they depend on a variety of factors including the regulatory environment, participants' liquidity preferences and the gross quantity of government debt outstanding. We then consider two methods to estimate the steady-state quantity of settlement balances required in a floor system. The first uses a regression analysis estimated on Canadian money market quantities and repo rates. The second looks at operational considerations in implementing a floor system, based on internal analysis as well as discussions the Bank has had with participants in Lynx, Canada's high-value payments system.

[1] See Bank of Canada, "Bank of Canada provides operational details for quantitative tightening and announces that it will continue to implement monetary policy using a floor system" (market notice, April 13, 2022).
[2] Chu et al. (2022) provide an overview of settlement balances, including how the Bank adjusts their level for monetary policy implementation.

The two approaches suggest a range for the steady-state level of settlement balances between $20 billion and $60 billion, based on current institutional arrangements.[3] This is consistent with the range provided by Deputy Governor Gravelle in a recent speech (Gravelle 2023). While the first approach relies on several modelling assumptions, its value lies in arriving at an estimate of an appropriate range by trading off the social costs and benefits of settlement balances. The approach also highlights that this range depends on the external environment (e.g., the quantity of government debt outstanding). The second approach complements the first by leveraging the Bank's experience with monitoring settlement balance demand as well as including feedback from payment system participants.

Nevertheless, uncertainty remains in determining financial intermediaries' demand for settlement balances. Therefore, it is important for the Bank to continue to monitor money market conditions and maintain conversations with market participants as it transitions to the steady state. For example, if market participants' demand for settlement balances is higher than anticipated, the Bank would adjust upward the estimated steady-state quantity needed. This could happen if there are signs that settlement balances are below their appropriate level, such as persistent upward pressure on the Canadian Overnight Repo Rate Average (CORRA;) above the target rate.[4]

2. A framework for determining the optimum quantity of settlement balances

Witmer (forthcoming) builds on work by Martin et al. (2019) to estimate the optimum steady-state quantity of settlement balances, using a conceptual framework that trades off the benefits of additional settlement balances against the costs of creating them.[5] In this framework, the cost of creating settlement balances is that assets the private sector values are removed from the market. This happens because the Bank of Canada creates settlement balances, a liability on its balance sheet, by purchasing assets from the private sector, such as Government of Canada Treasury bills and bonds. For example, when the Bank of Canada buys $100 of Government of Canada bonds from the private sector, it pays for them using $100 of settlement balances.

In this framework, the optimum quantity of settlement balances occurs when the marginal social cost of additional settlement balances equals their marginal social benefit. The conceptual framework assumes that the private sector derives convenience benefits from holding government bonds or bills (e.g.,

[3] This estimate may vary, for instance, based on modifications of the Bank's operational tools or if there is a change in bank regulations.

[4] CORRA is a measure of the cost of overnight general collateral funding in Canadian dollars using Government of Canada treasury bills and bonds as collateral for repo transactions. See Bank of Canada, "Methodology for calculating the Canadian Overnight Repo Rate Average (CORRA)" for additional information.

[5] In Martin et al. (2019), the optimal quantity of reserves trades the liquidity benefits of reserves off against the costs incurred by commercial banks to hold them on their balance sheet. Witmer (forthcoming) achieves a similar result with different modelling choices that enable the model to be calibrated empirically. An alternative approach, taken by Lagos and Navarro (2023), emphasizes the heterogeneity in the benefits of holding reserve balances in a framework incorporating search frictions in the market for overnight lending.

Krishnamurthy and Vissing-Jorgensen 2012). These benefits could include the use of these securities for collateral and hedging purposes. As such, any action to remove these securities from the private sector's hands is viewed as a societal cost. The marginal social cost of settlement balances is equal to the loss of the convenience benefit of the government bonds or bills the Bank of Canada removes from the private sector. The marginal social benefit of settlement balances is twofold. First, banks derive liquidity benefits from their holding of settlement balances since they are generally a lower-cost source of liquidity to facilitate payment flows or can be used as a high-quality liquid asset for regulatory purposes.[6] Second, as pointed out in Acharya and Rajan (2022), when banks hold a greater quantity of settlement balances, their level of deposits may increase as a result. Witmer (forthcoming) assumes that bank clients derive liquidity benefits from these additional deposits because it helps them facilitate payment flows. Assuming banks are capital-constrained, this increase in deposits would be less than one-for-one with the increase in settlement balances. (Therefore, banks may view this as costly since they must partially fund their increase in settlement balances with equity.)

This simplified framework does not include other marginal social costs associated with larger settlement balances. One such cost, emphasized in Sims (2013) and Cavallo et al. (2019), is the maturity mismatch on a large central bank balance sheet. This is a source of risk for the central bank's net worth and monetary policy independence. In other words, Witmer (forthcoming) assumes that the resulting quantity of settlement balances in this simplified framework is not large, and thus the marginal social costs of these risks is likely to be small. Neither does this framework consider the impact of settlement balances on financial stability analyzed in Greenwood, Hanson and Stein (2016) and market functioning pointed out in Logan and Bindseil (2019). Finally, Witmer (forthcoming) also abstracts from the real effects of the central bank balance sheet size treated, for example, in Bigio and Sannikov (2021).

Witmer (forthcoming) shows that, at the optimum, the expected return on government bonds would be close to the expected return on settlement balances, which is the Bank's deposit rate in a floor system.[7,] [8] The intuition from the model is that the expected nominal return on financial assets reflects the marginal liquidity benefit of holding that asset noted above. If one asset has a lower nominal return than another (adjusted for differences in risk), the model infers that the private sector derives more liquidity benefits from holding the lower-yielding asset. For example, if the yield on short-dated Treasury bills was below the expected return to holding settlement balances, the model would infer that the private sector derives a higher convenience benefit from holding Treasury bills over settlement balances and that removing settlement balances and providing more Treasury bills to the market would be optimal. This could be, for example, because a wider set of private-sector market participants can hold Treasury

[6] In the absence of settlement balances, banks would need to access alternative sources of liquidity such as overnight loans.

