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Huberto M. Ennis and Elizabeth Klee

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The Fed's Discount Window in "Normal" Times

Huberto M. Ennis* Elizabeth Klee†

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Abstract

We study transaction-level data of bank borrowings at the Federal Reserve's discount window from 2010 to 2019. We merge these data with quarterly information on bank balance sheets and income statements. To aid in the interpretation of our empirical analysis, we also develop a detailed model of the decision of banks to borrow from various sources, including the discount window. The objective is to contribute to a better understanding of the reasons why banks use the discount window during "normal" times—periods of relative calm in financial markets. Consistent with our model, we find that borrowing from the discount window is tightly linked to the composition of banks' balance sheets. Most importantly, banks holding less reserves tend to borrow more often (and more) from the Fed's discount window. Similarly, banks with more expensive and fragile liabilities, and less marketable collateral, are also more likely to borrow from the Fed.

JEL Classification: E52, E58, G28
Keywords: Banking, Federal Reserve, Central Bank, Liquidity

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*Research Department, Federal Reserve Bank of Richmond; *huberto.ennis@rich.frb.org*

†Division of Financial Stability, Federal Reserve Board of Governors; *elizabeth.c.klee@frb.gov*

1 Introduction

The discount window is the most prominent and long-standing liquidity-support program offered by the Federal Reserve, the U.S. central bank. As such, it is a critical institution of the U.S. financial system. Studying the role of the discount window has generally been constrained by data availability. This has changed in recent years: there is now detailed and reliable transaction-level data published by the Fed on a regular basis. We take advantage of these new data and study, empirically and theoretically, bank activity at the discount window from 2010 and 2019, a period of relative calm in U.S. financial markets.

The idea behind a central bank serving as lender of last resort has been around for more than two hundred years (Humphrey, 1989). While the role of the central bank as a backup source of funding has been prominent during financial crises, the discount window is used *at all times*, during crises and in "normal" times. It is natural then to ask the questions: What is the role of the discount window in normal times? Which banks borrow from the discount window in normal times and why? We address these questions below with a combination of empirical analysis and a theoretical framework that is deliberately designed to help us interpret the empirical findings that we uncover.

The discount window has benefits and costs. On the benefits side, the discount window plays a dual role in the interbank market. One role is to provide a upper bound on overnight interbank interest rates, which helps the Federal Reserve to maintain short-term interest rate control and implement monetary policy (Ennis and Weinberg, 2016). Another role is to supply short-term liquidity insurance to eligible depository institutions. Both roles are related, as interbank rates reflect, at times, normal trading as well as liquidity events experienced by clusters of banks. A further benefit is that the discount window is "ready to go" in case of urgent liquidity needs, or a full-blown crisis.

On the costs side, the discount window has explicit and implicit costs. For explicit costs, in addition to operational costs, the central bank is often involved in monitoring potential borrowers to discern in a timely manner whether liquidity stress is tied to the possibility of insolvency. For implicit costs, there are also potential moral hazard distortions associated with the availability of central bank funding, as this contingent support changes banks' incentives to manage their liquidity and credit risk (Ennis and Price, 2015).

Answering questions about the discount window in normal times is critical to assess the balance between benefits and costs. In particular, it is essential to understand the motivations of banks to tap the discount window. With that in mind, we search for and identify systematic patterns in the data that describe the type of banks that use the discount window and the financial conditions of those banks around the time of borrowing.

Our work informs a long-standing policy debate around the value of a discount window. On one side are those who question the need to have a discount window for the provision of liquidity to the banking system and the market more broadly (Goodfriend and King, 1988; Selgin, 2017) and those who emphasize the risk of the discount window becoming a vehicle for subsidizing poorly operated and possibly insolvent institutions (Friedman, 1960; Schwartz, 1992). On the other side are those who view the discount window as a potential source of liquidity for banks, filling gaps produced by transitory liquidity shortfalls (Clouse, 2000) and those who emphasize the role that the discount window and banks' preparendness to use it can play in promoting stability of the financial system, not only during crisis, but more generally, at all times (Fischer, 2016; Barr, 2023).

Market frictions are a key justification behind discount window lending. If frictions are not significant, then open market operations should be sufficient to achieve the central bank's objectives (Goodfriend and King, 1988). The nature, strength, and implications of such frictions can vary widely with general financial market conditions. For example, some of the frictions most important for understanding discount window activity during normal times may be trumped by the general disruptions occurring during crisis. So, while in normal times banks carefully evaluate the time and resources necessary to secure suitable trading counterparties, those trading links might be disrupted during a financial crisis. For these reasons, our approach accounts for and emphasizes aspects of the problem that are particularly relevant in normal times.[1]

A crucial and novel feature of our data is the level of detail. Until recently, public information about activity at the discount window was limited. Traditionally, the Federal Reserve published discount window lending only at an aggregate level and at a weekly frequency. One justification for providing limited information has been the fear that the disclosure of information could impact the effectiveness of the facility (Kleymenova, 2016). Indeed, in March 2020, the Fed made changes to its weekly reporting to reduce the amount of discount window information available at higher frequencies. The view supporting

[1] The role of the discount window during crises has been more extensively studied in recent years. For example, Berger et al. (2017), Gauthier et al. (2015), Li, Milne, and Qiu (2020), Gilbert et al. (2012), and Gerlach and Beyhaghi (2020) study empirically discount window lending in the U.S. during the financial crisis. Klee (2019) and Armantier et al. (2015) focus more narrowly on discount window stigma, also during the financial crisis. Drechsler et al. (2016) study empirically discount window lending in Europe during the financial and sovereign debt crises. The study by Gerlach and Beyhaghi (2020) includes the period under consideration here, but the focus of that paper is on the signal value of discount window activity about the financial conditions of the bank and, in particular, their probability of failure. Here, instead, we focus on the determinants of discount window activity itself.

such a change is that banks might become reluctant to access the discount window if they perceive that the information will be made public and subsequently interpreted negatively by potential counterparties. This type of stigma effect is often discussed by policymakers (Bernanke, 2008) and has received attention in the theoretical and empirical literature.[2]

A competing view and a common reaction to the events of the 2008 financial crisis is that transparency is particularly important when it comes to the administration of government lending programs. In response to such demand for extra information, starting in July 2010, the Dodd-Frank Act required the Fed to make public detailed information about individual loans extended at the discount window. In a compromise that reflects the concerns associated with excessive disclosure of information, the transaction-level data is released with a two-year delay. The availability of this new, more detailed information provides an opportunity to take a closer look at what motivates actual borrowing at the discount window. We take that opportunity in this paper using the first ten years of data.

Aside from the relative calm during our sample period, an important factor is that the banking system was operating in an environment with ample reserves (Carpenter et al., 2015; Ennis and Wolman, 2015). This was a significant change from conditions pre-2008 (the previous period of normal times). In principle, ample reserves could reduce the exposure of banks to liquidity shocks material enough to push them to borrow from the discount window. Nevertheless, non-trivial amounts of borrowing occur at the discount window during this time (Ackon and Ennis, 2017).[3]

As a preliminary step, Section 2 reports some broad correlations between bank characteristics and the use of the discount window. We find that larger banks are more likely to borrow from the discount window, even though most of the borrowing is done by smaller banks, which are more numerous. Borrowers tend to hold less reserves and more illiquid asset portfolios. On the liability side, borrowers rely more on short term funding (such as repurchase agreements) and Federal Home Loan Bank (FHLB) advances. Borrowers also seem to have more risky assets that tend to lower their risk-based capital ratios. In general, discount window borrowers share some characteristics with larger banks, although less than 10 percent of the banks borrowing at the discount window are larger than $10 billion in assets. Accounting for these broad patterns is relevant, but the confounding of

[2]See, for example, Klee (2019), Ennis and Weinberg (2013), Armantier et al. (2015), Gauthier et al. (2015), Ennis (2019), Hu and Zhang (2021), Ennis and Price (2020), and the citations therein.

[3]Large quantities of excess reserves can push many banks to be close to indifferent to holding an additional unit of reserves. Hence, holding patterns in the cross section of banks may be harder to identify. However, as our model will illustrate, for those banks that actually borrow from the discount window, their holdings of reserves are likely to be tightly linked to other financial decisions.

size with other various characteristics quickly makes clear that a multivariate analysis is needed to untangle the origin of such patterns.

Before moving to a more thorough empirical analysis, we present in Section 3 a model of the decision of a bank which, under some circumstances, values having access to the discount window and borrows from it. The model is intended as a framework to guide our thinking when searching and interpreting various patterns present in the data. The decision of the bank in our model is similar to that studied in Ennis (2018) and Afonso, Armenter, and Lester (2019) and is in the tradition of Poole (1968) and the extensive literature that derives from that seminal paper.[4] Relative to the previous literature, and given our specific interest in the discount window data, our model involves a more complete description of the bank's balance sheet and a more flexible interpretation of the trading possibilities of the bank facing liquidity or payment shocks.

In the model, when the interest rate charged at the discount window is higher than the rate in the interbank market, as is generally the case in the U.S., a bank with access to the interbank market will not use the discount window. However, in some situations, depending on the availability of eligible collateral and the nature and timing of the liquidity shocks, the bank my not have ready access to the various segments of the interbank market. In such a case, the bank will follow a "pecking order" to cover its liquidity needs, using first its holdings of reserves, then discount window borrowing and, finally, if the shock is large enough to exhaust the bank's collateral pledged at the discount window, an overdraft in its account at the central bank, which is generally most expensive. This pecking order, in turn, determines the way the bank will choose ex ante its level of reserves and other components of its balance sheet.

Importantly, the model also illustrates how the structure of the distribution of shocks influences the ex-ante choice of the level of reserves and of other components of banks' balance sheets. Those decisions, in turn, interact with the shocks and determine the actual probability of borrowing from the discount window. This interaction makes the relationship between balance sheet components and discount window borrowing far from straightforward and the model helps to parse out the various forces at play.

Section 4 connects our model to the data, and presents our empirical results. We start by looking at the probability that a bank borrows from the discount window, conditional on having taken the necessary steps for access. Some banks may not have taken those steps and hence may not have immediate access to the discount window. Unfortunately,

[4]See, for example, Ennis and Keister (2008) and, more recently, Bianchi and Bigio (2022), Armenter and Lester (2017), Berentsen, Kraenzlin, and Mueller (2018).

the data do not include bank-level information on access, so we construct a proxy based on the information available.

We obtain several important empirical results. First, as highlighted in the model, we establish conclusively that banks holding less bank reserves as a proportion of assets, ceteris paribus, are more likely to tap the discount window for funding. This finding survives when we control for the bank's balance sheet composition, size measured by assets, and a number of other bank characteristics that, in principle, could matter. Furthermore, the finding is robust to accounting for possible endogeneity in reserve holdings. Moreover, we find that banks that obtain discount window access also have lower reserves, consistent with our model's predictions.

Second, also as suggested by the model, banks that rely more heavily on less stable funding sources, also find themselves more often needing to borrow from the discount window. We take particular care to explore the relationship between FHLB advances and discount window borrowing. We find that banks are more likely to borrow at the discount window if FHLB advances outstanding are towards the upper ends of their distribution, suggesting that banks first turn to the FHLBs for funding, and then to the discount window.

Third, we find deliberate decisionmaking with respect to collateral posted at the discount window. Collateral tends to be "sticky," and banks generally post collateral that is less useful in other contexts, such as C&I loans. Taken together, our empirical results suggest that banks' decisions to borrow from the discount window in "normal" times is the consequence of a deliberate liquidity-management decision. Banks are intentional with their use of the discount window, and use it when it becomes the economically relevant marginal source of funding for the bank.

We close the paper with a short Section 5, where we briefly discuss how we read and understand our findings more broadly and, then, conclude.

2 Background

2.1 Data

Our dataset comes from a combination of various regulatory and central bank data sources. The primary source is detailed information on daily borrowings at the discount window, available on the Federal Reserve Board's public website.[5] The data include information

[5] Refer to https://www.federalreserve.gov/regreform/discount-window.htm.

on the name of the borrower, the size and duration of the discount window loan, the type of loan (primary credit, secondary credit, or seasonal credit), and the borrower's Federal Reserve district. Also available is information reported on the types and amounts of collateral posted at the discount window at the time of borrowing. The universe is all discount window loans extended from July 2010 to December 2019.

Another data source is quarterly Call Report filings, which we merge with the discount window data using a crosswalk provided in the depository institution structure data from the National Information Center (NIC). We obtain information for all depository institutions eligible to borrow at the discount window, which include commercial banks (form FFIEC 031/041), foreign banking organizations (FFIEC 002), and credit unions (NCUA 5300). These reports provide information on balance sheet items, including various assets and liabilities, as well as some off-balance sheet items, such as unused loan commitments for commercial banks. We focus on commercial banks in most of our analysis, as these institutions have the most detailed Call Reports.

2.2 Overview

There are three discount window programs: primary credit, secondary credit, and seasonal credit. Primary and secondary credit are the main programs through which the Federal Reserve provides back-up, short-term funding. The seasonal credit program is aimed at satisfying longer-term seasonal funding needs.

The primary credit program is a standing facility (no questions asked) available to depository institutions in sound financial condition. Primary credit loans carry a "penalty" interest rate, which was set at a spread of 50 basis points above the upper bound of the target range for the federal funds rate during our sample period. Secondary credit is available (subject to the discretion of each Reserve Bank) to depository institutions ineligible for primary credit. The interest rate for secondary credit loans is 50 basis points higher than the primary credit rate. In our sample period, most lending in the primary and secondary credit programs was overnight.[6]

As shown in Table 1, between July 2010 and December 2019, there were almost 23,000 primary credit loans and and nearly 800 secondary credit loans. The main focus of our study will be primary credit loans, as they are the most common and most in line with

[6]By contrast, seasonal credit does not carry a penalty rate and instead is offered at a floating market rate based on the average of the federal funds rate and the rate on three-month certificates of deposit. The interest rate is reset every two weeks and applies to all outstanding seasonal credit loans. Seasonal credit is generally longer term than overnight. Refer to https://www.frbdiscountwindow.org/.

