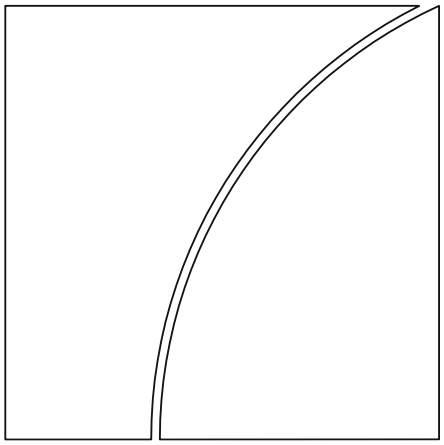

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Monetary and Economic Department

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JEL classification: E41, E58, E52, G21

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What determines banks' excess demand for reserves?

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Abstract

What determines banks' demand for holding reserves at the central bank overnight? This has become a critical question for central banks that are shrinking their balance sheets. We exploit the unique operational framework in Sweden and quantify the factors that drive banks' demand to hold excess reserves at the central bank. Using granular data, we document significant fragmentation in interbank markets with a set of banks that never trade in interbank markets (inactive banks) and others that do (active banks). Active banks' excess reserves increase with their payment flow volatility and the cost of borrowing in interbank markets. Furthermore, excess reserve holdings shrink when aggregate interbank activity is high. Inactive banks' excess reserves also increase with their payment flow volatility but show greater persistence over time, underlining their passivity. Our findings not only shed light on the bank-level drivers of excess reserve demand but also on likely dynamics in untested demand-driven floors.

Keywords: excess reserves, reserve demand, interbank markets, demand-driven floor

JEL codes: E41, E58, E52, G21

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1 Introduction

The size of the central bank balance sheet and the associated supply of central bank reserves have become highly contentious policy issues. While there is a consensus that a very large, so-called abundant supply of reserves created by quantitative easing (QE) is no longer desirable, there is far less agreement on what the appropriate level of reserves should be going forward, or how to get there.

One central argument in favour of maintaining a larger reserve supply is that demand for reserves has increased structurally since the Great Financial Crisis (GFC).[1] Proponents point to several potential drivers: i) liquidity regulation, in particular the liquidity coverage ratio (LCR), may have made reserves more valuable as high-quality liquid assets (eg Logan (2023); Schnabel (2023); Bailey (2024); Williams (2025)); ii) monetisation frictions in interbank markets may have raised the cost of obtaining reserves on short notice so that banks may wish to hold additional reserves as precautionary buffers against unexpected payment outflows. The increased size and speed of potential deposit runs (as demonstrated by the bank failures in 2023) may have further reinforced the case for larger liquidity buffers (eg Hauser (2023); Bailey (2024)); iii) high payment flow volatility more generally may have additionally increased banks' demand for precautionary buffers (Logan (2026a); Duffie (2026)), iv) fragmented interbank markets that may no longer effectively redistributed reserves across the banking system, raising bank's demand (Åberg et al. (2021); Schnabel (2023); Borio (2023)). Some also contend that the increase in demand for reserves is at least partly endogenous to the prolonged periods of large reserve supply (Borio (2023); Nelson (2025)).

Even where there is agreement that reserve supply should be reduced, there is disagreement on how to achieve it. Several central banks, notably the Bank of England and the ECB have adopted a "demand-driven floor". Such an operational framework is designed to elastically supply reserves in line with banks' revealed demand, and to minimise the risk of money market disruptions as reserves shrink (Schnabel (2024), Saporta (2024)). The Fed, on the other hand, supplies ample reserves, operating on the flat part of the reserve demand curve close to the satiation point (ie the lower"kink" of the reserve demand curve). In this context, many have proposed that supply reduction should

[1] Anderson et al. (2026) review some of the most discussed drivers in the United States and how addressing them could reduce the demand for reserves.

be preceded by an inward shift in reserve demand (eg Miran (2026); Logan (2026b); Duffie (2025)).

Yet, empirical evidence on what drives reserve demand and banks' desire to hold reserve buffers beyond required minima has not kept up with this debate. This paper seeks to fill this gap by providing novel evidence on the bank-level drivers of excess reserve demand and on how this demand interacts with frictions and fragmentation in interbank markets.

Empirically identifying the determinants of banks' reserve demand is far from straightforward for several reasons. First, bank-level granular data on reserve holdings and money market activity are often confidential and unavailable for researchers. This means that existing research has focused primarily on estimating aggregate reserve demand or the slope of the aggregate demand curve, without being able to investigate the bank-level factors that shape demand (Hamilton (1997), Afonso et al. (2025), Lopez-Salido and Vissing-Jorgensen (2025); Lagos and Navarro (2025)).[2] Second, the factors driving demand may have changed over the past decade with the shift from QE to quantitative tightening (QT), diluting the relevance of historical relationships. Third, central banks often endogenously adjust the supply of reserves in response to changes in the very factors that shape demand (for example, in response to sudden spikes in money market rates), making it difficult to disentangle demand- from supply- side effects.

We overcome these challenges by exploiting unique features of the Riksbank's operational framework that lead banks to reveal their reserve demand at the individual level on a weekly basis. The central feature of our analysis is the Riksbank's weekly auction of certificates. Every Tuesday, commercial banks can choose to invest their reserves in Riksbank certificates, or to keep them in the Riksbank's deposit facility. Reserves deposited at the deposit facility pay 10 basis points less than certificates. Certificates are transferable securities that pay the policy rate and mature in one week. They are also highly liquid: they can be used as collateral (with zero haircuts) at the Riksbank's standing lending facility, sold back to the Riksbank with next-day settlement, or traded in the secondary market. In a frictionless world with profit-maximising banks (as in Poole (1968) or Whitesell (2006)), banks would optimally invest all available reserves in certificates and rely on interbank markets and central bank standing facilities to manage payment imbalances. Hence, on the day banks make this allocation choice, the amount placed in the deposit facility provides a

[2] An exception is Anbil et al. (2026), which uses bank-level data to account for heterogeneity when estimating reserve demand in the US federal funds market during the transition from abundant to ample reserves.

directly observable, bank-level measure of excess reserve demand.

Several additional features of the Swedish institutional setting facilitate our identification of banks' reserve demand. Since 8 March 2023, the Riksbank has offered to absorb the entirety of the banking system's liquidity surplus through full-allotment certificate auctions. We focus our analysis on the period from this date to May 2025 so that our results are not confounded by supply-side changes. Moreover, there are no reserve requirements for banks in Sweden; the Riksbank provides interest-rate-free intraday credit for payment settlement and autonomous factors play virtually no role.[3] Together, these features mean that aggregate reserve holdings are determined entirely by banks' demand for reserves.

We are also able to exploit microdata covering 27 banks and all key money market segments (unsecured, repo, and FX swap markets). We build a bank-level panel dataset and estimate a linear model with a bank's excess reserves (normalised by its total assets), measured as the amount placed in the deposit facility on Wednesdays (after certificate settlement) as the dependent variable. Our independent variables capture the main potential drivers of excess reserve demand: bank-specific borrowing and lending spreads in interbank markets before the auction (to capture opportunity costs of holding reserves in the deposit facility), the average payment flow volatility in the last 180 days (to proxy for the likelihood of unexpected payment shocks); the liquidity coverage ratio (LCR) before the auction (to assess the impact of liquidity regulations); aggregate interbank market activity in the last 30 days (to capture market functioning) and the CBOE Volatility Index (to control for global uncertainty driving potential precautionary buffers). We include bank fixed effects and lagged excess reserves to control for unobserved heterogeneity and persistence. As discussed next, we also account for interbank market fragmentation.

Our analysis yields several important findings.