[7] For simplicity, the model assumes that the Bank of Canada holds only government bonds and Treasury bills, but this could be extended to other asset classes. The model does not consider the social costs of the credit risk exposure of the central bank; it instead assumes that the central bank is constrained from holding corporate bonds or other assets. The arguments for other asset classes are similar, though extending the model to consider them could change the optimum quantity.

[8] In some cases, the central bank may be constrained and cannot implement this optimum. For example, the central bank may have no Treasury bills, yet it could still be optimal for the market to have more Treasury bills and fewer reserves. In this case, the central bank is constrained because it can't hold negative Treasury bills. Since there is a lower supply of Treasury bills to the market, there would be a lower Treasury bill yield relative to the case when the central bank is not constrained.

bills than hold settlement balances, or alternatively, that Treasury bills can more readily be used as collateral (thus generating greater liquidity/convenience benefits) than settlement balances. By similar arguments as above, at the optimum, banks' reverse repo lending rates would equal the expected return to holding settlement balances, which is approximately equal to the deposit rate in a floor system.

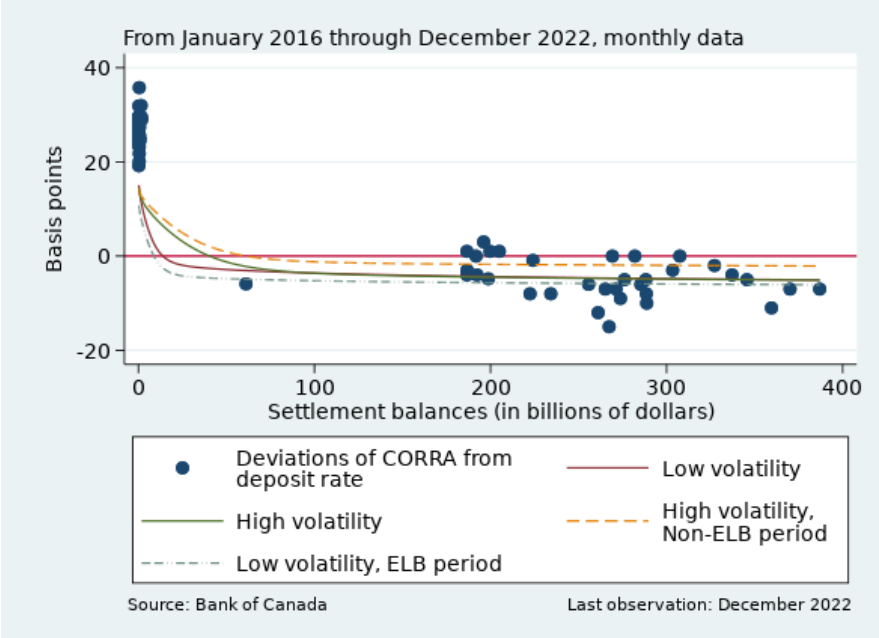
Translating these optimum returns into an optimum quantity of settlement balances requires estimating demand curves for the different assets. The demand for different short-term financial assets such as settlement balances and Treasury bills are driven by various factors including bank capital regulation as well as the preferences for liquidity described above. In Witmer (forthcoming), the optimum quantity fluctuates as participants' liquidity preferences fluctuate and as gross government bond issuance changes.

3. Estimating the demand for settlement balances

In this section we use a regression framework to estimate the demand for settlement balances. Rather than estimating a demand curve for every asset, we take a simpler approach and focus only on a repo demand curve. We label the point on the estimated demand curve at which CORRA equals the Bank's deposit rate as an "appropriate" quantity of settlement balances since it would be consistent with the effective implementation of monetary policy in a floor system. It would also be consistent with the optimal quantity of settlement balances if the expected return on settlement balances (and the expected overnight return on government bonds and bills) is equal to the Bank's deposit rate.

First, we estimate the demand for settlement balances using an ordinary least squares (OLS) regression using monthly data from January 2016 through December 2022. **Chart 1** plots the observed relationship between the quantity of settlement balances and deviations of CORRA from the deposit rate. It shows that overnight repo yields were close to the deposit rate for a wide range of the level of settlement balances—emphasizing that the demand in the overnight repo market varied significantly over time. To account for this potential time-varying demand, we use the data in Chart 1 to estimate four different demand curves, with different assumptions underlying each of them (see Box 1 for details on the estimation). These demand curves are overlayed on top of the data in Chart 1.

Chart 1: Repo yields and the quantity of settlement balances



Note: The "Low volatility" demand curve is estimated using the results in Column (1) of Table 1-A, whereas the "High volatility" demand curve is estimated using the results in Column (5). "Low volatility, ELB period" is estimated using the results in Column (2) with the effective lower bound (ELB) set to equal 1. "High volatility, Non-ELB period" is estimated using the results in Column (6) with ELB set to equal 0. CORRA is the Canadian Overnight Repo Rate Average.

Second, we use these estimates to illustrate how the demand curve and the appropriate level of settlement balances are sensitive to modelling choices. For example, the demand curve estimated on the post–effective lower bound (post-ELB) sample lies above the demand curve from the ELB sample, indicating that the demand for settlement balances may have increased recently, relative to the demand for repo collateral. The appropriate level of settlement balances occurs when the deviation of the overnight repo rate from the deposit rate is close to zero. In Chart 1, this would be where the demand curve intersects the x-axis. Since estimates in the post-ELB sample indicate a higher demand for settlement balances, Chart 1 shows that they also suggest a higher optimum quantity of settlement balances.