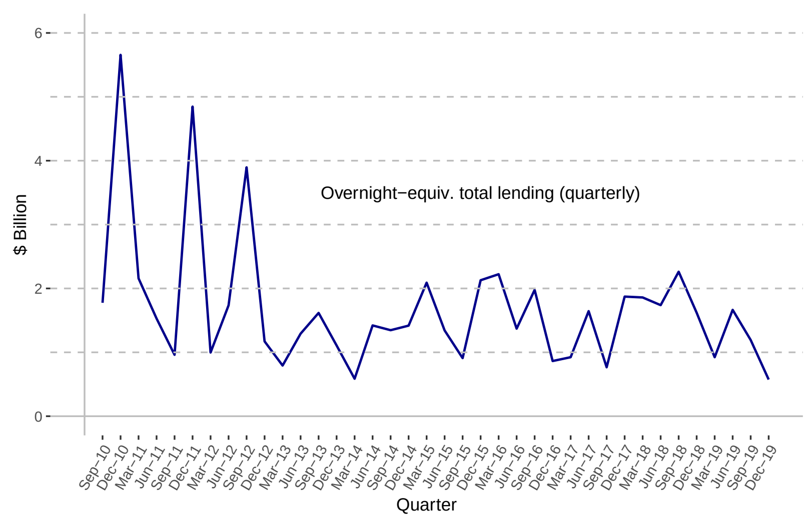
Table 1: Primary and secondary credit, July 2010 – December 2019

	All loans	Loans greater than $1 million					
			Amount in $ millions				
	N	N	Mean	Median	Min	Max	Std. dev
Primary credit	22,999	4,529	13.29	4.88	1	2,700	58.69
Secondary credit	797	27	7.71	4.5	1.5	68	13.56

Note: Reflects overnight-equivalent borrowing amounts. For example, the maximum primary credit loan of $2.7 billion reflects a three-day loan for $900 million. If restated in raw amounts, mean and maximum loan summary statistics are lower, with a maximum primary credit loan of $1.017 billion. Source: Federal Reserve Board, https://www.federalreserve.gov/regreform/discount-window.htm.

traditional central-bank liquidity provision to healthy banks.[7]

Figure 1: Total lending – Primary credit (quarterly)



Note: The figure provides information on the aggregate amount of primary credit extended on a quarterly frequency. Overnight-equivalents are calculated by mulitplying the loan amount by the loan term. Source: Federal Reserve Board and authors' calculations.

Figure 1 plots the total amount of primary credit loans in each quarter of our sample period. Because some loans have longer maturities than overnight, we calculate overnight-equivalent amounts that are then summed by quarter.[8] While discount window lending is an order of magnitude smaller during normal times than in crisis periods, it is still a

[7]Secondary credit loans often involve special circumstances. For a discussion of specifics regarding recent secondary credit loans, see Ennis, Ho, and Tobin (2019).

[8]In these calculations, a loan of $100 million for two days is equivalent to two overnight loans of $100 million each. This transformation is necessary to account for varying maturities across loans in the computation of aggregates.

meaningful amount – in many quarters during the sample period more than $1 billion in loans were made. In our sample period, primary credit borrowing did not meaningfully increase with broader market events, such as the European debt crisis in the summer of 2011. On the other hand, there appears to be some seasonality in lending, with credit picking up in the last quarter of each year. This will motivate our use of year-quarter time fixed effects in the multivariate analysis of Section 4.[9]

2.3 Test loans and access

Many of those discount window loans granted during our sample period were for relatively small amounts (see Table 1) and were initiated by the borrowing institution in order to *test* the processes and systems involved in executing a transaction. The data do not include information on which loans are tests and which ones are not. To study banks' lending behavior uncontaminated from (tangential) administrative decisions, we focus on loans greater than $1 million. Even though this subsample of 4,529 primary credit loans is much smaller than the full sample, we think that only relatively larger loans reflect a deliberate economic decision by the borrower.[10]

That said, we do use the information on smaller loans and testing to construct our proxy for "access" to the discount window. To have immediate access to primary credit, institutions need to take some basic steps, including internal approvals, a lending agreement, and the pledging and evaluation of collateral at their respective Reserve Bank. These steps can take time—sometimes days, or even weeks. Since we do not have information on which institutions had the needed arrangements in place to borrow at the discount window during our sample period, we construct a proxy: If a bank has taken a loan (test or otherwise) at any time during our sample period, then we consider that bank as having access to the discount window. The largest banks are also very likely to have taken the steps necessary to access the discount window. For this reason, in our summary statistics, we assume that any bank with $50 billion or more in assets also has access, even in cases when we do not actually observe the bank borrowing from the discount window at some point in our sample. In our multivariate empirical investigations, we explore different definitions of access, including those related to the $50 billion asset threshold.

[9] For a more detailed discussion of possible seasonality, see Ackon and Ennis (2017) (including their Figure 4 and Table 7).

[10] Smaller loans are not likely to receive much managerial scrutiny, either because the loan is just a test loan or because it is too small to warrant much attention: just as an example, a $1 million overnight loan at an interest rate 100 basis points higher than the lowest alternative rate generates an additional $30 in interest costs, a very small amount.

This approach to access is surely an approximation. There may be banks that have access to the discount window but have less than $50 billion in assets and have not borrowed or tested during our sample period. Likewise, some banks may have gained access late in our sample period, while we consider these banks as having access for the entire period. These are important considerations to keep in mind. Yet, we think this is an acceptable approach to overcome a clear data limitation. In general, the behavior of banks that have access to the discount window can be expected to differ from the behavior of banks without access; we study this issue theoretically and empirically below.

2.4 Borrower types and sizes

The discount window data include borrower-identifying information which can be linked with other data to determine characteristics of each institution tapping the discount window. Using the linked data, we are able to determine the type of institutions that is borrowing from the discount window. There are three broad type categories: domestic banks, credit unions, and foreign banking organizations (FBOs). We also group borrowers in two broad size classes: larger institutions defined as those with greater than or equal to $10 billion in assets, and smaller ones with less than $10 billion in assets.

As shown in Table 2, smaller domestic banks account for the greatest number of borrowers, where borrowing is defined as taking a loan greater than$1 million. The percentage of institutions of each type, however, is highest for larger domestic banks (31 percent), followed by FBOs (13 percent).

For frequency of use, both larger and smaller domestic banks rarely borrow meaningful amounts repeatedly from the discount window. Of 107 larger and 7,607 smaller domestic banks, only 2 percent of each category borrowed at least five times during the sample period.

An important caveat is that we define the group of "larger" banks as those that have $10 billion or more in assets.[11] As is well-known, the asset distribution of banks in the U.S. is skewed, with only a few very large banks accounting for the majority of assets. None of those very large banks borrowed from the discount window during our sample period. Even when considering those banks with $100 billion or more in assets, only four borrowed over the sample. And when these banks borrowed, it was infrequent and for extremely small amounts relative to their total assets–roughly 4 tenths of a basis point on average. For this reason, when we discuss larger bank borrowing, it is not a reference

[11] Our "smaller" banks generally overlap with the supervisory category of "community banks."

Table 2: Discount window borrowing by type and size, July 2010 – Dec. 2019

		Borrow at least once		Borrow at least five times	
	Number of inst.	Number of inst.	Percent of total	Number of inst.	Percent of total
Smaller institutions (less than $10B in assets)					
Domestic banks	7,607	615	8	181	2
Credit unions	7,528	175	2	54	1
Foreign banks	196	26	13	5	3
Larger institutions ($10B or more in assets)					
Domestic banks	107	33	31	2	2
Credit unions	5	0	-	0	-
Foreign banks	44	6	13	1	2

Note: "Borrowers" are depository institutions that file Call reports, and that execute at least one discount window loan of over $1 million during the sample period. "Larger institutions" are banks with at least $10 billion in assets in the fourth quarter of 2014, roughly the midpoint of the sample.

to the very largest banks, so prominent in the U.S. financial system.

For the most part, in the empirical discussion, we narrow our focus to domestic banks. We do so for three reasons. First, most borrowers in our sample are domestic banks; for that reason, even if we pooled credit unions and FBOs with domestic banks, our conclusions are unlikely to change meaningfully. Second, there is a richer set of balance sheet information available for domestic banks than for credit unions or FBOs, reflecting distinct reporting requirements. We use this more detailed information productively. And third, business models differ across these groups of depository institutions. Consequently, the specific situations and motivations to borrow from the discount window may diverge somewhat across these groups. We do not have sufficient data to study them separately and pooling all groups could create more noise than insight.

2.5 Balance sheet composition

As shown in Table 2, larger domestic banks are more likely to borrow from the discount window than smaller banks. But larger banks' balance sheets may also imply a different approach to liquidity management. In Table 3, we report the average balance-sheet composition of domestic banks that borrowed from the discount window at least once in our sample (middle columns). We compare these borrowing banks with non-borrowing banks (left columns) and with all larger domestic banks (with more than $10 billion in assets, right columns), regardless of whether these banks were borrowers or non-borrowers.

Table 3: Balance sheet ratios – Domestic banks

	Non-borrowers		Borrowers		Larger banks	
	Mean	Median	Mean	Median	Mean	Median
1. Share of assets						
Reserve balances	0.04	0.032	0.035	0.020	0.059	0.029
Treasury securities	0.007	0	0.005	0	0.017	0.001
Agency MBS	0.051	0.022	0.054	0.032	0.060	0.046
Agency debt	0.056	0.027	0.041	0.018	0.016	0.002
Residential real estate	0.198	0.164	0.184	0.162	0.167	0.152
CRE	0.263	0.256	0.306	0.308	0.159	0.138
C & I	0.079	0.064	0.100	0.080	0.129	0.114
Consumer	0.034	0.020	0.035	0.013	0.113	0.034
Unused commitments	0.125	0.081	0.183	0.122	0.470	0.240
2. Share of liabilities						
Transaction deposits	0.284	0.288	0.200	0.147	0.099	0.085
Uninsured deposits	0.156	0.132	0.208	0.182	0.303	0.280
Federal funds	0.002	0	0.003	0	0.006	0
Repo	0.007	0	0.014	0	0.019	0.005
FHLB advances	0.033	0.006	0.050	0.029	0.046	0.021
3. Balance sheet size and capital						
Log(assets)	12.172	12.030	13.503	13.317	17.56	17.242
Return on assets	0.034	0.034	0.035	0.033	0.032	0.029
Tier 1 capital to RWA	0.179	0.153	0.151	0.137	0.145	0.128
RWA to assets	0.659	0.670	0.709	0.720	0.710	0.731
Tier 1 capital to assets	0.110	0.102	0.103	0.097	0.097	0.092
Number of banks	7,020		648		107	
Number of observations	217,560		22,593		3,885	
4. Collateral						
Collateral to assets	0.040	0.017	0.055	0.031	0.080	0.048
Loan amount to collateral	0.053	0.001	0.290	0.022	0.015	0.000
Number of banks	1,505		648		85	
Number of observations	7,664		4,832		638	

Note: This table provides summary statistics on balance sheet items for domestic banks. "Borrowers" are defined as domestic banks that file Call reports, and that borrow from the discount window for more than $1 million at least once over the sample period. "Non-borrowers" are defined as banks that file Call reports and do not take out a discount window loan for more than $1 million at least once over the sample period. "Larger banks" are defined as banks with at least $10 billion in assets at the end of 2014; these can be either borrowers or non-borrowers. An observation is a bank-quarter. Statistics based on bank averages are similar. We eliminate banks with missing or inconsistent values for assets, capital, or risk-weighted capital ratios. Eliminating these banks leads to a smaller sample size than in Table 2.

As shown in the first panel, on the asset side, discount window borrowers tend to have less liquid assets than non-borrowers. Overall, borrowers have lower average shares of assets in reserves and Treasury securities, and higher shares of commercial real estate (CRE) and commercial and industrial (C&I) loans. Some of these patterns are also observed for larger banks. Still, the median borrower seems to hold less reserves than both non-borrowers and larger banks, which suggests that size is not the determining factor. Finally, borrowers have more unused commitments relative to assets compared with non-borrowers. This pattern may be driven by the relative predominance of larger banks among borrowers: Unused commitments at larger banks are higher than those at both borrowers and non-borrowers, and given the difference between mean and median, this pattern may be driven by a few banks with high unused commitments-to-assets.

As shown in the second panel, on the liability side, borrowers tend to have less liquid liabilities than non-borrowers. Borrowing banks hold lower shares of transaction deposits, although not quite as low as the larger banks. Likewise, borrowing banks hold higher shares of uninsured deposits relative to non-borrowers, but lower shares than larger banks. Fed funds and repo borrowings tend to be small in general, but borrowers and larger banks have higher shares than non-borrowers. Banks that borrow at the discount window also tend to secure advances from their Federal Home Loan Bank (FHLB); differences in shares are particularly notable when looking at the difference in medians for borrowers and non-borrowers. Based on these patterns, we cannot rule out that the differences between borrowers and non-borrowers on the liability side of the balance sheet is driven by differences in size.

The third panel focuses on balance sheet size and capital. On average, borrowers are somewhat larger than non-borrowers (as we saw in Table 2). Still, the median borrower is much smaller than the median larger bank, consistent with the fact that there is little to no borrowing among the very largest banks. Also, we see that there are no significant differences in return on assets across the different subsamples. Yet, borrowers do appear to have slightly lower tier-1 capital ratios relative to non-borrowers.

One of the main findings in Drechsler et al. (2016) is that banks that borrowed from the discount window in Europe during the sovereign debt crisis in 2011-12 held less capital and more risky assets. In principle, this could be a pattern that arises mainly during crises. However, Table 3 suggests that U.S. domestic banks present a similar pattern in our sample period of "normal" times in the financial system. As in the rest of the table, we see that borrower banks tend to have lower tier-1 capital ratios relative to non-borrowers, but slightly higher than larger banks. In theory, the lower ratios may be explained by higher risk-weighted assets (RWA) for a given level of total assets (i.e., more risky assets) or lower capital levels. In practice, risky assets drive the difference. Borrowers tend to have more risky assets that translate into higher levels of risk-weighted assets (RWA) relative to un-weighted assets–this ratio hovers around 71 percent for borrowers and large banks but is 5 percentage points lower for the mean non-borrower. By contrast, tier-1 capital to total assets is similar across all three categories of banks.

In general, in terms of balance sheet composition, capital ratios, and profitability, borrowers are different from non-borrowers, and do not just replicate larger banks. Moreover, multiple factors appear to simultaneously influence discount window borrowing. The multivariate approach of Section 4 addresses this complexity directly.