First, we document significant fragmentation in interbank markets. Throughout our sample period, we identify two distinct groups of banks: those that actively trade in both unsecured and secured interbank markets ("active banks") and those that never participate in any interbank market segment ("inactive banks"). This fragmentation has direct consequences for reserve demand.

[3] Autonomous factors change the aggregate supply of reserves independent of central bank monetary policy operations. In many countries, important autonomous factors are bank notes in circulation, which play only a very limited role as Sweden is a near cashless society, and the treasury account, which plays no role at all as the Swedish state does not bank with the Riksbank.

Relative to their total assets, inactive banks maintain substantially higher reserve balances than active banks. Their reserve demand is also highly persistent, reflecting a slow-moving, passive approach to liquidity management. For these banks, the only statistically significant positive driver of reserve demand is payment flow volatility, consistent with their reliance on reserve holdings at the central bank to manage their payment flows.

Second, active banks consistently hold excess reserves. This is the case even though the profit-maximising strategy in a frictionless setting would be to hold zero reserves overnight and fully rely on money markets and central bank standing facilities to manage imbalances. For these banks, the level of excess reserves increases with the payment flow volatility and with the cost of borrowing in interbank markets, and decreases when aggregate interbank market activity is higher. The results are intuitive: when it is costlier to obtain reserves from other banks, banks increase their precautionary buffers; when the market is more active, banks may be more confident that they can obtain reserves when needed and therefore hold smaller buffers. Notably, we find no statistically significant effect of the LCR despite frequent arguments that liquidity regulation increase reserve demand. This is also in line with the theoretical prediction of Drehmann and Fu (2026) who show that the LCR does not shift reserve demand since banks can use not only reserves but a range of high quality liquid assets (HQLA) to meet the requirement.

Third, we confirm that the differences in behaviour between active and inactive banks are statistically significant. In particular, the degree of persistence (lagged excess reserves) and the sensitivity to payment flow volatility differ significantly between the two groups.

We conduct several robustness checks and find that our results remain consistent across different econometric specifications. These include incorporating different types of time fixed effects, lending and borrowing spreads measured across different horizons, controlling for seasonality and international money market days and controlling for the weekly differences in aggregate liquidity position of the banking system.

Our findings offer three broad lessons for the policy debate.

First, when the opportunity cost of holding reserves is low (as it is in Sweden at 10 basis points), banks demand reserve buffers well beyond what would be theoretically optimal in a frictionless setting. These buffers increase with the payment flow volatility but, notably, not with liquidity regulation, contrary to arguments in the literature. Moreover, banks seem to be willing to bear the

cost of these buffers: we estimate that Swedish banks on average forgo SEK 2.25 million per day by placing reserves in the deposit facility rather than in certificates.

Second, it is not only the price of interbank borrowing that matters for reserve demand, but the structure and functioning of the interbank market itself. It is well understood that search and matching frictions in money markets affect the shape of the reserve demand curve (see eg Lagos and Navarro (2025) for a recent contribution). But our results go further. We show that interbank market fragmentation and anaemic interbank markets shift aggregate reserve demand outward for two reasons: first, inactive banks fully rely on their reserve buffers at the central bank to manage payment flows. Second, active banks increase excess reserve holdings when interbank market activity falls, seemingly for precautionary reasons.[4] Suggestively, several banks transitioned from active to inactive status with the onset of large-scale QE, indicating that the participation margin, and hence reserve demand, may be at least partly endogenous to reserve supply.

Third, as the Riksbank's operational framework is functionally equivalent to a demand-driven floor, our findings offer an early empirical window into how these newly adopted frameworks may perform in the UK and the euro area, where the transition to a new steady state is still underway and total reserve supply remains very large. In both settings, the opportunity cost of holding reserves at the central bank is low, which our results suggest will sustain elevated demand for reserve buffers. Our evidence points to the importance of three complementary measures for the effective functioning of demand-driven floors: building and verifying operational readiness across all counterparties, strengthening price-based incentives to reduce idle reserve balances, and addressing the stigma associated with borrowing from central bank standing facilities.

Related literature: Our paper also contributes to a large literature on how market frictions affect banks' reserve demand and interest rate formation in the overnight market. Starting with Poole (1968), there is a long theoretical literature analysing various frictions including stigma, search and matching, bank-specific credit risk, transaction cost, the LCR, or intraday liquidity requirements (eg Whitesell (2006); Hamilton (1997); Afonso and Lagos (2015a,b); Bech and Klee (2011, 2012); Bech and Keister (2017); Link and Neyer (2017); Lagos and Navarro (2025); d'Avernas et al. (2025)). Recently, Drehmann and Fu (2026) assess the effects of liquidity regulation, moneti-

[4]Drehmann and Fu (2026) show theoretically how fragmentation affects reserve demand and that it leads to a break-down in the one-to-one mapping from aggregate reserve supply to the interbank market rate.

sation frictions and interbank market fragmentation within the context of this model. As mentioned earlier, the empirical literature so far has mainly estimated aggregate reserve demand curves without being able to identify demand drivers at the bank level. Anbil et al. (2026) are the exception. They use bank-level data to study the US federal funds market and conclude that rate stability depends less on aggregate reserve targets and more on the distribution and liquidity constraints of key intermediaries. Our paper complements this literature by providing direct evidence on how interbank market fragmentation, not just pricing frictions, shapes bank-level reserve demand, and by documenting that the extensive margin of market participation (active vs. inactive) is itself a first-order determinant of aggregate reserve demand.

The rest of the paper is organised as follows. Section 2 describes the Riksbank's operational framework. Section 3 describes the data and main variables. Section 4 presents descriptive statistics. Section 5 presents the empirical model and results. Section 6 provides robustness checks and Section 7 concludes.

2 The Riksbank's operational framework

We conduct our analysis using data from March 2023 to May 2025.

In 2019, the Riksbank began reforming its operational framework. In a transition phase, it operated an asymmetric interest rate corridor with the overnight deposit facility rate set 10 basis points below the policy rate and the overnight lending facility rate set 75 basis points above the policy rate.[5] This changed with the Covid-19 pandemic, when the Riksbank established a narrow and symmetric interest rate corridor. Banks could then use the Riksbank's deposit facility at 10 basis points below the policy rate and the Riksbank's lending facility 10 basis points above the policy rate.[6]

Throughout the period, the Riksbank has also offered to issue certificates to absorb excess

[5]Before 2019, the Riksbank operated a symmetric corridor with a width of 150 basis points, ie the deposit and lending facilities were 75 basis points below and above the policy rate respectively. To limit excess volatility, the Riksbank also conducted daily fine-tuning market operations where banks could borrow or deposit an amount equal to the banking system's net liquidity position with respect to the Riksbank at 10 basis points above or below (respectively) the policy rate on a first come first serve basis. Daily fine tuning operations were stopped in 2019.

[6]The reform was finalized in 2022 when the eligible collateral was divided into two separate sets, and an additional lending facility, the supplementary liquidity facility, was introduced. Borrowing in the lending facility was then restricted to pledging assets from the primary collateral pool and borrowing against the secondary pool was made possible in the new facility at a rate 75 basis points above the policy rate. For the evolution of the policy rates and the rates at the lending and deposit facility see Figure A.3 in Annex A.

reserves. The Riksbank certificates have a maturity of one week, are transferable securities and pay the policy rate. They are eligible as collateral at the lending facility and can be sold back to the Riksbank at a cost of ten basis points with settlement on the next day. Certificates are allocated via auctions. They are offered at a fixed price (the policy rate) and banks bid for their desired volume. If there is overbidding, the allocation is pro rata. The auction takes place every Tuesday with settlement on the following Wednesday. The Riksbank sets the maximum quantity of certificates offered each week. The rule of thumb is to offer an amount equal to the banking system's aggregate position towards the Riksbank, though there have been deviations from this rule occasionally but outside our main period of analysis.[7]

The design features of the Riksbank's operational framework make it a close analogue to a demand driven floor. The demand driven floor approach was pioneered by the Bank of England and has been recently adopted by the ECB and the Reserve Bank of Australia. The essence of such a framework is to fully satisfy banks' reserve demand, typically at a weekly frequency, at a cost that is slightly higher (eg 10-15bp) than the cost (to the central bank) of holding reserves at the deposit facility. The Riksbank framework is the reverse in that banks have excess reserves and are able to transfer as many as they want into certificates. In both cases, banks' choices determine the aggregate amount of reserves in the system.