The estimated model suggests that a range of settlement balances between about $10 billion and $60 billion would keep CORRA close to the Bank's deposit rate, depending on assumptions about the relationship between settlement balances and the overnight rate.[9] Given that the overnight repo rate has recently traded close to the deposit rate, the conceptual framework would infer that the current level of settlement balances may already be close to "appropriate," and our range could be

[9] In particular, it is possible that demand for settlement balances adjusts to supply, which is not captured in the conceptual framework. This could lead to some temporary upward pressure on the overnight rate before it subsides as demand adjusts to a reduced quantity of settlement balances. As emphasized throughout this paper, the Bank should continuously monitor market conditions to identify whether such deviations are temporary or are reflective of deeper structural factors leading to a higher-than-anticipated steady-state demand.

underestimated. However, it is possible that demand for settlement balances adjusts to supply, which is not captured in the regression analysis. As settlement balances decline, this could lead to some temporary upward pressure on the overnight rate before it subsides when demand adjusts to the lower quantity.

This analysis has two main caveats. First, the estimates of the demand curve are based on historical data and may not reflect the future demand for settlement balances since liquidity preferences, bank regulation and the government debt supply have changed or will likely change. Second, the Bank of Canada has limited historical experience with settlement balances between $10 billion and $170 billion, so the regression has too few data points to precisely estimate the demand curve in the range where the appropriate level of settlement balances possibly resides. Given these caveats, in the next section we consider another approach to estimating the appropriate quantity. The second approach accounts for other factors—such as operational considerations—that may be important in determining the appropriate range of settlement balances.

Box 1

Estimating the relationship between settlement balances and CORRA

We use OLS regressions to estimate the relationship between CORRA and settlement balances. We collect month-end data on CORRA, the deposit rate and settlement balances for the sample period from January 2016 through December 2022 from the Bank of Canada's website. The CORRA spread is measured as:

CORRA spread = CORRA – deposit rate

$$- (\text{Bank rate} - \text{deposit rate}) * (1-1/(1+\exp(-\text{settlement balances}/s))). \qquad (1\text{-}A)$$

The adjustment to CORRA attempts to undo the "mechanical" inverse relationship between the CORRA spread and the level of settlement balances due to changes to the monetary policy implementation framework.[10] For a better intuition of the adjustment, note that it reduces the CORRA spread by half the width of the corridor when settlement balances are zero, and leaves the CORRA spread unadjusted when they are "infinitely high". More generally, this term applies a smooth and rapidly decreasing downward adjustment to the CORRA spread as the settlement balance increases.

Motivated by Lopez-Salido and Vissing-Jorgensen (2023), the first regression estimates the relationship between this CORRA spread and the logarithm of settlement balances:[11]

[10] For tractability, the adjustment to the CORRA spread is assumed to follow a logistic distribution for the daily change in settlement balances. In this equation, s is a scale parameter that is a measure of the spread of the distribution of *daily* changes in settlement balances. We set s = $5 billion, s = $10 billion and s = $20 billion in our measurement of the CORRA spread (for comparison, the standard deviation of *weekly* settlement balance changes is about $10 billion over our sample period).

[11] This is a simplified version of the regression in Lopez-Salido and Vissing-Jorgensen (2023) since it uses OLS instead of an instrumental variables framework and does not include the logarithm of deposits as an explanatory variable. In unreported results, the logarithm of deposits is not a significant explanatory variable in Canada.

$$\text{CORRA spread}_t = \alpha + \beta \ln(\text{settlement balances}_t) + \varepsilon_t. \quad (2\text{-A})$$

The results are presented in Table 1-A. There is a significant negative relationship between settlement balances and the CORRA spread: doubling the level of settlement balance is associated with a reduction of 0.7 basis points (bps) in the adjusted CORRA spread. Further, for a wide range of assumptions about the spread of the distribution of daily changes in settlement balances used in the analysis (s = $5 billion, s = $10 billion and s = $20 billion), the relationship between CORRA and settlement balances is stable. The constant term suggests that the adjusted CORRA spread would be about 1–2 bps when the settlement balances are close to zero.

Finally, to illustrate the potentially time-varying demand for settlement balances not captured in the framework of Witmer (forthcoming), columns 2, 4 and 6 include a dummy variable for the ELB period. The coefficient on this variable indicates that the CORRA spread was about 4 bps lower during the ELB period, after controlling for the size of settlement balances.

Table 1-A: The relationship between settlement balances and the CORRA spread

	s = 5		s = 10		s = 20	
	(1)	(2)	(3)	(4)	(5)	(6)
Ln (settlement balances)	-0.011***	-0.006***	-0.010***	-0.006***	-0.010***	-0.005***
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
ELB		-0.041***		-0.040***		-0.040***
		(0.015)		(0.015)		(0.015)
Constant	0.014**	0.018***	0.009**	0.013***	0.007**	0.011***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)

Note: Month-end data on CORRA, the deposit rate and settlement balances are from January 2016 through December 2022. The dependent variable in these regressions is the adjusted CORRA spread. This adjustment is made assuming a logistic distribution in daily changes in settlement balances with a scale parameter s. s=5 in columns (1) and (2), s=10 in columns (3) and (4), and s = 20 in columns (5) and (6). The independent variables include the logarithm of aggregate settlement balances, Ln (settlement balances), as well as a dummy variable (ELB) that takes the value of 1 when the target rate is at the effective lower bound of 25 basis points. *** indicates statistical significance at the 1% level, and ** indicates statistical significance at the 5% level.