2.6 FHLB advances

FHLBs are active providers of backup liquidity to member banks, and sometimes are considered to be the "lenders of next-to-last resort" (Ashcraft, Bech, and Frame, 2010; Gissler and Narajabad, 2017). It is particularly important, then, to understand the interaction between discount window activity and this alternative source of funding. FHLB advances are also collateralized loans but with terms that are usually longer than the typical *overnight* discount window loan. Additionally, acceptable collateral at FHLB is limited to real-estate-related assets and government securities, a narrower set than the collateral accepted at the discount window.[12]

Table 4 provides a breakdown of the banks in our sample according to whether they are active borrowers from FHLBs and discount window. Overall, banks in our sample are more likely to borrow from an FHLB than from the discount window. Nearly 80 percent are "FHLB-active," defined as reporting nonzero FHLB advances at some point in the sample period. By contrast, less than 10 percent borrow from the discount window a meaningful amount (i.e., more than $1 million). Nearly all banks that borrow from the discount window (648) also borrow from FHLBs (606).

For loans of comparable maturity, interest rates offered by FHLBs tend to be lower than the primary credit rate. Banks can also obtain longer-maturity advances at FHLBs than at the discount window. A common maturity for FHLB advances is one year, and sometimes even extend to 30 years. In contrast, during our sample period, discount window loans were generally overnight.[13]

[12]For more information, see https://fhlbanks.com/advances/.

[13]The Fed often increases the maximum discount window loan maturity during periods of financial markets stress. This was the case during the 2008 crisis, although discount window terms had all but

Table 4: FHLB advances and discount window borrowing – Domestic banks

Category	Number of banks	Share of bank-quarter observations (within category)
All banks in sample	7,668	1.00
Borrow from FHLBs	6,117	0.70
Borrow from only FHLBs	5,511	0.67
Borrow from discount window	648	0.08
Borrow from both FHLBs and discount window	606	0.06
Borrow from only discount window	42	0.10

Note: This table provides information on domestic banks' activity at the discount window and/or the FHLBs, based on an unbalanced panel of 7,668 banks at a quarterly frequency. The number of banks in each "borrower" category is based on whether a bank is observed in a category at some point over the entire sample period. Discount window borrowers are defined as domestic banks that file Call reports and that borrow more than $1 million from the discount window at least once over the sample period. FHLB borrowers are defined as banks that file Call reports and that report nonzero outstanding amounts of FHLB borrowing at some point in the sample period.

Why would banks borrow from both the FHLBs and the discount window? Even though the all-in cost of borrowing from FHLBs is generally lower than the cost of borrowing from the discount window, banks may have insufficient eligible collateral required to borrow there. Furthermore, primary credit loans are available later in the business day, when FHLB advances may be more difficult to arrange. For these reasons, banks that find themselves with limited access to advances often turn to the discount window for additional funding.

2.7 Collateral at the discount window

The Federal Reserve requires all discount window loans to be fully collateralized. Consequently, all banks in our sample that execute a loan at the discount window have collateral pledged at a Reserve Bank. Our view into bank collateral holdings is limited because we only observe collateral holdings when a bank executes either a loan (test or otherwise). Some banks that do not take a loan at the discount window during our sample period may also have pledged collateral, but we do not observe those holdings. In addition, we do not observe changes in collateral holdings outside of borrowing events. Given these limitations, we limit our analysis to the collateral holdings of banks that execute loans.

The transaction-level data include the total amount of collateral and its composition. The fourth panel of Table 3 provides information on collateral posted relative to assets.

normalized by the beginning of our sample period in 2010. During the COVID-19 financial stress in March 2020, discount window loans were again made available at maturities of up to 90 days; see https://www.federalreserve.gov/regreform/discount-window.htm for more information.

The mean is calculated as the average of bank-quarter observations of total collateral to assets.[14] Posted collateral is a notably higher share of assets for banks that borrow at the discount window (borrowers columns), than for banks that engage in testing only (reported under the "non-borrowers" category, for conciseness). Larger banks tend to post relatively more collateral, approaching 8 percent of bank balance sheets on average.

Figure 2 presents information on the composition of collateral as a share of total collateral across loan observations. In general, collateral tends to be concentrated in one type for any particular observation, and the "barbell" shapes of the histograms suggest that banks either post a significant proportion of a given collateral type, or not at all. Most borrowers do not pledge a high share of liquid securities but a high proportion of banks use significant amounts of real estate collateral at the discount window. Business and household loans have shares somewhere in the middle. Of note, C&I loans comprise roughly 10 percent of banks' balance sheets but are not acceptable collateral at FHLBs, making this (relatively illiquid) category of bank assets better suited for pledging at the discount window.

Although we only observe collateral when a bank borrows, evidence suggests that the level and composition of posted collateral is persistent. For banks with more than one loan during our sample period (and hence with more than one collateral observation), the simple correlation coefficients within bank transactions of types of collateral shares are around 0.95. In addition, the estimated autocorrelation coefficients for the share of type of collateral across bank-loan observations are also high and statistically significant (see Table A1 in the online appendix). These correlations give us some comfort that, although we observe collateral only when banks execute loans, it is reasonable to assume some stasis in posted collateral, and available information provides a reasonable approximation.

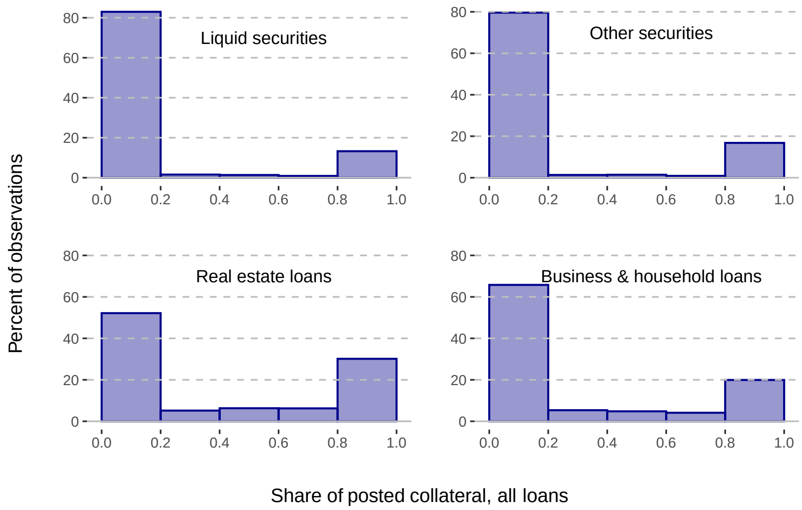
2.8 Interest rates

Before we move to the theoretical framework, it is helpful to discuss briefly the configuration of interest rates most relevant for understanding this period in the U.S. financial system. As we will see, portfolio decisions depend on the relative level of various interest rates. During our sample period, interest rates exhibit patterns that will allow us to narrow the set of theoretical and empirical possibilities.

The interest rate on overnight overdrafts at the Federal Reserve was set at a penalty rate equal to the primary credit rate plus 4 percentage points (annual rate). There was

[14] If a bank executes more than one loan in a quarter, collateral values are averaged for the quarter.

Figure 2: Distribution of collateral types



Note: The figure provides information on the composition of collateral by asset type — each type expressed as a share of total collateral. The height of the bars gives the percent of observations on collateral shares that fall into a particular range. Calculated from bank-loan observations. Source: Federal Reserve Board and authors' calculations.

also a minimum fee (regardless of the size of the overdraft), and the rate increased after running an overdraft for several consecutive days.

The primary credit rate was 50 basis points higher than the top of the target range for the federal funds rate (the policy rate). The interest rate on reserves was set to equal the top of the target range from 2010 through June 2018 and, hence, 50 basis points lower than the primary credit rate. Thereafter, the interest rate on reserves was lowered to below the top of the target range in a series of steps, and so the spread between the primary credit rate and the interest rate on reserves widened to as much as 70 basis points.

Interest rates in the interbank market were generally below the interest rate on reserves, as market rates traded within the range set by policy. Some of the interbank transactions are between commercial banks and the FHLBs. This are uncollateralized and usually overnight transactions. As discussed above, FHLBs also provide collateralized loans to "member" banks via advances. The comparison between posted interest rates on FHLB advances and other market and administered rates is complicated by the additional benefits and requirements of being members of an FHLB network (Ashcraft, Bech, and Frame, 2010). As a general matter, however, the all-in cost of borrowing from FHLBs was below the primary credit rate during the full span of our sample period.

3 A theoretical framework

In this section, we introduce a framework to help with the interpretation of our empirical strategy and results. The framework describes the decisions of a bank that is exposed to shocks and needs to make adjustments to its balance sheet in response to those shocks. Under some conditions, but not always, the optimal response of the bank is to borrow from the discount window. The framework is intended to illustrate the mechanisms that generate the patterns observed in our data.

3.1 The model

Consider the problem of a bank that makes loans (l), holds liquid and illiquid securities (s^L and s^I, respectively) and reserves (f) and funds those assets by attracting deposits (d) engaging in other borrowing (b), and holding equity capital (k). The bank also has an administrative resource cost $\chi(l)$ from managing a portfolio of loans of size l.

After choosing the initial allocation of assets and the structure of its liabilities, the bank is exposed to various shocks that can alter certain components of its balance sheet.[15] For example, the bank may experience an outflow of borrowed money (b), or a valuable client may choose to draw down a line of credit that changes total bank lending (l). To confront the funding needs that result from those shocks, the bank may use its reserves, liquidate some of its holdings of securities, or borrow from the interbank market (collateralized, b^{FH}, and uncollateralized, b^{FF}) or from the central bank, via a discount window loan, b^{DW}. In the context of the model, FHLB advances can be seen as part of the bank's collateralized borrowing from the interbank market.

The framework is sufficiently general to allow us to interpret shocks as potentially reflecting access (or lack thereof) to different markets that the bank can use to adjust its balance sheet in response to those shocks. In particular, the bank may be able to trade in the securities market, the interbank market, or in no market at all, depending on the timing of the shocks and the time-sensitivity of the required adjustment.

For example, if a source of borrowed funds is unavailable late in the day, a bank's only alternatives may be to use reserves or to borrow from the central bank through the discount window to cover certain payments needs (as in Poole, 1968). Some shocks, however, may give the bank more time to adjust, in which case the bank may be able to

[15] The bank's problem is similar to the one presented in Ennis (2018), but modified to consider a situation where the bank experiences liquidity shocks that need to be accommodated with reserves, other holdings of liquid assets, or short-term borrowing from the interbank market or central bank.

liquidate short-term securities or borrow in the interbank market.

Denote by ϵ the vector of shocks that a bank experiences. Initially, the bank chooses loans, securities, reserves, deposits, other borrowing, and capital, subject to the balance sheet constraint:

$$l + s^L + s^I + f = d + b + k, \tag{1}$$

with all variables restricted to be positive. After these decisions are made, the bank is exposed to the shocks ϵ which (possibly) impact the values of l, d, and/or b. We denote by $l(\epsilon)$, $d(\epsilon)$, and $b(\epsilon)$ the value of these variables, respectively, after the shocks.

In response to a shock, we assume that the bank can adjust its reserves and, possibly, its securities holdings. We denote by $f(\epsilon)$, $s^L(\epsilon)$, and $s^I(\epsilon)$ the ex-post value (after the adjustment) of these variables. We also assume that, after the shock, the bank cannot sell more than the amount of securities it holds (no short selling is allowed).

The bank may also borrow in the interbank market, $b^{FH}(\epsilon)$ and $b^{FF}(\epsilon)$, or at the discount window, $b^{DW}(\epsilon)$. If the bank cannot fully fund its cash position, it may incur an overnight overdraft on its account at the central bank, $o(\epsilon)$. All these decisions together must satisfy the following "flow" constraint:

$$\begin{aligned}(l(\epsilon) - l) + (d - d(\epsilon)) + (b - b(\epsilon)) =& \\ (f - f(\epsilon)) + (s^L - s^L(\epsilon)) + \omega(s^I - s^I(\epsilon)) &+ b^{FH}(\epsilon) + b^{FF}(\epsilon) + b^{DW}(\epsilon) + o(\epsilon),\end{aligned} \tag{2}$$

where the parameter ω is the liquidation value per unit of illiquid securities.

If a variable is not affected by the shocks or is not adjusted (potentially due to the timing of the shocks in the presence of market frictions), then its ex-post value equals its ex-ante value. For example, if total loans are not affected by the shock and cannot be adjusted in a timely manner in response to the shock (because, say, they are longer-term commitments), then $l(\epsilon) = l$. Similarly, if the timing of the shock ϵ is such that it is not possible for the bank to adjust its securities holdings, then $s^L(\epsilon) = s^L$ and $s^I(\epsilon) = s^I$. That is, the bank's securities holdings after the shock are the same as before the shock. One way to interpret such a situation is that the shock is realized after securities markets are closed for the day, or activity in these markets is so reduced that no significant trading can be executed effectively.

We denote by c^{DW} the amount of collateral that the bank has pledged at the discount window. Discount window borrowing, then, has to satisfy the collateral constraint:

$$b^{DW}(\epsilon) \leq c^{DW}. \tag{3}$$

Note that c^{DW} is not contingent on the shock as most discount window collateral in the U.S. needs to be prepositioned well in advance of the time of borrowing. The bank may pledge as discount window collateral a portion of its loans and/or its securities.

Similarly, the amount the bank can borrow in the collateralized portion of the interbank market is limited by the availability of suitable collateral. We have:

$$b^{FH}(\epsilon) \leq c^{FH}(\epsilon). \tag{4}$$

Interbank market collateral is generally comprised just of securities and, in that sense, has a narrower composition than that at the discount window. Furthermore, it is usually the case that illiquid securities are subject to a haircut in their role as collateral. We will denote by θ the proportional haircut applied to these securities.

Finally, there are natural non-negativity constraints on reserves, discount window borrowing, and overnight overdrafts:

$$f(\epsilon) \geq 0, \quad b^{DW}(\epsilon) \geq 0, \quad o(\epsilon) \geq 0. \tag{5}$$

The bank takes as given the interest rates paid on deposits, r_D, interbank loans, r_{FH} and r_{FF}, and other borrowings, r_B, the rates earned on loans, r_L, securities, r_{SL} and r_{SI}, and the cost of capital, r_K. Also, the bank takes as given the interest rates set by the central bank: the rate of interest on reserves, r_{IOR}, the discount window rate, r_{DW}, and the interest and fees charged for overnight overdrafts, r_o.