In Sweden, aggregate reserve holdings are determined entirely by the excess reserves banks hold i.e. the amount banks do not invest in certifcates and as such three factors facilitate our analysis. First, compared to many other central banks, there are no reserve requirements. Second, the Riksbank offers interest rate free intraday credit (stigma free) to facilitate smooth payments throughout the day i.e. there is no need to hold reserves for settlement purposes. Third, the Swedish state does not bank with the Riksbank, meaning that in- and outflows to the treasury account do not change the aggregate volume of reserves in the system. Moreover, other autonomous factors, such as changes in cash holdings play only a minimal role since cash use in Sweden is minimal.

[7]Specifically, the Riksbank restricted the supply of certificates between October 2019 and February 2023. The purpose was to facilitate a smooth transition to a framework with a narrower corridor and later, to provide support for the banking system during the Covid-19 pandemic. Between October 2019 and May 2021 the Riksbank restricted the supply of certificates each week to SEK 380 billion and between May 2021 and March 2023 to half of the banking system's total liquidity surplus.

3 Data

All the data used in this paper are provided by the Riksbank. We build a bank-day level panel dataset to conduct our analysis. We observe 27 banks. We classify them into large, medium and small based on the size of their total assets. We have 5 large banks, 6 medium banks and 16 small banks.

The main variables used for analysis are:

Standing facilities: We observe banks' end of day balance in the Riksbank's standing deposit facility and lending facilities between 2019-2025. This data is obtained through RIX, the Swedish real time gross settlement system. While deposits are frequent, loans are not. In terms of interest rates, we observe the policy rate, deposit facility rate and the rates for the two lending facilities, all set by the Riksbank.

Riksbank certificates: For each bank, we observe the end-of-day holdings of Riksbank certificates at the daily frequency between 2019-2025. For large banks, using SELMA data, we also observe secondary market activity in certificates at the daily frequency, i.e. banks' sale and purchase of certificates among themselves as well as other agents. Specifically, we observe the trade and settlement date of the secondary market activity, type of transaction (sale or purchase) and transaction amounts.

Unsecured interbank market: 18 out of the 27 banks are daily reporters of their transactions in the unsecured interbank market. For these banks, we observe transaction level data for the period 2019-2025.[8] This includes the maturity (overnight), trade and settlement dates, the nominal amount, the direction (borrowing/lending), the interest rate (paid/received) as well as the identity of the counterpart (another monetary policy counterparty). As such, the data covers all transactions among the daily reporters as well as those between daily reporters and non-reporters. The only transactions that we do not observe are the ones where both counterparties are banks that do not report their transactions daily. However, based on Riksbank's yearly data of these banks, this is a very small proportion of the overall unsecured interbank market.

[8]The reporting requirement is linked to market activity. Consequently, the reporting start date is not uniform across the 18 banks, with some banks commencing reporting after 2019.

Secured interbank market: For these 18 banks, we also observe repo transactions with overnight maturity backed by government bonds, covered bonds and municipal bonds at the transaction level between 2019-2025. Additionally we observe the reporters' USD-SEK overnight swap transactions at the bank level at a daily frequency over 2019-2025. Again, the only potential missing transactions are those between banks that do not report these data daily.

Bank characteristics: We also observe banks' liquidity coverage ratios, volume of high quality liquid assets and net outflows. We observe these data at the daily frequency for large banks and at the quarterly frequency for other banks. These data are provided by the Swedish Financial Supervisory Authority (Finansinspektionen). We also observe banks' total assets and runnable deposits, collected from the Riksbank's Monetary Financial Institution balance sheet (MFI) statistics. The frequency of the series depends on the size of the bank, with large banks reporting these data monthly, medium banks reporting quarterly and small banks reporting annually.

4 Descriptive statistics

In this section, we use data from March 2023 to May 2025, our main period of analysis.

4.1 Holdings at the deposit facility

Panel A of figure 1 shows the evolution of total reserves placed in the Riksbank's deposit facility between March 2023 and May 2025. Despite the Riksbank offering full supply of certificates (that pay 10 basis points more), during this period, large, medium and small banks continued to place reserves overnight in the deposit facility. On average, banks placed SEK 140 billion in the deposit facility during this period.

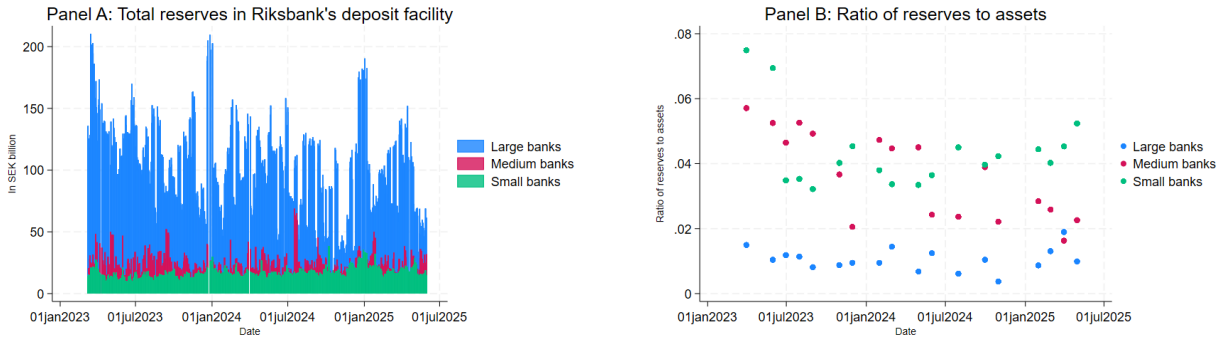

Figure 1: Small, medium and large banks' reserves in Riksbank's deposit facility (2023-2025)

Panel B of figure 1 depicts the reserves that banks place in the deposit facility in proportion to their total assets. While large banks account for most of the volume of reserves in the deposit facility in absolute terms, small and medium banks hold a much bigger proportion of their total assets as reserves.

4.2 Riksbank certificates

Panel A of figure 2 shows the total volume banks place in certificates between March 2023 and May 2025. Since March 2023, the Riksbank set the total offered supply of certificates equal to the total liquidity surplus of the banking system. From that point onward, total take-up by banks has varied between 65 and 96 percent of the offered volume.