Source: Bank of Canada

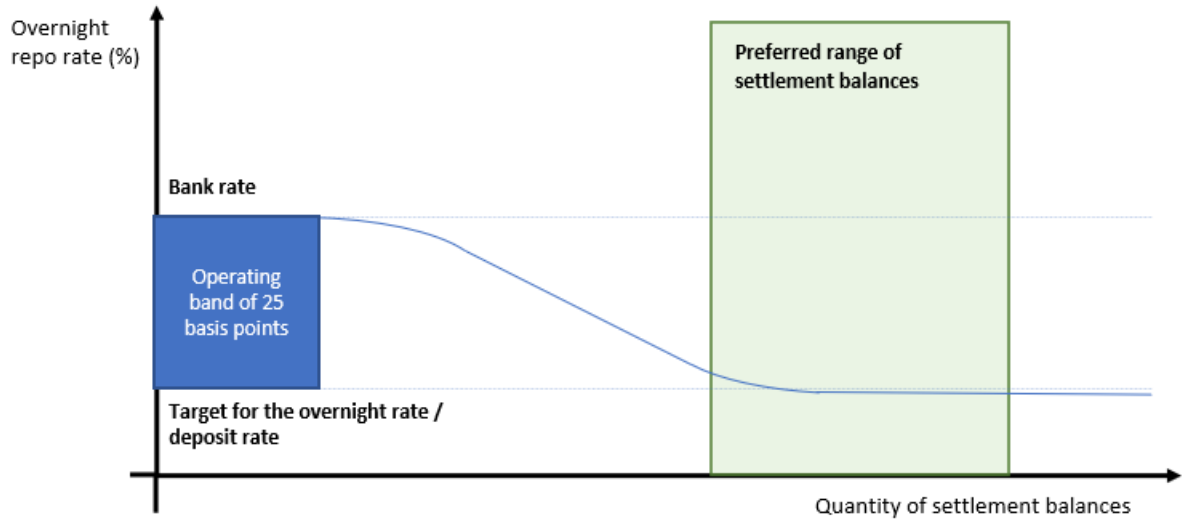
4. Operational considerations for estimating the appropriate quantity of settlement balances

Since March 2020, the Bank of Canada has conducted monetary policy using a floor system, where it aims to maintain its target for the overnight repo rate at the rate it accepts on overnight deposits from Lynx participants (i.e., the deposit rate). Under the floor system, although the Bank does not target a

specific level of settlement balances, it must ensure that the level is more than enough to meet demand from Lynx participants. If settlement balances are plentiful, the expectation is that they would be widely available. This means that all Lynx participants would generally have positive settlement balances at the end of the daily payment cycle, which they would then have to deposit with the Bank overnight and earn the Bank's deposit rate.[12] If the level of settlement balances is insufficient, a Lynx participant may find themself short and unable to borrow from another participant, which would require them to take an overnight advance from the Bank at the Bank rate (i.e., the target rate plus 25 basis points). An insufficient level of settlement balances could also lead to sustained pressures on the overnight repo market.

Figure 1 depicts the relationship between settlement balances and the overnight repo rate in a floor system. This diagram shows that when settlement balances are very low, financial institutions are expected to transact at an overnight repo rate close to the Bank rate. As settlement balances increase, the overnight repo rate will likely gradually decline toward the deposit rate. Eventually, once settlement balances are large enough to satisfy demand from financial institutions, the overnight repo rate is expected to transact close to the Bank's deposit rate.

Figure 1: Settlement balances in a floor system



The Bank will aim to keep settlement balances within a range above the minimum level needed to satisfy the demand of Lynx participants; however, there is considerable uncertainty around the preferred range of settlement balances (PRSB) that would ensure that the overnight repo rate is close to the Bank's target. In terms of Figure 1, this means that the range of the PRSB is not precisely known. The framework presented in Section 3 identifies this as the quantity limiting the deviation of the overnight repo rate from target. Here, we take two complementary approaches to estimating the PRSB.

[12] Other financial institutions that are not Lynx participants can deposit their excess balances with a Lynx participant but will likely earn an interest rate below the target rate. Given this, non-Lynx financial institutions have an incentive to place their funds in the overnight funding market where they can earn returns potentially closer to the deposit rate.

First, we use a survey of Lynx participants conducted in the summer of 2023 to obtain estimates of the aggregate demand for settlement balances. The survey approach for estimating the level of settlement balances suggests that the aggregate demand by Lynx participants could be between $55 billion and $85 billion. More generally, survey respondents expressed the opinion that the Bank should target the upper end of the $20 to $60 billion range that was previously communicated by Deputy Governor Gravelle (Gravelle 2023). The survey also indicates that regular payment activity is the key driver for the demand of settlement balances.

Second, the Bank's guiding principles of prudence, transparency and neutrality for managing the Bank's balance sheet favour maintaining settlement balances as low as possible while effectively implementing monetary policy. Consistent with this preference, we use another approach that analyzes how settlement balances are used in the payment systems based on observations of how liquidity is used in Lynx. The approach also considers how flows into the other major liabilities on the Bank's balance sheet can lead to drawdowns in the amount of settlement balances. Using this approach, we estimate that the Bank could operate in a floor system with a range of settlement balances (i.e., PRSB) between $20 billion and $55 billion. We offer further details in the sections below.