Given rates, the bank chooses the initial values of l, s^L, s^I, f, d, b, and k. The bank also chooses the functions $f(\epsilon)$, $s^L(\epsilon)$, and $s^I(\epsilon)$ subject to the feasibility constraints imposed by the timing of trade and the possibility that some markets are no longer available at the time a particular shock gets realized. Finally, the bank also chooses $b^{FH}(\epsilon)$, $b^{FF}(\epsilon)$, $b^{DW}(\epsilon)$, and $o(\epsilon)$. The objective of the bank is to maximize profit:

$$\begin{aligned} E[(1+r_L)l(\epsilon) + (1+r_{SL})s^L(\epsilon) + (1+r_{SI})s^I(\epsilon) + (1+r_{IOR})f(\epsilon) \\ -(1+r_D)d(\epsilon) - (1+r_B)b(\epsilon) - (1+r_K)k - \chi(l) \\ -(1+r_{FH})b^{FH}(\epsilon) - (1+r_{FF})b^{FF}(\epsilon) - (1+r_{DW})b^{DW}(\epsilon) - (1+r_o)o(\epsilon)], \end{aligned} \tag{6}$$

subject to constraints (1), (2), (3), (4), and (5).

To understand the decisions of the bank, we start with the ex-post optimal adjustment that the bank makes in response to a shock. Then, we study the ex-ante decisions on reserves holdings and other variables given that optimal ex-post response.

3.2 Ex-post response to shocks

Consider a bank that has chosen the level of loans (l), deposits (d), securities holdings (liquid and illiquid, s^L and s^I), and capital (k). After the shock ϵ, the bank's liquidity needs are $\Delta(\epsilon)$, given by:

$$\Delta(\epsilon) \equiv (l(\epsilon) - l) + (d - d(\epsilon)) + (b - b(\epsilon)).$$

To simplify the exposition, assume that the timing of the shock is such that the bank is not able to adjust securities after the shock. Then, using equation (2), we have:

$$\Delta(\epsilon) = (f - f(\epsilon)) + b^{FH}(\epsilon) + b^{FF}(\epsilon) + b^{DW}(\epsilon) + o(\epsilon), \tag{7}$$

which tells us the bank will use reserves and borrowed funds (from the interbank market or the discount window) to cover its ex-post liquidity needs (and will incur an overnight overdraft for the amount of any shortfall).

The relevant portion of the bank's payoff function (6) in the ex-post decision-making process is given by:

$$(1+r_{IOR})f(\epsilon) - (1+r_{FH})b^{FH}(\epsilon) - (1+r_{FF})b^{FF}(\epsilon) - (1+r_{DW})b^{DW}(\epsilon) - (1+r_o)o(\epsilon), \tag{8}$$

with the bank still subject to constraints (3), (4), and (5). The bank needs to choose $b^{FH}(\epsilon)$, $b^{FF}(\epsilon)$, and $b^{DW}(\epsilon)$ to maximize objective (8) given that $f(\epsilon)$ satisfies (7).

In terms of the relevant configurations of interest rates to consider, as discussed in Section 2.8, it is standard to have that $r_{IOR} < r_{DW} < r_o$. That is, the central bank's lending rate r_{DW} is higher than the central bank's deposit rate r_{IOR}, and overnight overdrafts carry a significant penalty over borrowing from the discount window. To simplify notation, we interpret the interest rates as "all inclusive." Hence, for example, the value of r_o is intended to capture all fees and implicit costs from incurring an overnight overdraft at the central bank. Similarly, r_{DW} may include the implicit *stigma cost* often associated with borrowing at the discount window.

With respect to the interbank market, given the simplified nature of the model, it makes sense to restrict attention to $r_{IOR} \leq r_{FF} < r_{DW}$ and $r_{FH} \leq r_{FF}$. If $r_{FF} < r_{IOR}$, it would be profitable for any bank (facing no other balance sheet costs, as assumed here) to borrow in the interbank market to hold reserves and earn interest on reserves. Since all banks would want to do the same, such a configuration of interest rates would be inconsistent with the clearing of the interbank market.[16]

The case when $r_{FF} = r_{DW}$ is less relevant in practice and hence not discussed here. This would be a situation where the system as a whole is systematically "short" on reserves and some banks have to borrow at the discount window to balance aggregate supply with aggregate demand. While historically this situation was within the realm of possibilities in the U.S. (see, for example, Kasriel and Merris, 1982), such a configuration of interest rates is not relevant for understanding discount window activity during our sample period.

3.2.1 Active interbank market

The ex-post funding decisions of the bank will depend crucially on the funding alternatives open at the time of receiving the liquidity shock. In particular, if the bank still has access to the interbank market when the shock occurs, then the discount window will not be used, as the following proposition demonstrates.

Proposition 1 (Active interbank market) *If the timing of the shock ϵ is such that the bank can trade in the interbank market when the shock is realized, and we have that $r_{IOR} \leq r_{FF} < r_{DW} < r_o$ and $r_{FH} \leq r_{FF}$, then $b^{DW}(\epsilon) = 0$ and $o(\epsilon) = 0$. Furthermore, if $r_{IOR} < r_{FF}$, then $b^{FH}(\epsilon) + b^{FF}(\epsilon) = \Delta(\epsilon) - f$.*

For the relevant configurations of interest rates, if the bank can trade in the interbank market, then it does not borrow from the central bank. Note that $b^{FH}(\epsilon)$ and $b^{FF}(\epsilon)$ may be positive or negative, depending on the relative size of $\Delta(\epsilon)$ compared with the ex-ante level of reserves held by the bank, f. When $r_{IOR} < r_{FF}$, the bank will borrow or lend in the interbank market the reserves that it needs to end the period with no holdings of reserves (i.e., so as to have $f(\epsilon) = 0$; see expression (7)). If instead $r_{IOR} = r_{FF}$, then whenever $\Delta(\epsilon) < f$, the bank may choose to finish the period with a positive level of (*excess*) reserves (i.e., so as to have $f(\epsilon) > 0$).

When $r_{FF} > r_{FH}$, the bank will borrow in the collateralized segment of the interbank market until $b^{FH}(\epsilon) = c^{FH}$. From expression (7) then we have that $f(\epsilon) - b^{FF}(\epsilon) = f - \Delta(\epsilon) + c^{FH}$ and whenever $r_{IOR} < r_{FF}$ we have $f(\epsilon) = 0$. In other words, the bank is engaged in arbitrage by borrowing in one segment of the interbank market either to hold reserves (if $r_{IOR} = r_{FF}$) or to lend them in the other segment of the market (if $r_{IOR} < r_{FF}$). Since the timing of the shock is such that the bank can no longer trade

[16]For a paper where balance sheet costs are explicitly modeled, and hence the interbank rate can be below the interest on reserves, see Afonso, Armenter, and Lester (2019).

securities, c^{FH} is not contingent on the shock. This, then, places some limits on arbitrage. If this were not the case, equilibrium would require that $r_{FH} > r_{FF}$.

We have assumed that $r_{FF} < r_{DW}$. It is possible for certain banks, at certain times, to face interest rates in the interbank market that are higher than the discount window rate. This could happen, for example, if market segmentation led to lenders' market power (Bech and Klee, 2011). The situation in that case is equivalent to the case when the bank does not have access to the interbank market altogether, which we study next.

3.2.2 No active interbank market

Proposition 1 describes the case when the bank can (effectively) use the interbank market as its marginal source of funding to accommodate a given shock. Other shocks may happen at a time when the interbank market is not immediately accessible to the bank, either because the shock occurs late in the day, when the interbank market is thin or no longer active, or because the bank's usual counterparties are not able to accommodate its liquidity demand and the bank is not able to find other suitable trading partners on short notice. In that case, some discount window borrowing may be optimal.

Evidently, when $c^{DW} = 0$, the bank has no available collateral to borrow at the discount window and, in consequence, $b^{DW}(\epsilon) = 0$ regardless of the shock. Furthermore, in that case, whenever $\Delta(\epsilon) > f$, the bank incurs an overnight overdraft $o(\epsilon) = \Delta(\epsilon) - f$. To focus on the more interesting case when discount window borrowing can happen, assume that $c^{DW} > 0$.

Proposition 2 (The pecking order with no access to interbank markets) *Assume $c^{DW} > 0$. If the timing of the shock ϵ is such that the bank cannot trade in the interbank market when the shock is realized, and $r_{IOR} < r_{DW} < r_o$, then:*

- *when $f \geq \Delta(\epsilon)$ we have $f(\epsilon) > 0$, and $b^{DW}(\epsilon)$ and $o(\epsilon)$ equal zero;*
- *when $f < \Delta(\epsilon)$ we have $f(\epsilon) = 0$, $b^{DW}(\epsilon) > 0$, and:*
  - *if $\Delta(\epsilon) - f \leq c^{DW}$ then $o(\epsilon) = 0$,*
  - *if $\Delta(\epsilon) - f > c^{DW}$ then $o(\epsilon) > 0$.*

The bank follows *a pecking order* for funding the liquidity shock. If the shock is relatively small, the bank uses its holdings of reserves to cover the shock. For larger shocks, when the ex-ante stock of reserves held by the bank is not enough, the bank borrows from the discount window. In such case, the bank may or may not incur an overnight overdraft, depending on whether the collateral pledged at the central bank is enough to back a sufficiently large discount window loan.

Figure 3: The pecking order

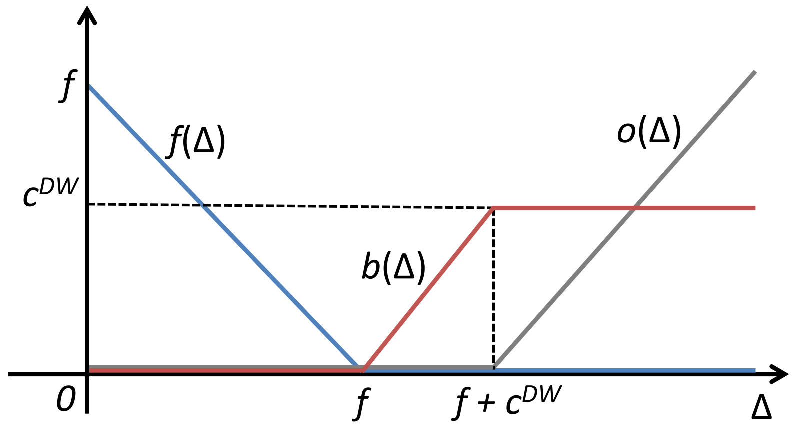


Figure 3 illustrates this pecking order. On the horizontal axis, we measure the size of the shock Δ. When Δ is smaller than ex-ante reserves f, the bank adjusts its reserves holdings down to accommodate the shock. No central-bank funding is used in this case and ex-post reserves are given by $f(\Delta) = f - \Delta$. When Δ is greater than the level of ex-ante reserves, f, discount window borrowing, $b(\Delta)$, is positive and ex-post reserves are zero. Finally, if the shock is greater than ex-ante reserves *plus* the discount window borrowing capacity of the bank, given by its available (prepositioned) collateral, c^{DW}, then the bank incurs a positive overnight overdraft $o(\Delta)$ (i.e., a negative balance in its account at the central bank).

3.2.3 The case of FHLB advances

Collateralized borrowing from FHLBs, in the form of advances, can at times function as an alternative to discount window borrowing. As we discussed earlier in Section 2.6, collateral eligibility differ across these alternatives. In particular, FHLB collateral is narrower. For example, bank loans can be used as collateral at the discount window but not at the FHLBs. Some securities, on the other hand, can be used at both. For concreteness, assume that the bank has prepositioned collateral at the discount window $c^{DW} = l + s^{DW}$ where s^{DW} is a portion of its securities holdings, with the rest available to borrow collateralized from the interbank market, including the FHLBs.

Most banks in the U.S. have a relationship with their corresponding FHLB, which may allow them to access funding when other interbank channels are closed. To study this case in the model, suppose that when the shock hits, the uncollateralized segment of the interbank market is closed, but the collateralized one is still open.

Proposition 3 (FHLB advances in the pecking order) *Assume* $c^{DW} = l + s^{DW}$ *and* $c^{FH} = s^L + \theta s^I - s^{DW}$*, where* θ *is the haircut on illiquid securities. If the timing of the shock* ϵ *is such that the interbank market is closed, except for the bank's ability to* ***borrow*** *collateralized from an FHLB (i.e.,* $b^{FH} \geq 0$*) at rate* r_{FH}*, and* $r_{IOR} < r_{FH} < r_{DW} < r_o$*, then:*

- *when* $f \geq \Delta(\epsilon)$ *we have* $f(\epsilon) = f > 0$ *and* $b^{FH}(\epsilon)$*,* $b^{DW}(\epsilon)$*, and* $o(\epsilon)$ *equal zero;*
- *when* $f < \Delta(\epsilon)$ *we have* $f(\epsilon) = 0$ *and:*
  - *if* $\Delta(\epsilon) - f \leq c^{FH}$ *we have* $b^{FH}(\epsilon) > 0$*,* $b^{DW}(\epsilon) = 0$ *and* $o(\epsilon) = 0$*;*
  - *if* $\Delta(\epsilon) - f \in (c^{FH}, c^{FH} + c^{DW}]$ *then* $b^{FH}(\epsilon) = c^{FH}$*,* $b^{DW}(\epsilon) > 0$*, and* $o(\epsilon) = 0$*;*
  - *if* $\Delta(\epsilon) - f > c^{FH} + c^{DW}$ *then* $b^{FH}(\epsilon) = c^{FH}$*,* $b^{DW}(\epsilon) = c^{DW}$*, and* $o(\epsilon) > 0$*.*

When FHLB advances are still available to the bank when the shock happens, the pecking order incorporates that possibility and, given that $r_{FH} < r_{DW}$, the bank borrows from its FHLB before borrowing from the central bank. This pattern is consistent with the data presented in Table 4, illustrating that most banks that borrow from the discount window also borrow from the FHLBs, and many banks that borrow from the FHLBs do not borrow from the discount window. In summary, given that $r_{FH} < r_{DW}$, the bank borrows from the discount window either because its FHLB is inaccessible (due to timing or other reasons) or because, while accessible, the bank has exhausted its collateral capacity at the FHLB, and some collateral at the discount window is still at its disposal.

3.3 Ex-ante balance sheet decisions

When the bank is choosing the composition of its balance sheet, it anticipates that it will be exposed to shocks. Depending on the size and timing of those shocks, the bank may have different alternatives (including discount window borrowing) for addressing the resulting liquidity needs. In this section, we study the ex-ante portfolio decision of banks. To simplify the analysis, consider a situation in which the bank has already decided the amount of loans, other borrowed money, and capital and now has to decide the amount of reserves, securities, and deposits to hold. For concreteness, we also assume that the shocks affect only the amount of other borrowed money; i.e., $\Delta(\epsilon) = b - b(\epsilon)$. We consider the more general case in Section 3.4.