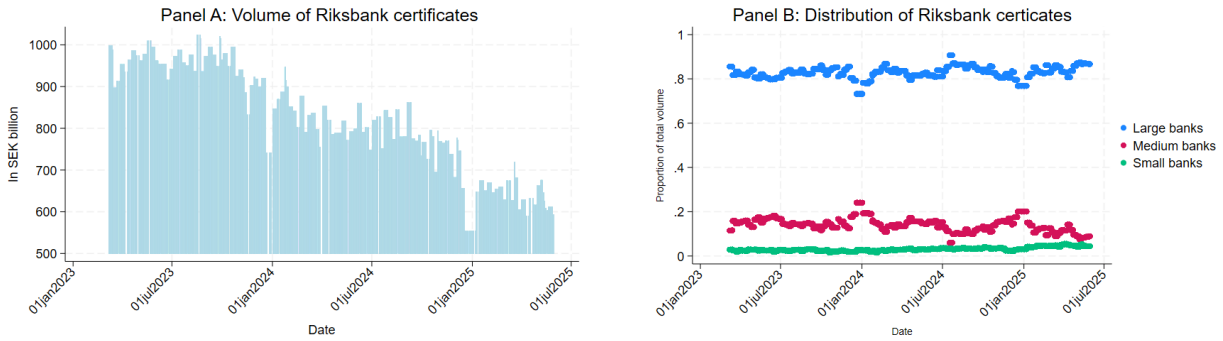

Figure 2: Volume of Riksbank certificates over time (2023-2025)

Holdings of certificates vary substantially with bank size (Panel B, Figure 2). Large banks held between 80-90% of all the certificates sold by the Riksbank. The remainder was largely held by medium sized banks and small banks generally held only 1-5% of the certificates. As shown in the

figure, these proportions have remained broadly stable over time.

4.3 The Swedish interbank money markets

Table 1 provides a high-level overview of the activity in the various money market segments in Sweden. In terms of the total volume of interbank activity as well as the number of transactions, the unsecured interbank market and the market for FX swaps (SEK-USD) were the biggest during 2023-2025.

Table 1: Summary of interbank activity in Sweden (March 2023 to June 2025)

	Unsecured	FX swaps	Repo (govt)	Repo (covered)	Repo (municipal)
Inactive banks	12	12	20	19	19
Active large banks	5	5	5	5	4
Active medium banks	4	5	0	2	2
Active small banks	6	5	2	1	2
Market size (SEK bn)	4.7	4.9	0.6	0.8	0.7
Daily transactions	6.1	7.6	3.4	6.5	4.7

Unsecured money market: Between March 2023 and June 2025, 15 out of 27 banks were active in the unsecured interbank market. This included all 5 large banks, 4 medium banks and 6 small banks. The average number of transactions per day was 6.1 and the average size of the market was SEK 4.7 billion. The average borrowing spread from the policy rate was 0.32 percentage points (in absolute terms) and the average lending spread from the policy rate was 1.44 percentage points in absolute terms.

SEK-USD FX swap market: 5 large banks, 5 medium banks and 5 small banks were active in the market for SEK-USD swaps. 12 out of 27 banks were inactive during this period. The average number of transactions per day in this market was higher than in the unsecured money market at 7.6. The average size of the market was SEK 4.9 billion and the lending and borrowing spreads were 0.22 and 0.44 percentage points in absolute terms.

Repo market: The interbank market for repos was smaller in size, both in terms of number of participants and daily number of transactions. Out of the 27 banks, 20 were inactive in the market for repos backed by government bonds and 19 were inactive in the market for repos backed by

covered and municipal bonds. The average volumes traded and the number of transactions per day in the market for repos are provided in Table 1.

5 Empirical model and results

Sweden provides an ideal testing ground to understand banks' demand for reserves beyond daily payments needs or risk-return considerations in the money market. The weekly auction of Riksbank certificates can shed light on banks' choice of holding excess reserves overnight. Recall that every Tuesday, banks can bid for Riksbank certificates that pay the policy rate and have a maturity of one week. Hence, on Tuesdays banks face a choice between keeping reserves at Riksbank's deposit facility each day for the next week (net of payment and money market flows) or placing them in certificates that pay 10 basis points more. Certificates are highly liquid. They can be used as collateral (with zero haircut) to access the standing lending facility, resold to the Riksbank (at a cost of 10 basis points with one day settlement lag), or traded in the secondary market. Furthermore, certificates are classified as a level 1 high quality liquid asset, just as reserves.

Given this operational framework, what is the optimal value of certificates (or alternatively, the level of excess reserves) banks should hold each week? The period after 8 March 2023 is a suitable setting to answer this question. Starting on this day, Riksbank began to supply as many certificates as the banks demanded i.e. the total volume of the banking system's liquidity surplus. In this framework, in theory, banks could reduce their level of excess reserves to zero by purchasing certificates. This would also be optimal if reserves do not have value beyond the benefits of trading in the money market or transacting with the central bank. If the interbank markets are frictionless and there is no stigma associated with using the Riksbank's standing lending facilities, the banking system can operate with zero reserves in the aggregate as payment shocks net out at the end of every day. In this case, banks can trade with each other or use the Riksbank's standing facilities in case of shortfall/surplus.

To formalise the setting, consider first the case where banks do not trade in interbank markets, and rely only on the central bank's deposit and lending facilities and Riksbank certificates to manage their liqudity needs. For the period we study, this is the case for 14 out of 27 banks. For the sake of illustration, consider a simple one-day model. In the morning, the bank chooses how much of its

initial liquidity X to hold as reserves R and how much to place in certificates $C = X - R$. During the day, the bank faces a random payment shock $\varepsilon \sim F(0, \sigma^2)$. Certificates earn the policy rate p and reserves earn $p - \delta_1$. If at the end of the day, the bank is short on reserves (ie $\varepsilon > R$), it covers its shortfall by accessing the lending facility at the rate $p + \delta_2$ providing certificates as collateral (with zero haircut).

The bank's expected profit, a function of its reserve holdings, is given as follows:

$$\mathbb{E}[\Pi(R)] = p(X - R) + (p - \delta_1)\mathbb{E}(R - \epsilon)^+ - (p + \delta_2)\mathbb{E}(\epsilon - R)^+ \tag{1}$$

Normalising $p = 0$ to simplify, we have:

$$\mathbb{E}[\Pi(R)] = \delta_1\mathbb{E}[(R - \epsilon)\mathbb{1}(R \geq \epsilon)] - \delta_2\mathbb{E}[(\epsilon - R)\mathbb{1}(\epsilon \geq R)] = -\delta_1 \int_{-\infty}^{R} (R - \epsilon) f(\epsilon) d\epsilon - \delta_2 [\int_{R}^{\infty} (\epsilon - R) f(\epsilon) d\epsilon]$$

Banks maximise their expected profit and choose an optimal level $R*$ of reserves in the deposit facility. Taking first order conditions with respect to R, we have:

$$-\delta_1 F(R) + \delta_2(1 - F(R)) = 0 \tag{2}$$

$$R^* = F^{-1}\left(\frac{\delta_2}{\delta_1 + \delta_2}\right) \tag{3}$$

In case of a symmetric corridor around the policy rate, as is the case in Sweden in the period of our analysis, $\delta_1 = \delta_2$. In this case, the optimal level of reserves is:

$$R^* = F^{-1}\left(\frac{1}{2}\right) = 0 \tag{4}$$

Thus, the profit-maximising solution in this case is to hold zero reserves and fully invest X in certificates, borrowing in the central bank's standing lending facility against certificates as collateral at the end of the day if there are unexpected payment outflows. This rests on the assumption that the unexpected payment shocks that a bank faces are centred around 0, the interest rate corridor is symmetric and that there is no stigma associated with using the central bank's standing lending

facility.

Note that adding frictionless interbank markets to the model would not change the optimal level of reserves. As long as banks can lend and borrow seamlessly among themselves, as well as use the central bank's lending facility when needed, it will still be optimal to hold zero reserves and fully invest in certificates. Banks would initially invest everything in certificates and use the interbank markets or the standing facilities to balance payment shocks.

However, as we note in the descriptive evidence, in reality, banks often maintain a positive reserve balance in the overnight deposit facility of the Riksbank. In our illustrative set up, this can be rationalised if there is substantial stigma in borrowing from the Riksbanks' lending facility. This would imply that $\delta_2 > \delta_1$, as such, the optimal level of reserves would be greater than zero.