4.1 Demand for settlement balances based on use in payment systems

A synthesis of the current evidence suggests that the level of settlement balances does not significantly affect the efficiency of large-value payments systems, including Lynx (please see the appendix for details). Settlement balances are one source of liquidity used by Lynx participants to meet their payment obligations. As such, in the absence of settlement balances, the Lynx payment system can still operate efficiently given that its participants have access to other sources of liquidity—including incoming payments, intraday loans and overnight advances from the Bank of Canada, and loans from other financial institutions.[13]

Even though settlement balances do not appear to be closely tied to payment system efficiency, they are important for the effective implementation of monetary policy in a floor system. In other words, the Bank must ensure the level of settlement balances is large enough to fully satisfy the demand of Lynx participants to mitigate the risk of the overnight repo rate deviating persistently from target. This demand can be separated into two components: demand to fully fund regular payment activity and demand for other reasons, including diversification, regulatory purposes and risk management against funding large or unexpected payment flows. Both components are important to consider. For example, if not enough settlement balances exist to satisfy all the Lynx participants' needs (whether for regular payment activity or other uses), there could be competition to obtain the settlement balances, which may lead to upward pressure on the overnight repo rate.

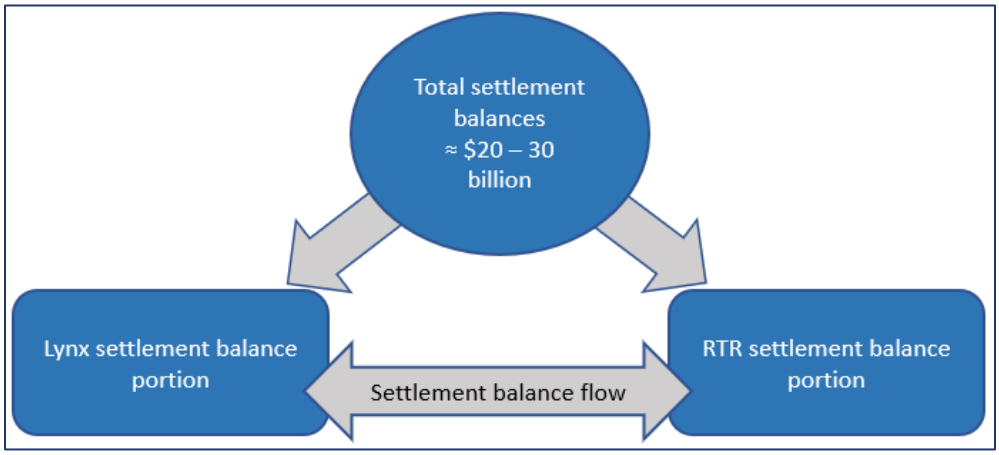
Based on observations of how participants use liquidity in Lynx, we estimate that $20 billion to $30 billion of settlement balances are likely sufficient for participants to fund their regular daily Lynx payment activity. This is based on participants maintaining aggregate liquidity between $20 billion and

[13] Note that the introduction in August 2021 of the Lynx payment system (a real-time gross settlement model) to replace the Large Value Transfer System was not a driver for the Bank to maintain a higher level of settlement balances. In anticipating potentially higher liquidity needs for Lynx, the Bank expanded the set of eligible collateral under its Standing Liquidity Facility to enable participants to obtain more payment system liquidity (via intraday loans) if needed.

$30 billion from 8 a.m. to 6 p.m. in the liquidity saving mechanism (LSM) in Lynx, through which almost all Lynx payments (and payment value) are settled.[14]

In the future, settlement balances will also be used by financial institutions to settle payments in Canada's real-time payment system, the Real-time Rail (RTR), once it is deployed.[15] However, we believe the level of settlement balances required for the RTR will be much less than that required for Lynx since the overall payments settled through the RTR are expected to be significantly lower than those through Lynx.[16] Overall, this means that the $20 billion to $30 billion range of settlement balances estimated above will be distributed between Lynx and the RTR, with the majority of balances being allocated for processing payments in Lynx, rather than the required range of settlement balances being raised materially higher. The distribution of settlement balances between Lynx and the RTR is illustrated in **Figure 2**.[17]

Figure 2: Distribution of settlement balances between payment systems



Note: Settlement balances can flow back and forth between Lynx and the Real-time Rail (RTR) during specific funding windows when Lynx is open. Most settlement balances are expected to be held in Lynx.

Even though the expectation is that the RTR will use much fewer settlement balances than Lynx, estimating the settlement balances required for operating the RTR is challenging because the RTR has not yet been deployed. Specifically, the total value of payments that will be settled in the RTR on a day-

[14] Lynx participants receive their settlement balances from the Bank of Canada into their LSM soon after the opening of the Lynx cycle at 12:30 a.m. By 8 a.m., nearly all Lynx participants move a proportion of their settlement balances out of their LSM into another Lynx account and maintain only the settlement balances in their LSM that they prefer to hold to effectively operate for the Lynx cycle. Hence, we use the 8 a.m. to 6 p.m. period to estimate the settlement balances needed for regular payment activity. Details on how the Lynx payment system works are available in an overview published by the Bank of Canada and Payments Canada (2022).

[15] The RTR will be Canada's new 24/7 real-time payment system. RTR Direct Settlement Participants will maintain settlement accounts at the Bank of Canada, which they will need to fund with settlement balances to have liquidity for settling RTR payments.

[16] RTR participants can only fund their account with a cash payment from Lynx (i.e., settlement balances). Unlike in Lynx, RTR participants cannot obtain a collateralized loan from the Bank to fund their payment activity in the RTR.