The problem of the bank at that point in the decision process is to choose reserves, securities, and deposits to maximize

$$\widehat{V} \equiv E_\epsilon[(1+r_{SL})s^L + (1+r_{SI})s^I + (1+r_{IOR})f(\epsilon) - (1+r_D)d + (1+r_B)\Delta(\epsilon) \\ -(1+r_{FH})b^{FH}(\epsilon) - (1+r_{FF})b^{FF}(\epsilon) - (1+r_{DW})b^{DW}(\epsilon) - (1+r_o)o(\epsilon)], \qquad (9)$$

subject to (1), (2), (3), (4), (5), and $f \geq 0$. The bank has to decide also how to allocate collateral to the discount window and its corresponding FHLB.

After the shock occurs, we assume that with probability q the bank is able to trade in the interbank market and with probability $1-q$ the bank can only cover a liquidity shortfall with either a discount window loan or an overnight overdraft. We denote with the subscript A the value of a variable when the bank can trade in the interbank market, and with the subscript N when it cannot.[17]

3.3.1 Link between reserves and discount window borrowing

We aim to show how the choice of reserves depends on the distribution of shocks and the ability of banks to use different sources of funding to accommodate those shocks. This will be particularly relevant for the interpretation of our empirical analysis.

To simplify the analysis, we will consider the case when the collateral constraints are not binding. This is the case, for example, when the rates of return on securities (r_{SL} and r_{SI}) are equal to the rate of interest on deposits, and $r_{FH} = r_{FF}$ so there are no arbitrage opportunities in the interbank market. For this combination of interest rates, the bank will hold enough securities to make collateral constraints non-binding.

Also for the sake of exposition, we assume the following distribution of the shocks, which allows us to capture the relevant tradeoffs in a clear and simple way:

$$\Delta(\epsilon) = \begin{cases} \Delta_0 = 0 & \text{with prob. } 1 - p_1 - p_2, \\ \Delta_1 & \text{with prob. } p_1, \\ \Delta_2 & \text{with prob. } p_2, \end{cases} \qquad (10)$$

with $0 < \Delta_1 < \Delta_2$.

Proposition 1 tells us that when the bank can trade in the interbank market after the realization of the shock (and $r_{FF} < r_{DW} < r_o$), it will neither borrow at the discount window nor incur an overnight overdraft. That is, $b_A^{DW} = 0$ and $o_A = 0$ regardless of the

[17] A third possibility would be that the bank has access to FHLB advances but not to the uncollateralized segment of the interbank market. The basic analysis is similar in that case.

size of the shock. This is the case because it is cheaper for the bank to access funding via the interbank market than via the central bank.

When the bank is not able to access the interbank market (with probability $1-q$), as in Proposition 2, the prior choice of reserves influences how much the bank borrows from the central bank. This choice, of course, depends on the cost of funding (in this simple case, the interest rate on deposits).

Denote by r_{CB} the bank's cost of credit at the central bank. This rate could be equal to r_{DW}, r_o, or a combination of the two. There are three relevant thresholds for the level of the interest rate on deposits (i.e., the bank's funding cost) that we need to consider:

$$\begin{aligned} r^{T_1} &= qr_{FF} + (1-q)r_{IOR} \\ r^{T_2} &= qr_{FF} + (1-q)[(1-p_2)r_{IOR} + p_2 r_{CB}] \\ r^{T_3} &= qr_{FF} + (1-q)[(1-p_1-p_2)r_{IOR} + (p_1+p_2)r_{CB}]. \end{aligned}$$

A way to think about these thresholds is that they represent the value for the bank of holding an extra unit of reserves, depending on whether or not the bank needs access to central bank liquidity in response to the different realizations of the liquidity shock Δ. The bank will compare such value with the cost of obtaining an extra unit of reserves ex ante, which is given by r_D here.[18]

So, for example, if the bank is holding reserves sufficient to cover all possible realizations of the liquidity shock, then with probability q the bank will be able to lend out leftover reserves in the interbank market. With probability $1-q$, however, the bank will not be able to trade in the interbank market and will keep those leftover reserves, remunerated at the level of the interest on reserves. This possibility generates the threshold rate r^{T_1}, and if the interest rate on deposits is higher than this threshold then the bank would have no incentives to hold such a high level of reserves.

Notice that if the interest rate on deposits r_D is below the threshold rate r^{T_1}, then the bank benefits from increasing deposits and reserves indefinitely. This situation would not be compatible with equilibrium, so we only consider situations where $r_D \geq r^{T_1}$. Interestingly, if $r_D = r_{FF} = r_{IOR}$, then r_D equals r^{T_1} and the bank will choose to hold sufficient reserves to cover all possible shocks and possibly a significant level of *excess*

[18]In principle, the cost of funding an extra unit of reserves is the cost of the marginal liability created by the bank to obtain those reserves. Here, we have simplified the timing so that deposits always represent the marginal liability for the bank. Importantly, this presumes that the bank does not need to increase capital as its balance sheet grows – the capital constraint is not binding. If it were binding, then the marginal cost of funding would include a capital charge (as in Ennis, 2018).

reserves. While this choice appears relevant for many banks in the U.S. during our sample period, it is inconsistent with active discount window lending in the model. For this reason, since we observe discount window borrowing by many banks during our sample period, we proceed to study the model under the assumption that $r_D > r^{T_1}$.[19]

When the bank holds enough securities (or pledgeable loans) to make the discount window collateral non-binding, we have that $r_{CB} = r_{DW}$. We later consider cases when $r_{CB} = r_o$ for some realizations of the shock. This can happen when the bank has no access to the discount window or when collateral pledged there becomes binding.

Denote by b_{iN}^{DW} the amount borrowed at the discount window when the shock equals Δ_i with $i = 0, 1, 2$. Depending on how the interest rate on deposits compares with the threshold rates, the bank will hold reserves to cover either partially or fully the different possible realizations of the liquidity shock. The next proposition describes these decisions.

Proposition 4 (<u>Ex-ante decisions. No overdrafts.</u>) *When $r_{IOR} \leq r_{FF} = r_{FH} < r_{DW} < r_o$ and $r_{SI} = r_{SL} = r_D$, we have that:*

- ∘ *if $r^{T_1} < r_D < r^{T_2}$ then $f = \Delta_2$, and if $r_D = r^{T_2}$ then $\Delta_1 \leq f < \Delta_2$,*
- ∘ *if $r^{T_2} < r_D < r^{T_3}$ then $f = \Delta_1$, and if $r_D = r^{T_3}$ then $0 \leq f < \Delta_1$,*
- ∘ *if $r^{T_3} < r_D$ then $f = 0$.*

Furthermore,

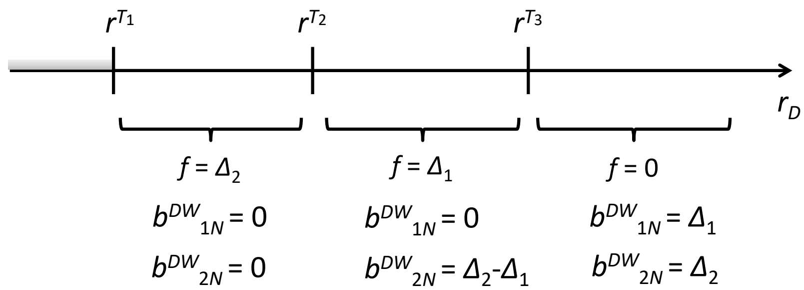
- *when the bank can access the interbank market, $b_{iA}^{DW} = 0$ and $o_{iA} = 0$ for $i = 0, 1, 2$; and*
- *when the bank cannot access the interbank market, $b_{iN}^{DW} = max\ \{0, \Delta_i - f\}$ and $o_{iN} = 0$ for $i = 1, 2$.*

Finally, $l + s_L + \theta s_I \geq c_{DW} \geq max\ \{b_{iN}^{DW}\}_{i=1,2}$.

Figure (4) summarizes the results from the proposition. The most interesting situation occurs when $r_D \in (r^{T_2}, r^{T_3}]$ because then, if the shock is large (equal to Δ_2) and the bank has no access to the interbank market, it borrows from the discount window even while holding a positive amount of reserves. For other interest rate values, either the bank never borrows from the discount window or it chooses to hold no reserves and hence borrows from the discount window whenever it receives a liquidity shock and has no access to the interbank market.

[19]There are many bank in many instances in the data that do not use the discount window. There are, of course, multiple reasons that could justify that outcome in the context of the model, including the plausible case where the cost of funding is heterogeneous across banks and the conditions are such that some banks hold significant excess reserves.

Figure 4: Interest rate thresholds



The proposition points to a negative association between the level of reserves and discount window borrowing, given that $b_{iN}^{DW} = \max\{0, \Delta_i - f\}$. In other words, for a given shock process, higher levels of reserves holdings tend to be associated with lower discount window lending. However, this negative association weakens when looking at a cross section of banks facing different shock processes. We illustrate this situation with the following corollary.

Corollary 4.1 (Heterogeneous shock-distributions.) *Consider two banks, 1 and 2, facing two different shock processes, both with the structure in expression (10) but with* $\Delta^2(\epsilon) = \rho\Delta^1(\epsilon)$ *and* $\rho > 1$. *When the conditions in Proposition (4) are satisfied and* $r_D \in (r^{T_2}, r^{T_3})$, *bank 2 will hold (ex ante) higher levels of reserves and borrow more (ex post) from the discount window.*

As we saw in Proposition 4, when $r_D \in (r^{T_2}, r^{T_3})$, bank i will hold reserves $f_i = \Delta_1^i$ and will borrow at the discount window $b_i^{DW} = \Delta_2^i - \Delta_1^i$ when the shock $\Delta^i(\epsilon)$ equals Δ_2^i. As a result, bank 2 will hold higher reserves, since $\Delta_1^2 > \Delta_1^1$, and will borrow more from the discount window since $\Delta_2^2 - \Delta_1^2 > \Delta_2^1 - \Delta_1^1$.

The proportionality factor ρ is, of course, not necessary for the result; it is assumed just for convenience.[20] The corollary highlights the importance of recognizing the endogeneity of reserves holdings. Conditional on a shock process, higher reserves imply that a bank is able to accommodate more of those shocks without tapping the discount window. However, banks exposed to larger liquidity shocks may choose to hold higher levels of reserves and, at the same time, may need to borrow more (and more often) from the discount window. While the first logic indicates a negative relationship between reserves and discount window borrowing, the second can generate a positive relationship.

[20] As long as bank 2 faces a shock process that has Δ_1 and $\Delta_2 - \Delta_1$ both larger than the corresponding values for Bank 1, then bank 2 will hold higher reserves and borrow more from the discount window.

3.3.2 The impact of discount window access

The ex-ante level of reserves (and other components of the balance sheet) also depends on the ability of banks to access the discount window. If the bank is not able to access the discount window (because it has not made the necessary arrangements, for example), then $r_{CB} = r_o$. As a result, the threshold values for interest rates change to reflect the fact that the bank, having no access to the discount window, will need to incur an overnight overdraft when short on reserves. Given these new thresholds, denoted with a prime below, the bank's ex-ante choice of reserves is given by the following proposition.

Proposition 5 (<u>Ex-ante decisions. No discount window access.</u>) *When* $r_{IOR} \leq r_{FF} = r_{FH} < r_{DW} < r_o$ *and the bank has no access to the discount window, we have that:*

- *if* $r^{T_1'} < r_D < r^{T_2'}$ *then* $f = \Delta_2$, *and if* $r_D = r^{T_2'}$ *then* $\Delta_1 \leq f < \Delta_2$,
- *if* $r^{T_2'} < r_D < r^{T_3'}$ *then* $f = \Delta_1$, *and if* $r_D = r^{T_3'}$ *then* $0 \leq f < \Delta_1$,
- *if* $r^{T_3'} < r_D$ *then* $f = 0$.

Furthermore, $o_{iA} = 0$ *for* $i = 0, 1, 2$ $o_{iN} = max\ \{0, \Delta_i - f\}$ *and for* $i = 1, 2$.

The parallels between propositions (4) and (5) highlight the fact that, during "normal" times, the discount window can operate as an alternative to more expensive overnight overdrafts.[21] It is also the case that for certain combinations of rates of return and funding costs, a bank with no access to the discount window will tend to hold higher levels of reserves than a similar bank that has access to the discount window, as the following corollary demonstrates.

Corollary 5.1 (<u>Ex-ante effects of discount window access.</u>) *Consider two banks, one with access to the discount window and one without it. Both banks face the same funding cost* r_D. *When the conditions in propositions (4) and (5) are satisfied and* $r^{T_2} < r_D < r^{T_2'}$ *or* $r^{T_3} < r_D < r^{T_3'}$, *the bank without access to the discount window holds more reserves than the bank with access the discount window.*

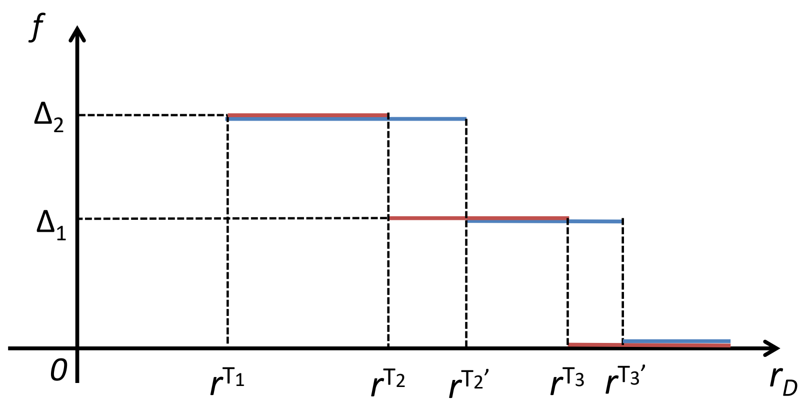
The basic logic behind this result is simple. When a bank has no access to the discount window, if the shock exhausts its reserves, then it has to incur an overdraft with the central bank, which is more expensive than a discount window loan ($r_{DW} < r_o$). For this reason,

[21] In fact, a common discussion in policy circles is the possibility of automatically transforming any shortfall in a bank's account at the central bank into a discount window loan, as long as the bank has the appropriate amount of collateral pledged with the central bank (see, for example, Nelson (2019)).

given the levels of interest rates, the bank with no access to the discount window has more incentives to hold reserves.