Another case where the optimal level of reserves could be positive is if there are interbank frictions arising from search and matching frictions, or fixed costs involved in trading. If some banks have prohibitively high fixed costs of trading, they may not participate at all in interbank markets (inactive banks) and hold consistently positive reserve balances overnight, effectively creating pockets of idle liquidity. Then if $\Sigma_i \epsilon_i > 0$ for banks that rely on interbank markets (active banks), it could be optimal for such banks to hold some excess reserves as well. Specifically, if active banks invest all their excess liquidity in certificates and face a high cost (or stigma) of borrowing at the central bank as well as difficulties to borrow sufficient reserves interbank, they would expect to fall short of reserves in aggregate terms.

To take these simple theoretical intuitions to the data, we turn to our empirical model. In comparison to the simple one day model, in our actual context, banks can only bid for certificates once a week. This does not materially change the reasoning of the model. The banks can still convert certificates to reserves on a daily basis by using them as collateral for borrowing in the standing lending facility or sell them back to the Riksbank. We start by measuring excess reserves by using the timing of the auction and the subsequent settlement of certificates. New and maturing certificates are settled on Wednesday each week and the amount placed in the deposit facility (normalised by the total assets of the bank) at the end of the day on Wednesday is our measure of excess reserves.[9]

[9]Ideally, the measure of excess reserves would correspond to the reserve balances after the settlement of maturing and new certificates but before any payment inflows and outflows. However, we do not observe intraday changes in reserve balances.

In line with our simple model, banks' excess reserves can be influenced by various factors: the expected opportunity cost of holding reserves in the deposit facility (instead of lending them in the interbank markets), the expected costs of borrowing reserves from the market, the likelihood that banks' net outflows are larger than reserve holdings and the benefits of holding reserves for liquidity regulation purposes.[10] Other factors that affect banks' excess reserves include market wide conditions such as the general functioning of interbank markets, global uncertainty or bank-specific preferences for holding reserves (determined by operational capacity, for example). Finally, there can also be persistence in the level of excess reserves a bank chooses to hold.

In our empirical model, we measure the opportunity cost of holding reserves in the deposit facility by the spread between the bank-specific average borrowing rate across all interbank markets and the policy rate. Similarly, we use the spread between the bank-specific average lending rate across all interbank markets and the policy rate to measure the cost of borrowing reserves. We measure the likelihood of banks' net outflows exceeding their reserve holdings by the average payment flow volatility they experienced in the last 180 days, normalised by its total assets. We measure persistence in the level of excess reserves by including lagged values of banks' excess reserves.

As such, our main economic specification is as follows:

$$\begin{aligned} ER_{j,t} = {} & \mathbb{1}(Net\,Lender_{j,t-2}) \times Average\,Lending\,Spread_{j,t-2} + \mathbb{1}(Net\,Borrower_{j,t-2}) \\ & \times Average\,Borrowing\,Spread_{j,t-2} + Payment\,Flow\,Volatility_{j,t} + LCR_{j,t-2} \\ & + VIX_{t-2} + Aggregate\,Interbank\,Activity_t + \lambda_j + ER_{j,t-7} + \epsilon_{j,t}. \end{aligned} \tag{5}$$

With

$ER_{j,t}$: Bank j's excess reserves on Wednesday as measured by the amount it places in the deposit facility, normalised by its total assets .

$\mathbb{1}(Net\,Lender_{j,t-2})$: Whether bank j was a net lender on average over the last 30 days across all interbank markets.

$Average\,Lending\,Spread_{j,t-2}$: Bank j's lending rate (average across all interbank markets) minus the policy rate on the Monday before the auction for certificates.

[10] Reserves and Riksbank certificates are both classified as high quality liquid assets (HQLA) and therefore receive the same treatment under liquidity regulation. In principle, banks should be indifferent between the two. In the absence of frictions in the interbank market, banks should also be indifferent between holding excess reserves and borrowing or lending reserves as needed, since interbank transactions are LCR neutral. However, to the extent that banks rely on the broader money market to obtain funding, balance sheet constraints arising from liquidity regulation may become binding and influence banks' decisions regarding the desired level of excess reserve holdings.

$\mathbb{1}(Net\,Borrower_{j,t-2})$: Whether bank j was a net borrower on average over the last 30 days across all interbank markets.

$Average\,Borrowing\,Spread_{j,t-2}$: Bank j's borrowing rate (average across all interbank markets) minus the policy rate on the Monday before the auction for certificates.

$Payment\,Flow\,Volatility_{j,t}$: Standard deviation of the daily change in reserves deposited in Riksbank's deposit facility over the last 180 days for bank j at day t, normalised by its total assets.

$LCR_{j,t-2}$: Bank j's ratio of high quality liquid assets to its net outflows on the Monday before the auction for certificates.

VIX_{t-2}: The global volatility index on the Monday before the auction for certificates.

$Aggregate\,Interbank\,Activity_t$: Average market-wide interbank activity in the last 30 days measured by the average number of transactions (lending or borrowing) in the unsecured interbank market.

λ_j: Bank fixed effect.

$ER_{j,t-7}$: Amount bank j places in the deposit facility on the Wednesday of the week before, normalised by its total asset.

$\epsilon_{j,t}$: Idiosyncratic error term assumed to be distributed normally.

We estimate this model on bank-level panel data using ordinary least squares (OLS) with fixed effects. The time index t is daily. But since banks bid for certificates at a weekly frequency, we only have one observation per week. Hence, to account for persistence and autocorrelation, we also include the lagged dependent variable which is the amount a bank places in the deposit facility on the Wednesday (our measure of excess reserves) in the preceding week (ie $t-7$.) For borrowing and lending spreads, LCR, VIX, we use the lagged values from Monday since banks bid for certificates on Tuesday morning. Taking the values from the Monday before the auction addresses endogeneity arising from these variables. Standard errors are clustered by bank.

We estimate the model separately for the group of banks that are never active in any interbank market and banks that do transact in all interbank markets. This is because the opportunity cost

Table 2: Regression results: sample of banks that do not participate in interbank markets

	Excess reserves on Wednesday
Excess reserves (lagged)	0.79***
	(0.02)
Average payment flow volatility	0.3***
	(0.13)
VIX (lagged)	-0.0001
	(0.0001)
LCR (lagged)	0.002*
	(0.0001)
Constant	0.008***
	(0.001)
Bank Fixed Effects	Yes
N	566
adj. R^2	0.80

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

of holding excess reserves is different for the two groups, with the former using only the standing deposit facility and Riksbank certificates to place their excess reserves.

5.1 Banks that do not participate in any interbank market

First we estimate the model for the sample of banks that do not participate in any interbank market (secured or unsecured) during our period of analysis. In this case, the empirical challenge is to measure the cost of holding excess reserves in the absence of any profits from interbank market activity. The corridor width between the Riksbank's deposit and lending facilities would reflect opportunity cost of holding excess reserves in this case. However, for our period of analysis, this is constant.

For these banks, our results indicate a statistically significant relationship between the level of excess reserves and the average payment flow volatility of the bank (Table 2). The higher the payment flow volatility in the last 180 days, the higher the level of reserves the bank places in the deposit facility. We also find statistically significant persistence in the level of excess reserves. The lagged dependent variable (last week's excess reserves) is positive and precisely estimated. We find

no statistically significant relationship between the lagged VIX and the level of excess reserves. Finally, we find a positive relationship between the lagged LCR and the level of excess reserves but this is not robust to including week and month time fixed effects or other specifications (see Section 6).