[17] It is worth noting that participants will earn the deposit rate on settlement balances held in either their Lynx account or their RTR account. Therefore, the interest rate that participants earn on their settlement balances will not be a factor influencing them to hold their balances in Lynx or the RTR.

to-day basis is uncertain, as is the balance RTR participants will maintain in their RTR settlement accounts to settle their payments plus provide for a precautionary buffer. Initially, RTR payment flows are expected to be relatively small but could grow over time if more payments migrate to the RTR.[18] If there is considerable growth or if the number of RTR participants increases, the level of settlement balances may also need to grow.

Aside from regular payment activity, estimating demand for other purposes, such as risk-management, diversification and regulatory needs, is very difficult based on observations of how liquidity is being used in Lynx. It is possible that the $20 billion to $30 billion used in the LSM captures some of the demand for other purposes but potentially not all. This is because not all Lynx participants manage their LSM balances in the same way. Some prefer to maintain minimal levels, while others may hold liquidity far beyond what they are likely to need for regular payment activity. Ultimately, given the difficulty with estimating the demand for other purposes, we use $20 billion–$30 billion as an estimate for the aggregate demand by Lynx participants.

4.2 Accounting for drawdowns in settlement balances by maintaining an operating buffer

The key driver of fluctuations in the level of settlement balances is changes to the Receiver General account, where the Government of Canada maintains its deposits with the Bank of Canada. This account fluctuates daily due to payments to and from the Government, which have an opposite effect on the level of settlement balances. For example, a large bond maturity or tax disbursements lead to the Government's deposits with the Bank decreasing, which increases settlement balances. In contrast, a large bond issuance or other major inflow increases deposits and leads to settlement balances declining. The Receiver General account is expected to fluctuate daily by less than $10 billion for most days but could see swings above $25 billion in some cases.

Other Bank of Canada balance sheet flows can also lead to fluctuations in settlement balances but generally to a much lesser extent than the Receiver General account. One source of these balance sheet flows is changes to the deposits of the Bank of Canada's client accounts.[19] Another balance sheet flow that can have a material impact is the daily change in bank notes outstanding, which is funded by settlement balances. While deposits by client accounts and changes in bank notes together typically result in settlement balances fluctuating daily by less than a few billion dollars, in extreme instances, the flows could lead to settlement balances changing by several billion dollars.

The fluctuations in the Bank's balance sheet flows can be large and difficult to forecast. Therefore, the Bank should exercise prudence by managing settlement balances with an operating buffer to account for drawdowns due to the Bank's balance sheet flows. In the floor system, the Bank does not need to hit a specific settlement balance target and therefore does not rely on the daily fine-tuning operations, such

[18] Interac e-Transfers are currently expected to be the only payment types settled through the RTR when it is deployed. As outlined in the "Bank of Canada Oversight Activities for Financial Market Infrastructures: 2022 Annual Report" (2023), the daily average value processed by Interac e-Transfer for 2022 was about $1 billion. Based on the RTR settling $1 billion–$2 billion when it is deployed, we expect between $1 billion and $5 billion in settlement balances will more than suffice for RTR purposes. Notably, the growth in the RTR daily average value settled over time is uncertain: it could remain relatively modest or increase substantially if many new payment types migrate to the RTR.

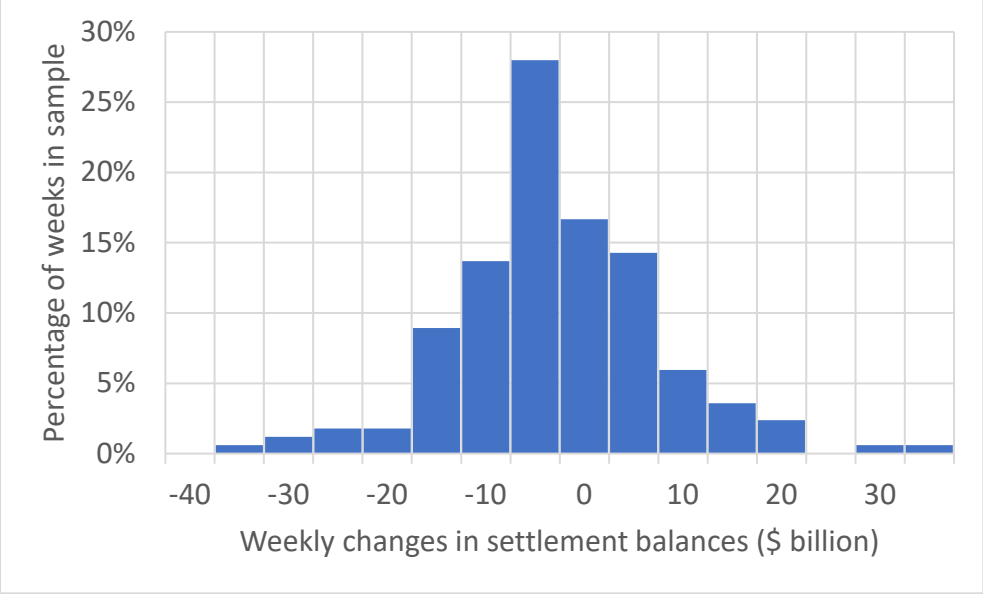
[19] These clients include financial market infrastructures, foreign central banks, international financial institutions and other domestic federal government agencies.

as Receiver General auctions used under the corridor system. Instead, the Bank would only need to provide a minimum level of balances to satisfy the demand of payment system participants. By providing an operating buffer beyond what is required to satisfy participant demand, the Bank would enable settlement balances to fluctuate within a range (the PRSB, as identified in Figure 1) and use fewer operational interventions. To support the balances staying within the PRSB and maintain the overnight repo rate close to target, the Bank can use operational tools as needed, such as conducting repos or issuing cash management bills with multiple tranches.[20] However, these tools are expected to be used much less frequently than the daily fine-tuning operations used under the corridor system.