More specifically, in the context of the model, this logic is captured by the fact that the relevant interest rate thresholds for a bank with access to the discount window are lower than the thresholds for the bank without access. As we see in Figure 5, when funding costs are between the two values of a given threshold, the bank with access to the discount window chooses a lower level of reserves (red lines) than the bank without access (blue lines). For example, when $r^{T_2} < r_D < r^{T_2'}$, the bank with access to the discount window will choose reserves equal to Δ_1, and the bank without access to the discount window will choose reserves equal to Δ_2.

Figure 5: Endogenous reserves with and without discount window access



Of course, economic reasons may drive a bank to make the necessary arrangements to access the discount window. In that sense, "access" could be partly determined by, for example, the distributions of shocks faced by the bank, as was the case with the level of reserves. For this reason, the relationship between reserves and access in a cross section of heterogeneous banks can be difficult to disentangle, as we discuss further in the online appendix.

3.3.3 Binding collateral

The ability of a bank to use the discount window also depends on the amount of collateral it has readily available. In the model, loans will be fully prepositioned as collateral at the discount window, since they cannot serve as collateral in any other way. However, securities have competing uses as collateral: for borrowing in the interbank market or at the discount window. Under our assumed configuration of interest rates, if the bank has access to borrowing from the FHLB system as in Proposition 3 and the collateral constraint is binding, then we have that the bank will dedicate all its securities holdings to borrow from the FHLBs. Discount window collateral is $c^{DW} = l$, and it may or may not be binding, depending on the size of the shock and the cost of funding for the bank.

The ex-ante decision by the bank to hold securities also interacts with the bank's expected need for collateral. As discussed above, when the return on securities (r_{SL} and/or r_{SI}) is equal to the funding cost (r_D), the bank holds enough securities so that the collateral constraint does not bind. When the collateral constraint binds (at least for some realizations of the shocks), the value from holding an extra unit of securities includes the shadow value of relaxing the collateral constraint. Denote that shadow value $\lambda_{CC} \geq 0$. For the bank to hold both types of securities in its portfolio, the following two conditions must hold:

$$
\begin{aligned}
1 + r_{SL} + \lambda_{CC} &= 1 + r_D \\
1 + r_{SI} + \theta\lambda_{CC} &= 1 + r_D.
\end{aligned}
$$

Since we are assuming that illiquid securities are subject to a haircut in the collateral pool ($\theta < 1$), the bank will only hold both kinds of securities if the illiquid securities have a higher rate of return than the liquid ones.[22]

Additionally, the shadow value of relaxing the collateral constraint depends on the level of reserves chosen by the bank. For example, if the funding rate is low enough so that the bank is choosing $f = \Delta_2$, then $\lambda_{CC} = 0$, and the bank will hold no collateral whenever the return on securities is below the funding cost.

Furthermore, if the return on securities is low enough, the bank will hold no securities regardless of its level of reserves, and the choice of reserves is equivalent to the case when the bank has no access to the FHLBs (as in Proposition 2). For intermediate values of the rate of return on securities, the bank simultaneously chooses reserves and securities/collateral to minimize the costs associated with funding the liquidity needs originated in the $\Delta(\epsilon)$ shocks. The general direction of this relationship is that, for a given shock process, a bank with higher reserves can afford to hold less collateral. But, as with Corollary 4.1, when banks differ in their exposure to shocks, the cross-sectional heterogeneity may attenuate these basic patterns.

[22] When the structure of shocks is such that for some realizations of the shocks the bank can liquidate securities to obtain the necessary funding, the decision to hold securities is also driven by these considerations.

3.4 Generalized implications

In the general version of the model, the shock can affect the amount of loans and deposits, in addition to the change in borrowed money discussed above. Also, depending on the timing of the shock, the bank may be able to liquidate securities to accommodate a shock. So, the bank can use reserves, central bank borrowing, and/or sales of securities to respond to changes in its liquidity needs. And, the distribution of shocks can have a more complex structure than the examples studied before, including continuum support and mean and variance heterogeneity.

More generally, we can posit that bank i at time t is facing general liquidity risk, which is proxied by a variable ψ_{it} and is, in turn, a function of the bank's size, balance sheet composition, and other factors. That is, we have

$$\psi_{it} = \psi(A_{it}, \mathbf{p}_{it}, ...),$$

where A_{it} is total assets of bank i at time t (a measure of size) and $\mathbf{p}_{it}$ is a vector of portfolio ratios capturing the bank's exposure to liquidity risks and access to funding.

As it was clear from the model, reserves holdings are in turn also a function of the bank's liquidity risk and whether the bank has access to the discount window (denoted with the indicator variable I^{DW}). That is

$$R_{it} = R(\psi_{it}, ...; I_i^{DW})$$

Discount window activity for bank i at time t, then, is a function of its liquidity risk, its holdings of reserves R_{it}, and other factors such as discount window access. We have:

$$DW_{it} = DW(\psi_{it}, R_{it}, ...; I_i^{DW}).$$

This is the generalized framework that we use in our empirical analysis. Beyond the specific details of the model, there are two basic reasons for a bank to borrow at the discount window: (1) the bank may not have ready access to cheaper sources of funding due to the timing of the liquidity shocks (or other constraints); (2) even when the bank has access to those cheaper alternatives, it may have exhausted its ability to tap them when the required collateral is scarce.

4 Empirical analysis

Our theoretical model provides a number of hypotheses that can be brought to the data. In addition, the information presented in Section 2 points to several regularities regarding discount window borrowing and bank balance sheets. Here, we bring together theory and data in a comprehensive empirical analysis. We split the analysis in two parts. The first part explores ex post discount window borrowing decisions, and how those decisions depend on balance sheet factors, business models, and FHLB borrowing. The second part evaluates ex ante decisions that also influence discount window borrowing, such as choices to gain access to the discount window, post collateral for operational readiness, or engage in balance sheet decisions that are co-determined with the shock.

4.1 Ex post decisions

4.1.1 Baseline discount window borrowing model

Our first task is to explore what factors are correlated with banks' decisions to borrow at the discount window. Propositions 2 and 3 shows that when a bank experiences a shock that requires an adjustment to its balance sheet, the bank's response follows a pecking order. We focus first on this ex-post borrowing decision, that is, after the bank has chosen its balance sheet composition and experiences a liquidity shock.

To evaluate propositions 2 and 3, we consider a panel linear probability model:

$$DW_{it} = \beta_R R_{it} + \beta_X X_{i,t-1} + \gamma_i + \delta_t + \epsilon_{it}, \tag{11}$$

where DW_{it} equals 1 if bank i borrows from the discount window in quarter t. In this baseline specification, as in Table 1, we define borrowing as executing a discount window loan for over \$1 million. Based on the discussion in Section 2, we restrict attention to primary credit loans by domestic banks. These are the loans for which we have the most information and are the most likely to represent traditional central-bank provision of short-term liquidity to healthy banks, which is the main focus of this paper.[23]

In accordance with the pecking order, reserve balances are tapped first in the process of offsetting a liquidity shock. As such, for our empirical investigation, a key variable of interest is reserve balances as a share of bank assets, R_{it}, and its associated coefficient

[23]Seasonal credit also addresses healthy bank funding needs. However, use of seasonal borrowing is concentrated in smaller banks and demand for seasonal borrowing usually reflects predictable, seasonal borrowing needs, which do not reflect the issues we aim to address in this paper.

β_R in expression (11). Also important are the balance sheet items that can bring about these shocks, and the other levers that can be adjusted to respond to the shock. These various items are capture by the vector $X_{i,t-1}$, which contains liquid and illiquid securities, household and business loans, deposits and wholesale funding, and other borrowing. Furthermore, we examine proxies for business models and include (the log of) total assets, unused loan commitments to assets, the tier-1 capital ratio, and return on assets. Table 3 shows that these balance sheet characteristics are significantly different across borrowers and nonborrowers, pointing to the importance of including these controls. In our baseline specification, we lag X_{it} by one quarter for most balance sheet items so that the controls are predetermined relative to the decision to borrow from the discount window.

In addition to balance sheet items, and as suggested by Proposition 2, we include discount window collateral as a share of assets to control for borrowing capacity. For more granular differences, in other specifications we incorporate bank-level fixed effects γ_i to control for bank-level unobserved heterogeneity that is constant over time. As suggested by Figure 1, quarterly fixed effects δ_t absorb broad time-varying factors that could prompt shifts in discount window borrowing, such as the financial or macroeconomic environment. Finally, we assume that ϵ_{it} is normally distributed and evaluate the model using an unbalanced panel linear probability model. We use standard clustering procedures at the bank level to control for heteroskedasticity and correlation of ϵ_{it} across observations.[24]

We limit our sample to banks that take at least one loan of any size (including possible test loans) at some point in the sample period. As is clear from Corollary 4.1, a bank's ex ante choice of reserves (and other balance sheet items) can be influenced by its perceived liquidity risk. Similarly, whether a bank takes the necessary steps to gain access to the discount window depends on the bank's ex ante assessment of its exposure to outsized liquidity shocks. Since banks obtain access to the discount window in advance of borrowing, restricting the sample to banks with access is an effective way to address unobserved heterogeneity and reduce the potential for omitted-variable bias in our estimates.

Estimates from our baseline specification are reported in Table 5. We highlight five main results. First, banks that hold less reserves are more likely to borrow from the discount window. This is consistent with the pecking order described in propositions 2 and 3. The first row of Table 5 reports β_R across multiple specifications with a range of controls. Across all specifications, the estimated coefficients on reserves to assets imply

[24]We eliminate data outliers and anomalies, such as banks with missing or negative assets, negative reserves, and various other inconsistencies. In general, results obtained when using a panel probit model are similar to those presented here (see Ennis and Klee, 2021).

that for a one standard deviation drop in reserves to assets (roughy 4.8 percentage points), the probability of borrowing at the discount window increases by 1 percentage point.[25] As the unconditional probability of borrowing at the discount window for this subsample of banks is 2.4 percent, this shift in the propensity to borrow is notable.

Second, banks' heterogeneous exposure to shocks influences the relationship between reserves holdings and discount window borrowing. We arrive at this result by comparing the estimates in columns (1), (2) and (3). Column (1) reports the estimated coefficient on R_{it} without any controls; column (2) controls for time fixed effects δ_t; and column (3) adds bank-level fixed effects γ_i. The magnitude and direction of change in the coefficients across columns suggest that controlling for individual-bank shock processes tends to strengthen the negative association between reserves and discount window borrowing. This result is consistent with Proposition 4 and its corollary. These findings recognize that the negative association between reserves and discount window borrowing can weaken when banks face different shock processes, as there is the potential for endogeneity in the choice of reserves and discount window borrowing. In what follows, we condition on bank-level fixed effects to overcome endogeneity concerns and provide a clean read on the relationship between reserves and other balance sheet items and borrowing. Later in the paper, we also provide a battery of instrumental variable analyses to investigate endogeneity further.

Third, banks with higher shares of expensive funding are more likely to borrow at the discount window. Columns (4) through (6) include coefficient estimates for key liabilities that are associated with discount window borrowing. The statistical and economic significance of these factors align with the pecking order hypothesis outlined in Propositions 2 and 3: Banks first use less expensive sources of funding, including the interbank market, and then turn to more expensive discount window funding once other sources are unavailable. Empirically, we see that banks use a range of funding sources, and those with more expensive liabilities are more likely to tap the discount window. Overall, for a one standard deviation increase in federal funds borrowing as a share of liabilities, the probability of borrowing at the discount window increases by 40 basis points; for repo borrowing, 86 basis points; and for FHLB advances, 70 basis points.

Fourth, consistent with our summary statistics in tables 1 and 2, larger banks tend to be more likely to borrow from the discount window. As indicated by the coefficient on the log of assets in column (4), for an increase from the 50th percentile to the 95th percentile

[25]The standard deviation of the reserves-to-assets ratio is 0.0483 (4.83 percentage points). This figure, multiplied by -0.229, the coefficient reported on the reserves-to-assets ratio in column (1), is roughly -1.1 percentage points. All subsequent economic impact estimates are calculated analogously.

Table 5: Borrowing, conditional on access

Dependent variable:	$DW_{it} = \{0, 1\}$					
	Reserve balances			Other balance sheet items		
	(1)	(2)	(3)	(4)	(5)	(6)
Asset composition (share of assets)						
Reserve balances	-0.229**	-0.228**	-0.252 **	-0.164 **	-0.177 **	-0.242 **
	(0.020)	(0.020)	(0.023)	(0.030)	(0.032)	(0.025)
Treasury securities (t-1)				-0.003	0.007	0.019
				(0.052)	(0.052)	(0.038)
Agency debt (t-1)				0.040	0.042	0.1004*
				(0.029)	(0.029)	(0.046)
Agency MBS (t-1)				0.008	0.010	0.034
				(0.024)	(0.025)	(0.023)
Residential (t-1)				-0.026	-0.021	0.021
				(0.016)	(0.019)	(0.028)
CRE (t-1)				-0.014	-0.015	0.009
				(0.018)	(0.019)	(0.020)
C & I (t-1)				0.030	0.030	0.031
				(0.031)	(0.032)	(0.029)
Consumer (t-1)				-0.057*	-0.055*	-0.006
				(0.025)	(0.026)	(0.030)
Unused commitments (t-1)				0.000	0.001	0.002
				(0.003)	(0.003)	(0.001)
Liability composition (share of liabilities)						
Uninsured deposits (t-1)				0.030*	0.037**	0.019
				(0.013)	(0.014)	(0.015)
Federal funds (t-1)				0.209*	0.223*	0.275**
				(0.090)	(0.089)	(0.104)
Repo (t-1)				0.190**	0.186**	0.333**
				(0.073)	(0.072)	(0.087)
FHLB advances				0.087**	0.090**	0.127**
				(0.021)	(0.022)	(0.030)
Other characteristics						
Log(assets) (t-1)				0.002*	0.002	-0.001
				(0.001)	(0.001)	(0.004)
Tier 1 capital ratio (t-1)				-0.004	-0.003	0.035
				(0.019)	(0.021)	(0.023)
ROA				0.650**	0.635**	-0.142
				(0.217)	(0.224)	(0.247)
Total collateral to assets				0.107**	0.096**	0.021
				(0.026)	(0.026)	(0.030)
Bank FE	N	N	Y	N	N	Y
Year-quarter FE	N	Y	Y	N	Y	Y
R^2	0.003	0.004	0.157	0.012	0.015	0.159

Notes: The number of observations is 73,250 and the number of banks is 2,152. This table provides estimates from evaluating a linear probability model of the effects of selected bank characteristics on the probability of borrowing at the discount window as described in equation 11. Sample is an unbalanced panel of commercial banks and is restricted to those banks that executed at least a test loan. The dependent variable is an indicator that equals one if a bank borrowed at the discount window in a quarter and zero otherwise. An observation is a bank-quarter. Bank-level cluster-robust standard errors in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

of bank assets (roughly from a $300 million bank to an $8 billion bank), the probability of borrowing at the discount window increases by 60 basis points. This coefficient loses significance once bank-level fixed effects are included, suggesting that the effect is mostly driven by the mean level of assets for a bank, rather than its variation over time.