5.2 Banks that participate in interbank markets

Next, we estimate our model for the sample of banks that participate in secured and unsecured interbank markets. Only 5 banks participate in both secured and unsecured interbank markets.

Our results are intuitive (Table 3). We find that the higher the payment flow volatility of the bank in the last 180 days, the greater the amount of excess reserves it holds. For net borrowers in the interbank market, the higher the borrowing spread before the auction (on Monday), the higher the expected cost of borrowing and the higher the level of excess reserves a bank holds. There is also statistically significant persistence in the level of excess reserves a bank holds, though the persistence is bigger for inactive banks. We find no statistically significant effect of the lending spread for net lenders.

Table 3: Regression results: sample of banks that participate in interbank markets

	Excess reserves on Wednesday
Excess reserves (lagged)	0.11***
	(0.04)
Average payment flow volatility	0.79***
	(0.19)
Net Lender X Lending Spread (lagged)	-0.0005
	(0.0007)
Net borrower X Borrowing Spread (lagged)	0.001***
	(0.0009)
LCR (lagged)	0.0003
	(0.001)
VIX (lagged)	0.00006
	(0.00006)
Aggregate interbank activity	-0.0006***
	(0.0003)
Constant	0.002
	(0.002)
Bank Fixed Effects	Yes
N	606
adj. R^2	0.23

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We also find a statistically significant relationship between aggregate interbank activity in the last 30 days and banks' excess reserve holdings. The level of the bank's LCR and the global VIX do not have a statistically significant relationship with the level of excess reserves a bank holds. However, the lower the number of transactions in the unsecured interbank market, the higher the level of excess reserves banks hold. We interpret this result as capturing banks' expectation of finding a match in the interbank market in case of a shortage or surplus of reserves. If the aggregate interbank activity is low, banks do not expect to find a match when they need to and thus hold excess reserves.

We find that the differences in behaviour between active and inactive banks are not driven by

random chance but are statistically significant (Table B.1). In particular, the degree of persistence in holding excess reserves and the sensitivity of excess reserves to payment flow volatility are statistically different among the two groups.

5.3 The opportunity cost of holding excess reserves

Given the institutional setting and our analysis, it is possible to approximate banks' opportunity cost of holding excess reserves. On Wednesdays, we observe the volume of reserves that banks could have placed in certificates but did not, instead placing it in the deposit facility. This allows us to approximate the counterfactual benefit of placing the excess reserves in certificates and the counterfactual cost of doing so in case the bank faces a shortfall of reserves due to an unexpected payment shock the next day.

Since the certificates pay 10 basis points more than the deposit facility of the Riksbank, the amount foregone by a bank by placing excess reserves in the deposit facility is given by:

$$Average\,daily\,benefit\,foregone_j = \frac{Reserves_{j,Wed} * 0.001}{52 * 7} \tag{6}$$

$Reserves_{j,Wed}$ is the amount a bank j places overnight in the deposit facility on Wednesday, our measure of excess reserves. Based on this approximation, the average daily amount foregone by the banks was SEK 2.25 million per day over our sample period.

5.4 The relationship between excess reserves and interbank market activity

A central question in the current policy debate is how the level of aggregate reserve supply interacts with the functioning of interbank markets. A key argument for reducing reserve supply is that abundant reserves crowd out interbank activity: when banks can satisfy their liquidity needs from ample reserve balances, they have little incentive to trade with one another, and money markets may atrophy. If this is the case, the redistributive function of interbank markets should weaken precisely when reserves are abundant and a reduction in supply might be expected to revive trading. Understanding this relationship is therefore central to assessing how demand-driven floors will perform as reserve supply is drawn down.

While our data do not allow us to identify this relationship causally due to limited cross-sectional variation, the Swedish setting offers a useful descriptive window into it. Figures 3 and 4 provide suggestive evidence on this relationship. Figure 3 plots aggregate deposit facility holdings and aggregate unsecured interbank volume at the monthly frequency over time. The two series are broadly negatively correlated: during the period of abundant reserves created by QE, deposit facility holdings were high and interbank activity was correspondingly thin. The subsequent contraction in aggregate reserve supply from early 2023 onward coincided with a slow revival of interbank trading.

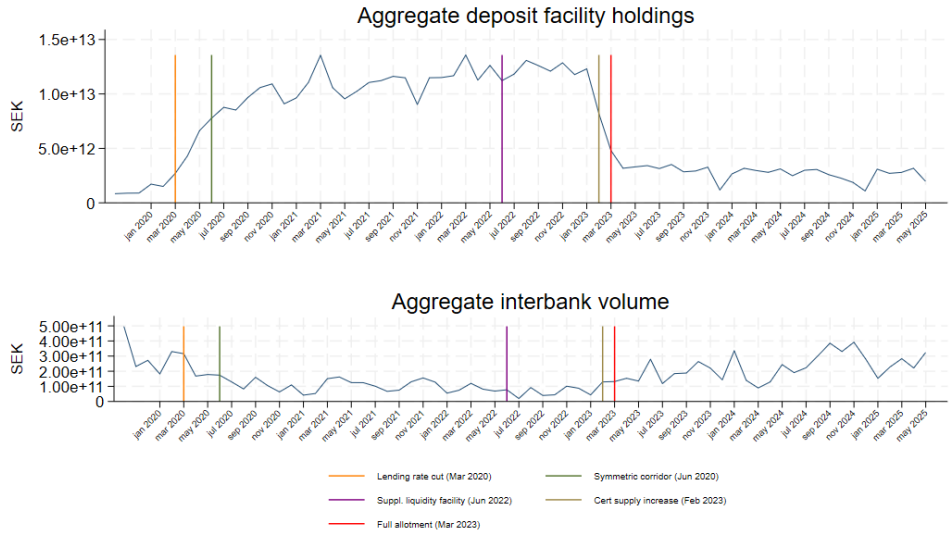

Figure 3: Monthly deposit facility holdings and interbank market activity over time

Figure 4 shows the correlation between weekly reserves in the deposit facility and weekly unsecured interbank volume and distinguishing observations before and after February 2023. In both sub-periods the relationship is negative: weeks with a higher level of reserves in the deposit facility are associated with lower interbank activity, consistent with the negative coefficient on aggregate interbank activity in our bank-level regressions for active banks (Table 3). While not causal, this pattern is indicative of the interpretation that abundant reserve supply and anemic interbank markets are mutually reinforcing. When reserves are plentiful, banks can accommodate payment shocks passively from their own balances and have little reason to trade, so interbank markets atrophy. Equally, as reserves become scarcer, banks are pushed back toward the market to manage liquidity.

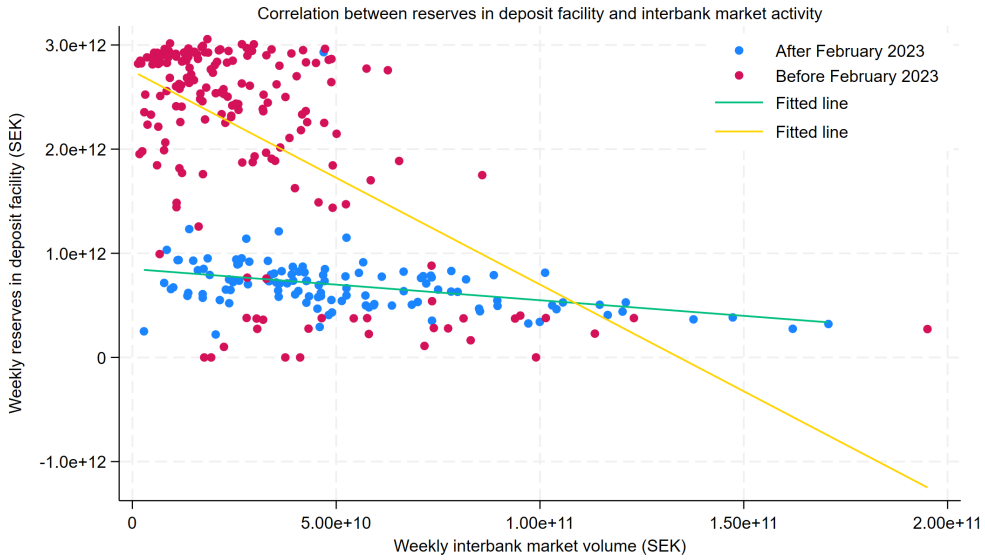

Figure 4: Deposity facility holdings and unsecured interbank market activity over time

6 Robustness

We conduct a series of robustness checks and find that results from our main specification are largely consistent.