At this point, we estimate this operating buffer to be up to $25 billion. Our estimate is based on **Chart 2**, which shows that the fall in settlement balances on a weekly basis due to changes in the Receiver General account, bank notes, and other deposits was less than $25 billion in over 97.5% of the weeks between April 2020 and May 2023. To be able to operate under a floor system, we expect the Bank to keep settlement balances high enough to avoid the overnight repo rate persistently deviating from the target rate. That said, the level of settlement balances demanded by participants is dynamic, i.e., participants' demand for them may adjust to supply. As the Bank better understands how settlement balances will fluctuate at lower levels than today and more fully understands the operational tools it will leverage to operate effectively in a floor system, it may be able to reduce the operating buffer.

Chart 2: Weekly changes in settlement balances due to changes in bank notes, Receiver General deposits and other deposits

From 1 April 2020 through 14 June 2023, weekly data



Note: Other deposits include deposits of other financial institutions, other organizations and unclaimed balances remitted to the Bank in accordance with governing legislation.

Source: Bank of Canada, "Bank of Canada assets and liabilities: Weekly (formerly B2)"

[20] Multi-tranche cash management bills can limit fluctuations in settlement balances by having their settlement and maturity dates occur on days that offset large government cash and payment flows.

4.3 Estimated range of settlement balances

Altogether, from an operational perspective, we expect a range of settlement balances between $20 billion and $55 billion may be appropriate. This amount considers the demand for settlement balances by payment system participants to be from $20 billion to $30 billion, based on observations of how they are used in the payment system. It also accounts for an operating buffer up to $25 billion, which can potentially be adjusted much lower as the Bank becomes more familiar with operating in a floor system. That said, given the uncertainty of how settlement balances may fluctuate when they remain at a lower level and the dynamic nature of participant demand for settlement balances, the lower bound of $20 billion for the estimated range may not be a hard limit. Settlement balances could fall below this range periodically, barring no adverse impact to monetary conditions (e.g., large or persistent deviations of the overnight rate from the target rate). **Table 1** summarizes the estimate range of settlement balances from an operational perspective.

Table 1: Summary of the estimated range for settlement balances

	Range of settlement balances
Demanded by payment system participants	$20 billion–$30 billion
Operating buffer	$0–$25 billion
Total estimated range	**$20 billion–$55 billion**

As settlement balances decline toward the estimated range outlined above, it would be prudent for the Bank to continually monitor for persistent pressures in the repo market to ensure it is providing enough to satisfy demand. Moreover, the Bank may continue to reduce settlement balances as long as the prevailing overnight repo rate does not persistently deviate from the target rate. To support this monitoring, it will be important for the Bank to monitor several indicators and hold regular discussions with Lynx participants to understand their demand as settlement balances decline.

5. Conclusion

The analysis in this paper indicates that a level between $20 billion and $60 billion could achieve an appropriate balance between the social benefits and costs of settlement balances, while ensuring that the Bank of Canada is able to operate a floor system. Given the uncertainty of the demand for settlement balances emphasised throughout the paper, we conservatively estimate the lower bound of the PRSB to be the larger of the lower bounds, and the upper bound to be the higher of the upper bounds, of the two approaches.

As noted previously, significant uncertainty exists even around this wide range of estimates due to the assumptions underlying the analysis. The modelling framework emphasizes that the benefits of additional settlement balances (e.g., facilitating payment flows) comes at the cost of a loss of liquidity services provided by the assets the Bank purchases. This does not consider factors that could influence settlement balance levels, such as the risks to the Bank arising from holding a larger quantity or changes to the regulatory environment that affects the cost of liquidity. It is also difficult to precisely forecast both the demand for settlement balances and the size of the buffer needed to counteract significant drawdowns in settlement balances due to Bank of Canada payment flows. This challenge comes from

the fact that demand for settlement balances is not easily observable and can change over time. Moreover, unlike in a corridor system where changes in settlement balances are expected to have noticeable effects on the overnight repo rate, these effects can be much less apparent under a floor system when the settlement balances are above the minimum level demanded by payment system participants.

Consequently, the Bank should closely and continuously monitor for indications that the level of settlement balances is not appropriate and then adjust as needed. To fine-tune its estimate of the appropriate level of settlement balances, the Bank could continue to hold discussions with payment system participants and continuously monitor several indicators, including:

- the persistence of the overnight repo rate trading above or below the policy interest rate as well as the persistence of the Bank undertaking operations to maintain it near its target
- the persistence of advances through the Bank's standing liquidity facility for funding end-of-day positions in Lynx
- RTR activity, including the use of participant-to-participant lending, the frequency of daily RTR funding and defunding, and instances of low or insufficient RTR payment capacity

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Appendix: Settlement balances and large-value payments system behaviour

Financial institutions use settlement balances as a source of liquidity to meet their interbank payment obligations. The demand for liquidity arising from the mismatched timing of payments could also be met by borrowing in the overnight market (see, e.g., Furfine and Stehm 1998 and Heller and Lengwiler 2003). Alternatively, participants in the large-value payments system could change the time of discharging the payment obligations to reduce their need to access costly liquidity. Such changes in timing impose externalities on other participants. Concretely, such decisions affect the liquidity available to the receiver of the payment, which could cascade through the system causing undesirable gridlock (as in Bech and Garratt 2003 and Galbiati and Soramäki 2011).