Of note, outside of reserve balances, bank asset composition generally does not predict discount window borrowing. That said, there is likely some collinearity of reserves-to-assets with other types of asset shares. To address this issue, we performed a double lasso test, similar to Belloni, Chernozhukov, and Hansen (2013), to determine whether some of the asset types could be dropped. The results (not reported) suggest that, despite some collinearity, it is important to include those asset shares in our specification.

Finally, banks that have posted more collateral relative to assets are more likely to borrow from the discount window. This result is consistent with Proposition 2, which suggests that a bank with collateral posted at the discount window will borrow to avoid a costly overnight overdraft. Quantitatively, and depending on the specification, a standard deviation rise in the collateral-to-assets ratio increases the probability of borrowing at the discount window by 15 to 65 basis points. Given the persistence in total collateral-to-assets and its presumed collinearity with the bank-level fixed effects, we place more weight on the higher estimates, which suggest a nearly 30 percent increase in the probability of borrowing at the discount window. We return to the ex-ante decision to post collateral later in this section.

Appendix Table A3 reports additional coefficients related to a bank's Federal Reserve District. All else equal, banks are more likely to borrow if they are in Districts 3, 6, 7 or 12. These may reflect differential costs of borrowing across districts. While plausible, these results should also be interpreted with caution, as some of our balance sheet controls may account only imperfectly for bank-level differences and, as a result, a bank's District may incorporate multiple factors.

The final row of the table provides R^2 statistics. Overall, the R^2 is modest, possibly because our quarterly data are only an approximation of banks' balance sheets at the time of borrowing. Furthermore, discount window borrowing is likely driven by heterogeneous, unobserved shock processes. As is often the case with panel data, bank-level fixed effects are important, with the R^2 increasing significantly from column (2) to (3), and from columns (5) to (6). Other differences in R^2 across specifications are less than 1 percentage point. Still, we reject the hypothesis that all coefficients are jointly equal to zero.

4.1.2 Robustness

The broad brush of the specification and sample in Table 5 provides results that are widely consistent with our model. However, a closer investigation could provide additional insights. Some robustness checks are also warranted.

Bank subsamples. To start, we evaluate our empirical model on a range of subsamples. The propensity to borrow at the discount window may vary across broad classes of banks. For example, for any given portfolio allocation, smaller banks may respond differently to funding needs, as they may have limited access to alternative sources of funding relative to larger banks. In addition, distinct business models could lead to different shock distributions, which in turn, could generate divergent discount window borrowing patterns. These divergences could be proxied by the size of institution—larger banks or smaller banks—or whether the bank is publicly traded.

The results of these exercises are reported in columns (1) through (3) of Table 6. The estimates reported in columns (1) and (2) confirm the negative relationship between reserves as a share of assets and the probability of borrowing, even when restricting to different size-based subsamples. The coefficient estimates on R_{it} indicate that the effect on the probability of borrowing at the discount window is somewhat smaller for larger banks than for smaller banks. In economic terms, however, the effect is similar: across all subsamples, a one standard deviation drop in the reserves-to-assets ratio leads to an increase in the probability of borrowing at the discount window of roughly 1.2 percentage points.[26] Taken together, this similarity suggests that our bank-level fixed effects sufficiently absorb potential unobserved factors that could influence our read on the connection between reserves and discount window borrowing.

Column (3) reports results for the publicly-traded bank subsample. The risks from any stigma associated with borrowing from the discount window could be higher for publicly-traded banks, given their exposure to stock price volatility. Yet, interestingly, we find that the coefficient on R_{it} is negative and of roughly the same magnitude and economic significance as in the overall sample or the other subsamples. This suggests to us that the sensitivity of the propensity to borrow with respect to reserves does not meaningfully differ if a bank is publicly traded.

While the effect of reserves-to-assets on borrowing is similar across subsamples, we find some differences related to balance sheet composition. Smaller and traded banks are more

[26] The similarity of economic magnitude reflects the relatively greater variation in the reserves-to-assets ratio for the larger bank subsamples than for the smaller bank subsample.

likely to borrow when they have higher exposure to agency debt and MBS. On the liability side, smaller and traded banks are more likely to borrow from the discount window when shares of non-deposit liabilities increase, including repos and FHLB advances.

Of course, the number of banks in some subsamples is modest relative to the overall sample considered in Table 5: for example, there are only 85 larger banks (greater than $10 billion in assets). Still, the specification explains a good chunk of the variability in borrowing, and so, we take comfort in the robustness of our overall results.

"Access" assumptions. So far, in our regression specifications, we have assumed that only banks that have tested or borrowed during the sample period have discount window access. This assumption may be too restrictive. For example, the largest banks likely have discount window access. In addition, banks of all sizes may have access, but did not test or borrow during our sample period. To address these two possibilities, in column (4) of Table 5, we treat all banks with more than $50 billion in assets as having ready access to the discount window, and in column (5), we include in the sample all banks that file Call Reports (regardless of any evidence of access).[27]

The estimated parameters reported in column (4) indicate that the economic magnitude of the effects of reserves-to-assets on the probability of borrowing under this adjusted definition of access is similar to that in the baseline specification. Interestingly, column (5) shows that, when including all banks, the estimated effect of reserves on borrowing becomes smaller, but remains statistically significant. This is consistent with our interpretation that restricting the sample to banks with access tends to reduce the endogeneity in reserves highlighted in corollaries 4.1 and 5.1 of Section 3. We return and further explore access decisions later in the paper.

Alternative borrowing definitions and outcomes. Our final set of exercises explores alternative definitions of discount window borrowing as well as borrowing outcomes.

So far, we distinguish borrowing from testing using a rule-of-thumb approach based on loan size, with $1 million as the threshold. The extra funding cost of an overnight loan of this size during much of our sample period was only about $15.[28] Because this funding cost is modest, borrowing decisions may not respond strongly to the financial motivations

[27] We adjust the specification to exclude total collateral to assets, as there is no information on this dimension for banks that never took a discount window loan (test or otherwise) during the sample period.

[28] This calculation is based on a 50 basis point spread between the primary credit rate at the discount window and the interest rate paid on reserves.

Table 6: Robustness

Robustness strategy:	Subsamples			Access		Definition of borrowing		
Dependent variable:	$DW_{it} = \{0, 1\}$					$DW_{it} = \{0, 1\}$ and $\text{loan}_{it} > \$10\text{M}$	Number of borrowings	Amount borrowed to total liabilities
Bank sample:	Larger (>$10B)	Smaller (≤$10B)	Traded	Assuming access for >$50B	All banks	Access	Access	Borrowing
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Share of assets								
Reserve balances	-0.179 *	-0.248**	-0.272**	-0.242**	-0.081**	-0.061**	-0.563**	0.649
	(0.081)	(0.026)	(0.052)	(0.025)	(0.009)	(0.013)	(0.080)	(0.488)
Agency debt (t-1)	0.144	0.097*	0.353	0.101*	0.016	0.012	0.264**	-0.009
	(0.119)	(0.048)	(0.215)	(0.046)	(0.010)	(0.013)	(0.092)	(0.046)
Agency MBS (t-1)	0.021	0.032	0.106*	0.034	0.007	0.003	0.141	0.003
	(0.093)	(0.024)	(0.046)	(0.023)	(0.007)	(0.011)	(0.073)	(0.051)
Unused commitments (t-1)	-0.001	0.003	-0.001	0.002	0.000	-0.001	0.013	0.038
	(0.008)	(0.001)	(0.008)	(0.001)	(0.000)	(0.001)	(0.009)	(0.047)
Share of liabilities								
Uninsured deposits (t-1)	0.024	0.017	0.046	0.019	0.003	-0.001	0.063	0.028
	(0.045)	(0.015)	(0.033)	(0.015)	(0.005)	(0.009)	(0.050)	(0.038)
Federal funds (t-1)	0.507	0.254*	0.389	0.274**	0.070*	0.050	0.946**	0.323
	(0.369)	(0.108)	(0.235)	(0.104)	(0.028)	(0.044)	(0.322)	(0.236)
Repo (t-1)	0.206	0.349**	0.447**	0.332**	0.160**	0.026	0.604*	0.045
	(0.241)	(0.093)	(0.135)	(0.086)	(0.047)	(0.036)	(0.246)	(0.065)
FHLB advances	0.072	0.128**	0.171*	0.127**	0.048**	0.024	0.330**	0.029
	(0.148)	(0.031)	(0.087)	(0.030)	(0.011)	(0.015)	(0.085)	(0.069)
Other characteristics								
Log(assets) (t-1)	-0.029	0.001	-0.014	-0.002	-0.001	0.003	0.006	-0.021**
	(0.017)	(0.005)	(0.009)	(0.004)	(0.002)	(0.002)	(0.017)	(0.004)
Tier 1 capital ratio (t-1)	0.059	0.037	0.020	0.034	0.007	0.010	0.177*	-0.114
	(0.082)	(0.024)	(0.047)	(0.023)	(0.005)	(0.013)	(0.090)	(0.119)
Total collateral to assets	-0.232*	0.032	0.038			0.018	0.025	0.283**
	(0.111)	(0.034)	(0.082)			(0.015)	(0.073)	(0.081)
Number of observations	3,104	70,146	15,087	73,250	239,834	73,250	73,250	1,739
Number of banks	85	2,067	466	2,152	7,557	2,152	2,152	648
R^2	0.083	0.162	0.162	0.159	0.170	0.136	0.149	0.194

Note: This table provides estimates from a fixed effects panel linear probability model of the effects of selected bank characteristics on the probability of borrowing at the discount window (columns (1) through (6)) and from fixed effects panel regression models of the effects of selected bank characteristics on the number of instances and amount of borrowing at the discount window (columns (7) and (8)). Except for column (5), all samples are restricted to those banks that executed at least a test loan. In all cases, an observation is a bank-quarter. Columns (1) and (2) evaluate equation (11) on larger and smaller bank subsamples, respectively. Column (3) evaluates the model on all publicly-traded commercial banks, and column (4) assumes banks with greater than $50 billion in assets have discount window access. Column (5) incorporates all commercial banks, regardless of access considerations. Column (6) increases the loan threshold to $10M, column (7) evaluates the number of loans in a quarter, and column (8) explores the dollar value of loans relative to total liabilities. Robust standard errors (shown in parentheses) are clustered at the bank level. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

that we aim to identify. Furthermore, our test threshold may be too low —some banks may execute a larger test loan or test multiple times per quarter.

One way to assess the importance of the loan-size threshold is to set it at a higher value. For this purpose, we choose $10 million as an alternative. The cost of borrowing this amount overnight during our sample period is still moderate, at around $300. The drawback from choosing this higher threshold is that we may miss some smaller loans, reducing relevant information. This drawback is particularly salient for smaller banks, with a mean loan amount of around $20 million.

Results for the higher threshold are displayed in column (6) of Table 6. Reassuringly, the results are in line with Table 5, although the estimated economic magnitudes are somewhat smaller. For example, with our baseline threshold, a one standard deviation increase in reserves to assets leads to a 1 percentage point decline in the probability of borrowing. With the higher threshold, the effect falls by about one-third. Overall, even with this new threshold, the amount of variation in the probability of borrowing explained by the specification is close to that in Table 5. Taken together, these observations suggest that our choice of threshold does not meaningfully affect our conclusions.

To this point, we have focused on the extensive margin for discount window borrowing. The intensive margin might also provide insight. We take two approaches to investigate this margin. First, we modify equation (11) and replace the dependent variable DW_{it} with N_{it}, the number of times bank i borrows from the discount window in quarter t. Second, we replace DW_{it} with $\frac{DWloan_{it}}{L_{it}}$, the total amount of discount window borrowing for bank i in quarter t normalized by bank liabilities.[29] Other variables are defined as before.

Columns (7) and (8) of Table 6 display the results. The estimated coefficients reported in column (7) indicate that banks that hold less liquidity tend to borrow more frequently from the discount window. The economic magnitudes of the estimated coefficients on reserve balances and wholesale funding are twice as large as those on the extensive margin. In addition, as shown in column (8), smaller banks tend to fund a greater share of their liabilities with discount window loans. Finally, there is a positive correlation between the ratio of posted collateral to assets and the ratio of the amount borrowed to liabilities; for every 1 percentage point in collateral as a share of assets posted, the share of liabilities funded increases by roughly 30 basis points.

All told, we see these results as supporting our approach to focus on the extensive

[29]The amount borrowed is calculated as the aggregate amount of daily borrowings outstanding over a quarter, including weekends.

margin, with the understanding that more frequent borrowers or more intensive borrowers also tend to have less liquid balance sheets than other banks.

4.1.3 FHLB advances

Our preliminary analysis in Table 4 as well as Proposition 3 suggest potential joint determination of discount window and FHLB borrowing decisions. Given the pecking order, if a bank has a relatively high ratio of FHLB advances to liabilities, it may be closer to exhausting its funding opportunities at the FHLB system, and may need to turn to the discount window for funding. Alternatively, a bank may have sufficient collateral at the FHLB, but at the time of day when the bank needs to borrow, FHLB advances are not readily available. Table 5 also shows that banks more active at the FHLBs are also more likely to borrow from the discount window. Here, we take a closer look at the link between discount window and FHLB borrowing.

To evaluate these important relationships, we augment the baseline specification with a proxy for the intensiveness of FHLB borrowing. Specifically, we include an indicator variable that equals one in a bank-quarter observation if the ratio of FHLB advances to liabilities is ranked in the "top 5" observations for this ratio for the bank over the sample. The dependent variable continues to be an indicator variable that equals 1 if a bank borrowed from the discount window that quarter.

The results are reported in Table 7. To facilitate the comparison, column (1) of the table repeats the estimation results from our baseline specification reported in column (5) of Table 5. Consistent with the summary statistics presented in Table 4, discount window borrowing is positively correlated with FHLB advances. The second column includes our new indicator variable. Here, we see that if FHLB advances as a share of liabilities are near a bank's peak, the probability of borrowing from the discount window increases by around 50 basis points. Given that the overall probability of borrowing is around 2 percent, a 50 basis point increase is an economically meaningful amount.