6.1 Time fixed effects

To test whether our results are driven by unobserved time varying heterogeneity, we estimate our model with weekly and monthly time fixed effects.

6.1.1 Weekly time fixed effects

Tables 4 and 5 provide estimation results including weekly time fixed effects for inactive banks and active banks respectively. Our results are largely consistent with the main econometric specification, with the exception of the parameter estimate on lagged values of LCR for inactive banks.

Table 4: Regression results: sample of banks that do not participate in interbank markets, week FE

	Excess reserves on Wednesday
Excess reserves (lagged)	0.82***
	(0.02)
Average payment flow volatility	0.3***
	(0.14)
LCR (lagged)	0.0001
	(0.0001)
Constant	0.011**
	(0.001)
Bank Fixed Effects	Yes
Time fixed effects	Yes
N	566
adj. R^2	0.84

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

6.1.2 Monthly time fixed effects

We also provide robustness checks with time fixed effects at the monthly frequency in table 6. Since the coefficient on the backward looking average of aggregate interbank activity is estimated using month-on-month changes in the volume of interbank market activity, including month fixed effects absorbs most of this variation. As such, the parameter estimate for this variable is no longer precisely estimated. Other results remain quantitatively and qualitatively robust.

Table 5: Regression results: sample of banks that participate in interbank markets, week FE

	Excess reserves on Wednesday
Excess reserves (lagged)	0.15***
	(0.04)
Average payment flow volatility	0.85***
	(0.33)
Net Lender X Lending Spread (lagged)	-0.0006
	(0.0008)
Net borrower X Borrowing Spread (lagged)	0.001*
	(0.001)
LCR (lagged)	0.0009
	(0.001)
Aggregate interbank activity	-0.004**
	(0.002)
Constant	0.01
	(0.03)
Bank fixed Effects	Yes
Time fixed effects	Yes
N	606
adj. R^2	0.34

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Regression results: month fixed effects

	Excess reserves Active banks	Excess reserves Inactive banks
Excess reserves (lagged)	0.08**	0.79***
	(0.04)	(0.02)
Avg. payment flow volatility	0.8***	0.3***
	(0.3)	(0.1)
Net Lender X Lending Spread (lagged)	-0.0007	
	(0.0007)	
Net borrower X Borrowing Spread (lagged)	0.002**	
	(0.0009)	
LCR (lagged)	0.0009	0.0002
	(0.001)	(0.0001)
VIX (lagged)	0.0001	-0.0003
	(0.0001)	(0.0001)
Aggregate interbank activity	0.0008	
	(0.002)	
Constant	0.0002	0.024***
	(0.006)	(0.006)
Bank fixed effects	yes	yes
Time fixed effects	yes	yes
N	606	566
adj. R^2	0.25	0.81

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6.2 Weekly average of lending and borrowing spread

To measure the opportunity cost of holding excess reserves for active banks, our main specification uses the lending and borrowing spreads in the interbank money markets from the Monday before the auction of the certificates on Tuesday. In this robustness exercise, instead of using the lagged spreads (on Monday), we use the average lending and borrowing spread in the week before the auction. Table 7 shows that our results remain robust under this specification.

Table 7: Regression results: weekly spreads

	Excess reserves
Excess reserves (lagged)	0.1***
	(0.04)
Average payment flow volatility	0.8***
	(0.2)
Net Lender X Lending Spread (lagged)	-0.0004
	(0.000727)
Net borrower X Borrowing Spread (lagged)	0.002**
	(0.0009)
LCR (lagged)	0.0004
	(0.0012)
VIX (lagged)	0.00006
	(0.00006)
Aggregate interbank activity	-0.0007*
	(0.0004)
Constant	0.003
	(0.003)
N	606
adj. R^2	0.22

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6.3 Quarter-end effects

In order to rule out the possibility that our results are driven by banks' behaviour specific to the end of the quarter (eg. holding extra reserves in the deposit facility as buffers), we conduct robustness check on our main specification by introducing a quarter-end dummy as a control variable. The quarter-end dummy equals 1 for the last 5 days of every quarter in the sample period. Table 8 presents the results for this specification, which remain consistent with our main model.

Table 8: Regression results: quarter-end dummy

	Excess reserves Active banks	Excess reserves Inactive banks
Excess reserves (lagged)	0.1***	0.8***
	(0.04)	(0.03)
Avg. payment flow volatility	0.8***	0.3**
	(0.2)	(0.1)
Net Lender X Lending Spread (lagged)	-0.0006	
	(0.0007)	
Net borrower X Borrowing Spread (lagged)	0.002**	
	(0.0009)	
LCR (lagged)	0.0003	0.0002*
	(0.001)	(0.0001)
VIX (lagged)	0.00007	-0.0001
	(0.00006)	(0.0001)
Aggregate interbank activity	-0.0007*	
	(0.0004)	
Quarter end dummy	0.001	0.008***
	(0.001)	(0.002)
Constant	0.003	0.007***
	(0.003)	(0.003)
N	606	566
adj. R^2	0.22	0.81

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6.4 International money market days

To ensure that our results are not driven by international money market (IMM) days, when several contracts in financial markets are settled, we explicitly introduce an indicator variable to capture these dates. Table 9 presents these results which are consistent with our main specification.

Table 9: Regression results: quarter-end dummy and IMM days

	(Excess reserves) Active banks	(Excess reserves) Inactive banks
Excess reserves (lagged)	0.1***	0.8***
	(0.04)	(0.03)
Avg. payment flow volatility	0.8***	0.3*
	(0.2)	(0.1)
Net Lender X Lending Spread (lagged)	-0.0006	
	(0.0007)	
Net borrower X Borrowing Spread (lagged)	0.002**	
	(0.0009)	
LCR (lagged)	0.0003	0.0002*
	(0.001)	(0.0001)
VIX (lagged)	0.00007	-0.0001
	(0.00006)	(0.0001)
Aggregate interbank activity	-0.0007*	
	(0.0004)	
Quarter end dummy	0.001	0.007*
	(0.001)	(0.002)
IMM day dummy	0.0002	0.002
	(0.001)	(0.002)
Constant	0.002	0.007***
	(0.003)	(0.003)
N	606	566
adj. R^2	0.23	0.81

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6.5 Amount of certificates offered last week

Banks' excess demand for reserves may depend on the amount of certificates offered in the prior weeks as it gives them information about the aggregate liquidity position of the banking system. For example, if they perceive the liquidity position to be scarce, they might be inclined to hold a higher volume of excess reserves. To ensure that our results are robust to this possibility, we add an additional control variable measuring the aggregate volume of certificates offered in the previous auction. Table 10 presents the results that are largely consistent with our main specification.

Aggregate interbank activity has the expected sign but is not precisely estimated any more.