Given how important a well-functioning large-value payments system is to the economy, researchers have investigated how participant behaviour is affected by the level of settlement balances. Key outcome variables used to summarize the performance of a payment system are liquidity efficiency, throughput and payment coordination.[21]

- High liquidity efficiency is desirable since liquidity is costly: financial institutions would prefer minimizing the amount required to process the payments without delay.
- Throughput indicates the flow of payments during the day. All else being equal, more consistent throughput is preferred, since it indicates an even flow of payments throughout the day, thus avoiding gridlock due to delays in receiving payments.
- Greater payment coordination, which enables incoming payments to be recycled to meet outstanding obligations, is similarly preferred since it improves liquidity efficiency and prevents gridlock.

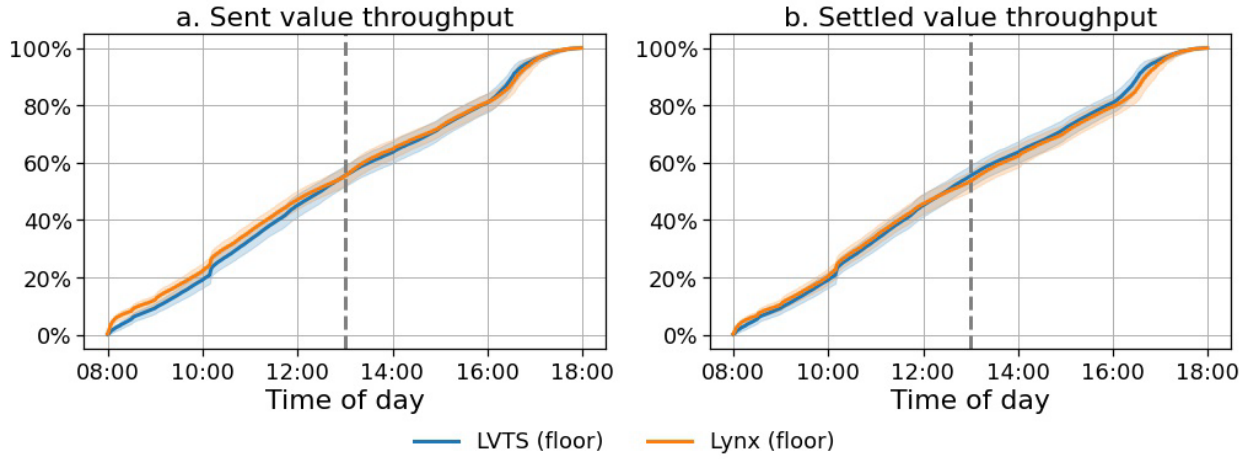
This appendix provides a summary of the current evidence, which indicates that large-value payments system considerations do not play a significant role in determining the appropriate level of settlement balances. This conclusion is based on studies of the effect of settlement balances on the payment system in Canada and around the world. In a cross-country study of large-value systems, Alexandrova Kabadjova et al. (2023) find that larger settlement balances are associated with minimal changes to liquidity efficiency and the timing of payments. Related to this, Afonso et al. (2022) show that the abundance of central bank liquidity in the United States following the global financial crisis (2008–09) has led to only a very marginal decrease in the coordination between incoming and outgoing payments.[22]

[21] Liquidity efficiency is the ratio of the total value of payments settled to the minimum amount of liquidity required to settle all payments without delay. Throughput at a given time is the fraction of total payments in the day settled until that point of time. Payment coordination is measured as the fraction of incoming payments quickly recycled, i.e., used to make payments to other participants.

[22] Copeland, Duffie and Yang (2022) present preliminary evidence that this relationship could be non-linear, due to the degree of recycling of incoming payments depending on various factors including the incentives to build up precautionary liquidity buffers. They argue using data from FedWire, the US large-value payments system, that this

The results of our analyses in Canada are broadly consistent with the international evidence. Bulusu and Chapman (forthcoming) find that the coordination of incoming and outgoing payments in Canada drops only slightly with an increase in settlement balances, in line with their use as an alternative source of liquidity to meet payment demand. Additionally, Desai et al. (2023) show no significant differences in liquidity efficiency and throughput, both between the Large Value Transfer System (LVTS) and Lynx, and based on the level of settlement balances on the Bank's balance sheet. For example, **Chart 3** (reproduced from their paper) shows that the system throughput exhibited only slight differences in the following three periods: between October 2018 and March 2019, when the LVTS operated with low settlement balances; between October 2020 and March 2021, during which time the LVTS operated with large settlement balances; and between October 2021 and March 2022, at which time Lynx was in operation and the settlement balances were higher than in the corresponding period of the previous year.[23]

Chart 3: Average cumulative percentage of total value of payments settled in a day



Note: The three periods studied are between October 2018 and March 2019 (green line), between October 2020 and March 2021 (blue line), and between October 2021 and March 2022 (orange line). The shaded area around each solid line represents the 95% interval in the sample. The dashed vertical line indicates 1 p.m., representing the time Canada's high-value payments system was open for half of its operation. LVTS is the Large Value Transfer System.

Source: Desai et al. (2023)

could lead to potential unintended shocks to short-term funding markets. To minimize the possibility of such consequences, we suggest that a preferred approach would be to build in buffers to the demand for settlement balances, observe participant behaviour and fine-tune the buffers as uncertainty around their use is reduced.

[23] For a sample of other system-level metrics: the average liquidity efficiency during these three periods was 8.3, 7.0 and 8.4, respectively; and the value-weighted average time at which payments were settled in the high-value payments system was 12:07 p.m., 11:49 a.m. and noon, respectively. Worth noting is that the throughput guidelines that Payments Canada advises LVTS and Lynx participants to follow significantly moderate the dependence of system-level outcomes on the level of settlement balances.