Table 10: Regression results: last week's certificates offered

	(Excess reserves) Active banks	(Excess reserves) Inactive banks
Excess reserves (lagged)	0.1***	0.8***
	(0.04)	(0.02)
Avg. payment flow volatility	0.7***	0.3**
	(0.2)	(0.1)
Net Lender X Lending Spread (lagged)	-0.0003	
	(0.0007)	
Net borrower X Borrowing Spread (lagged)	0.002**	
	(0.0009)	
LCR (lagged)	0.0003	0.0002
	(0.001)	(0.0001)
VIX (lagged)	0.00008	-0.0001
	(0.00007)	(0.0001)
Certificates offered last week	0.000003	-0.000001
	(0.000005)	(0.000005)
Aggregate interbank activity	-0.0005	
	(0.0006)	
Constant	-0.001	0.01
	(0.007)	(0.007)
N	594	555
adj. R^2	0.22	0.80

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

7 Conclusion

Our findings show that excess demand for reserves in Sweden is shaped by heterogeneity in participation and frictions in money markets. Active banks' holdings of excess reserves increase with the payment flow volatility and the borrowing spread relative to the policy rate, and fall when aggregate unsecured market activity is high. Inactive banks, which never trade in interbank markets, display strong persistence in excess reserves and respond to payment volatility. These patterns suggest

that factors beyond price signals (for example, operational capacity, search frictions or stigma) also drive the choice to hold excess reserves. Additionally, we also present suggestive evidence on the relationship between reserve supply and interbank market functioning. During QE, deposit facility holdings were high and interbank activity was correspondingly thin. The subsequent contraction in aggregate reserve supply from early 2023 onward coincided with a slow revival of interbank trading. Taken together, these findings speak directly to the policy debate over the appropriate level of reserve supply, money market functioning and the design of operational frameworks as central banks unwind their balance sheets.

Several avenues for future research follow. First, the participation decision of banks in money markets merits careful examination. Understanding the fixed costs, balance sheet constraints or institutional frictions that keep banks out of interbank money markets would inform the appropriate policy response of central banks. Second, our identification of the causal effect of reserve supply on interbank market activity is limited by the small number of banks in Sweden. Richer settings with more cross-sectional variation could test this relationship more directly.

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A Additional graphs

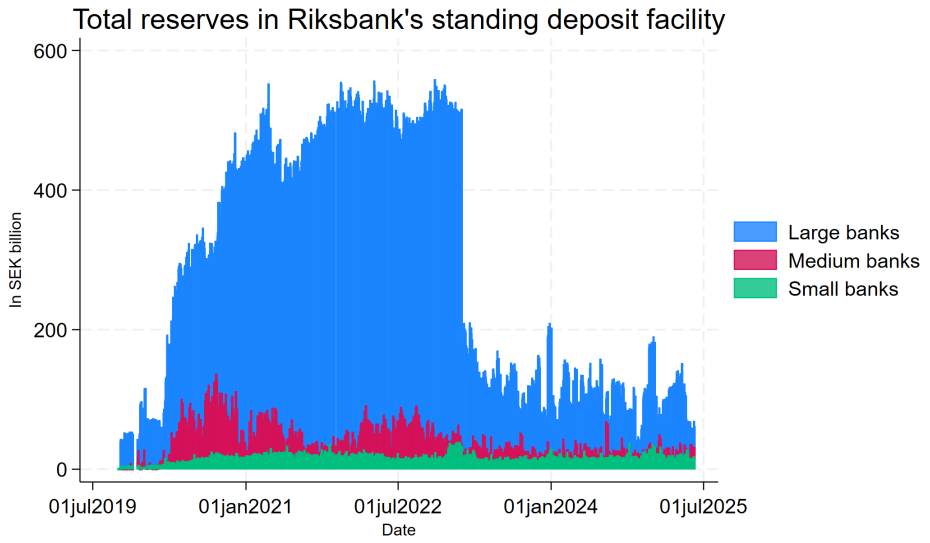

Figure A.1: Use of Riksbank's standing deposit facility (2019-2025)

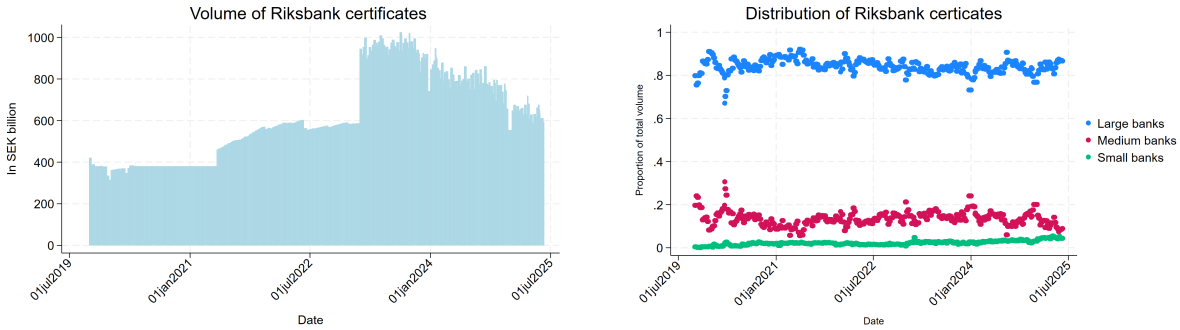

Figure A.2: Volume of Riksbank certificates over time (2019-2025)

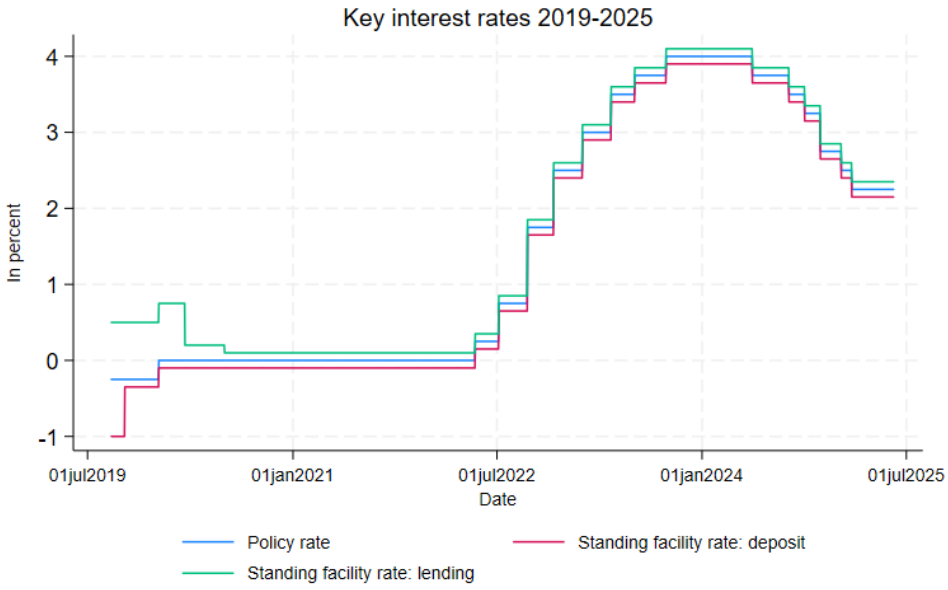

Figure A.3: Policy and standing facility rates in Sweden 2019-2025

B Comparing effects for active and inactive banks

Table B.1: Wald tests for equality of coefficients across active and inactive banks

Variable	$\chi^2(1)$	p-value
Lagged excess reserves	69.82***	0.0
Payment flow volatility	4.74**	0.02
VIX (lagged)	1.71	0.19
Constant	7.54***	0.006

Notes: This table reports Wald tests for the equality of estimated coefficients across the samples of active and inactive banks. The null hypothesis is that the coefficient is equal across the two groups. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.