Table 7: Borrowing and FHLB advances

Dependent variable	$DW_{it} = 1$					
	All		Larger banks (> $10B)		Smaller banks (< $10B)	
	(1)	(2)	(3)	(4)	(5)	(6)
Reserve balances	-0.242**	-0.240**	-0.179*	-0.178*	-0.248**	-0.247**
	(0.02)	(0.02)	(0.08)	(0.08)	(0.03)	(0.03)
FHLB advances	0.127**	0.099**	0.072	0.063	0.128**	0.099**
	(0.03)	(0.03)	(0.15)	(0.14)	(0.03)	(0.03)
"Top 5" FHLB advances		0.005*		0.002		0.006*
		(0.00)		(0.01)		(0.00)
Uninsured deposits (t-1)	0.019	0.018	0.024	0.024	0.017	0.017
	(0.01)	(0.01)	(0.04)	(0.05)	(0.02)	(0.02)
Federal funds (t-1)	0.275**	0.273**	0.507	0.505	0.254*	0.253*
	(0.10)	(0.10)	(0.37)	(0.37)	(0.11)	(0.11)
Repo (t-1)	0.333**	0.332**	0.206	0.205	0.349**	0.348**
	(0.09)	(0.09)	(0.24)	(0.24)	(0.09)	(0.09)
Total collateral to assets	0.021	0.020	-0.232*	-0.231*	0.032	0.031
	(0.03)	(0.03)	(0.11)	(0.11)	(0.03)	(0.03)
Number of observations	73,250	73,250	3,104	3,104	70,146	70,146
Number of banks	2,152	2,152	85	85	2,067	2,067
R^2	0.159	0.159	0.083	0.083	0.162	0.162

Note: This table provides estimates from a linear panel model of the effects of selected bank characteristics on the probability of borrowing at the discount window. Sample is restricted to those banks classified as having discount window access. The dependent variable is an indicator that equals one if a bank borrowed at the discount window in a quarter. An observation is a bank-quarter. Bank and quarter fixed effects in all specifications. Cluster-robust standard errors in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Columns (3) through (6) repeat the analysis in columns (1) and (2), but uses larger and smaller bank subsamples, as defined in Table 6. Looking at these columns, we see that the estimated coefficients on reserves-to-assets are little changed across samples and specifications. However, there is some notable difference in the coefficients on FHLB advances to liabilities and on our measure of intensity of borrowing from FHLBs. Larger banks, shown in columns (3) and (4) appear not to shift borrowing behavior materially, regardless of whether FHLB advances are towards the top of the range. By contrast, smaller banks, in columns (5) and (6), are more likely to borrow at the discount window even if FHLB advances to liabilities are in more normal ranges, and even more so if FHLB advances are relatively high.

Taken together, the results point to a few explanations for the coincidence of discount window and FHLB borrowing. Overall, banks that borrow from FHLBs are more likely to borrow from the discount window. But the motivations for borrowing may be different across business models. Larger banks, that presumably have better access to money markets and other alternative funding sources, do not appear to adjust discount window borrowing as FHLB advances climb. Smaller banks, without access to alternatives, tend to borrow from both programs simultaneously, and significantly more from the discount window when FHLB advances are unusually high. Still, the coefficient on reserves-to-assets is little changed, suggesting that discount window borrowing is usually prompted by an overall need for liquidity.

4.2 Ex ante decisions

4.2.1 Discount window access

A bank chooses its holdings of reserves taking into account its previous decision to gain access to the discount window. Corollary 5.1 predicts that a bank without discount window access will want to hold more reserves. We empirically evaluate this prediction using the following specification:

$$R_{it} = \beta_A A_i + \beta_X X_{i,t-1} + \gamma_i + \delta_t + \epsilon_{it}, \tag{12}$$

where A_i is the proxy for access described in Section 2, and all other variables are defined as in equation (11). To evaluate the correlation of access with discount window borrowing, conditional on balance sheet and other factors, we expand our sample to include all banks, not just those who have gained discount window access.

Table 8 presents the results. Across all specifications, banks with discount window access hold a lower proportion of reserves in their asset portfolios. However, relative to bank-level fixed effects, the variation in reserves-to-assets ratio explained by access and balance sheet factors is small. Taken together, these results suggest that banks take into account their access to the discount window when choosing their reserve holdings but, in general, multiple other considerations are part of those decisions.

4.2.2 Collateral levels and composition

Proposition 2 and 3 suggest that banks with more posted collateral relative to assets are more likely to borrow at the discount window. With these results in mind, we now turn to evaluating the ex-ante collateral choice. In particular, we evaluate whether a bank that is more likely to need to borrow from the discount window will tend to pledge more collateral

Table 8: Reserves and discount window access

	Dependent variable: Reserves to assets						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Access	-0.010 **	-0.007 **	-0.055 **	-0.049 **	-0.049 **	-0.041	-0.037 *
	(0.001)	(0.001)	(0.014)	(0.014)	(0.015)	(0.023)	(0.018)
Asset controls	N	N	N	Y	N	N	Y
Liability controls	N	N	N	N	Y	N	Y
Other controls	N	N	N	N	N	Y	Y
Bank FE	N	Y	Y	Y	Y	Y	Y
Year-quarter FE	N	N	Y	Y	Y	Y	Y
Number of observations	240,077	240,077	239,973	239,834	239,834	239,834	239,834
Number of banks	7,557	7,557	7,557	7,557	7,557	7,557	7,557
R^2	0.004	0.019	0.701	0.726	0.707	0.715	0.739

Note: This table provides estimates from a panel regression model of the impact of discount window access on the share of assets held in reserve balances, conditional on a range of bank characteristics and fixed effects. The sample includes all domestic banks with positive assets, and eliminates some outlier observations. The specification includes controls similar to those in Table 5.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

at the discount window in anticipation. In addition, we study whether the composition of the collateral posted a the discount window is a predictor of borrowing, and in particular, we focus on the share of collateral posted at the discount window that is ineligible for obtaining advances at the FHLBs.

Exploring the interaction between borrowing and collateral encounters two complications: First, we only observe discount window collateral when a bank executes a discount window loan; second, we do not observe collateral at all for banks that do not execute any discount window loans during our sample period. We cannot overcome the first complication. However, we can address the second with some reasonable assumptions. We observe that discount window collateral is sticky: Banks infrequently change the amount and composition of their posted collateral. Appendix Table A1 illustrates that, for banks for which we have multiple observations on posted collateral, the correlation between current collateral and lagged collateral ranges between 70 and 80 percent across all collateral types, with an R^2 of over 90 percent.[30]

Given the limited frequency of the collateral data, we take a cross-sectional approach here, and redefine the dependent variable to equal one if the bank borrows at any time in our sample, where borrowing is defined as before, using the $1 million threshold as in Table 5. Similarly, we redefine independent variables in shares using sample averages of nonzero values. More specifically, we use bank-level averages of observed collateral

[30]These correlations should be interpreted with caution still given the unbalanced nature of our panel data and other limitations.

Table 9: Borrowing and collateral

Dependent variable	$DW_i = \{0, 1\}$				$DW_{ij} = \{0, 1\}$
	(1)	(2)	(3)	(4)	(5)
Total collateral to assets	4.607**	4.744**	4.435**	4.322**	0.430*
	(0.867)	(0.891)	(0.876)	(0.880)	(0.192)
Treasury and agency	-0.082**			-0.049	-0.240 **
	(0.023)			(0.032)	(0.066)
Residential mortgages		-0.050		-0.034	-0.210
		(0.053)		(0.059)	(0.122)
CRE		0.022		0.028	-0.141*
		(0.031)		(0.041)	(0.072)
Agency MBS		-0.029		0.0003	-0.03
		(0.025)		(0.033)	(0.059)
Consumer			0.077	0.075	-0.239*
			(0.048)	(0.057)	(0.106)
C & I			0.092**	0.082*	-0.036
			(0.032)	(0.042)	(0.052)
Number of observations	2,155	2,155	2,155	2,155	15,600
R^2	0.054	0.051	0.055	0.058	0.613

Note: This table provides estimates from a linear probability model of the effects of selected posted collateral ratios on the probability of borrowing at the discount window. The sample is restricted to those institutions that execute at least a test loan. Observations are at the institution level for columns (1) through (4), and at the transaction (loan) level for column (5). The dependent variable equals 1 if an institution borrowed at the discount window at any time during the sample. Collateral variables are institution-level averages of nonzero values for columns (1)-(4) and actual values for column (5), normalized by total collateral. Also includes an intercept as well as controls for non-agency MBS and private securities. Column (5) includes bank and transaction date fixed effects. Robust standard errors are shown in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

to proxy for posted collateral over our sample period (although results would remain essentially unchanged if using interpolation to smooth collateral observations over time).

We estimate the following specification:

$$DW_i = \beta_0 + \beta_c \left(\frac{C}{A}\right)_i + \sum_l \beta_{lc} \left(\frac{C_l}{C}\right)_i + \epsilon_i, \quad \text{with} \quad l = 1, ..., L \tag{13}$$

where $(C/A)_i$ is the average of the ratio of total collateral posted by bank i to total assets, and $(C_l/C)_i$ is the share of collateral type l in total collateral, averaged over the sample, with L different collateral types.

Table 9 presents results. The first row examines the correlation between total collateral posted relative to assets and the decision to borrow. We confirm that institutions with higher collateral-to-assets ratios tend to be more likely to borrow. For a one standard deviation increase in the collateral-to-assets ratio (around 2 percentage points), there is a roughly 9 percentage point increase in the probability of borrowing at the discount window. Of note, in our cross section, there is a 30 percent probability attached to a bank borrowing at any point in our sample period, versus a 70 percent probability of only executing a test loan. In terms of economic magnitude, ex ante, if collateral-to-assets increases by one standard deviation, the probability of borrowing climbs 20 percent.

Given the correlation of posted collateral with the propensity to borrow from the discount window, we go further and investigate the association of borrowing with the types of collateral pledged at the discount window. We consider three broad types of collateral: liquid securities (Treasury and agency securities), housing-related assets (residential mortgages, CRE, and agency MBS), and loans generally ineligible to post at the FHLBs or elsewhere (such as consumer and C&I loans). The results are notable: Borrowing banks post more illiquid collateral that is ineligible for use at the FHLBs (or other secured short-term funding markets). While banks that post Treasury and agency debt are significantly less likely to borrow (Column (1)), banks that post C&I loans are more likely (Column (3)). The estimated coefficient on C&I loans reported in Column (3) suggests that for a one standard deviation increase in C&I loans posted as collateral, the probability of borrowing rises by 3 percentage points, equivalent to 10 percent of the unconditional probability of a bank borrowing at any point in our sample period, conditional on having access. This result appears robust: Column (4) includes all collateral types in the specification; the C&I coefficient estimate is essentially unchanged.

As a robustness check for our collateral results, we take an alternative approach to characterizing collateral holdings. Specifically, instead of summarizing or smoothing our collateral observations, we evaluate borrowing and collateral using each transaction as an individual data point. We include bank-level and transaction date fixed effects to control for the effects of an unbalanced panel. Column (5) reports the outcome of this exercise. Note that the number of observations increases by an order of magnitude. Importantly, the sign and significance of our total collateral to assets result remains robust, indicating a positive correlation between posted collateral and discount window borrowing. The magnitude is however smaller. Our results regarding liquid collateral also remains robust, indicating that banks are less likely to borrow against liquid collateral. Even so, some measure of care is in order with any overly granular interpretation of these results. In particular, our bank and date fixed effects may not control for possible selection effects of many observations for some banks and fewer for others on our parameter estimates.

4.3 Evaluating endogeneity

Our empirical investigation thus far presumes that conditioning for access is an effective way to control for unobserved factors and endogeneity. Corollary 4.1 makes clear that discount window borrowing and various balance sheet choices often respond to the same factors, creating the potential for endogeneity. To investigate this issue further, we turn to an instrumental variables approach. The main focus is on reserves holdings because our model suggests reserves are first in the pecking order when a bank experiences a liquidity shock, and so might be the most likely to be impacted by endogeneity.

We incorporate a range of variables and approaches that align with previous research addressing the endogeneity of reserve balances. We do not take a stand on the preeminence of any single approach. Rather, we interpret them collectively, consistent with settings in which no one strategy obviously dominates (Keane, Krutikova, and Neal (2022)).

4.3.1 Description of the instruments

We consider two sets of instrumental variables. One set consists of bank-specific factors interacted with aggregate levels or growth rates, and the other consists of aggregate Federal Reserve balance sheet items. Importantly, the exogeneity requirement is addressed because no individual bank can meaningfully affect any of the aggregate levels or growth rates we consider. The relevance requirement is addressed because these aggregates largely determine reserve balances on the Fed's balance sheet.

For the bank-specific instruments, we construct two different variables, both relying on predetermined bank-level reserves-to-assets ratios. For the first instrumental variable, we take advantage of pre-crisis bank-level variation in reserve holdings, similar to the approach used in Stevenson (2010), Bertrand et al. (2018) and Rodnyansky and Darmouni (2017). We set the pre-crisis comparison to June 2008, before the start of the quantitative easing programs.[31] To construct the instrument, we interact a bank's 2008 reserves-to-assets ratio with indicator variables for each year in our sample. We interpret this instrument as capturing the portion of current reserves-to-assets ratios that reflect the bank's behavior before the substantial increase in reserve balances.

For the second instrument, we interact a bank's 2008 reserves-to-assets ratio with the aggregate four-quarter growth rate in reserve balances corresponding to a bank's size.

[31] While an earlier start date may eliminate some bias related to balance sheet adjustments in the beginning stages of the financial crisis, an earlier start date also risks excluding some banks that underwent significant ownership or structural changes during the look-back period. As a practical matter, the average reserves-to-assets ratio changes little when we use June 2008 or an earlier time period.

Specifically, we calculate separate aggregate four-quarter growth rate in reserve balances for larger banks and for smaller banks. We then interact the corresponding growth with the bank's reserves-to-assets ratio in 2008. This formulation is in the spirit of a Bartik instrument (Goldsmith-Pinkham, Sorkin, and Swift, 2020). We interpret this instrument as capturing the exposure of an individual bank to a broader increase in reserve balances. In both cases, we aim to eliminate any unobserved factors associated with reserve-to-assets holdings that could potentially bias our estimates.

Our second group of instruments contains aggregate measures of Federal Reserve balance sheet items. We use two that have prominence in the literature: the aggregate reserves-to-assets ratio for all commercial banks, and the ratio of the level of the TGA to total Federal Reserve liabilities. These aggregate instruments reflect distinct, although related, phenomenon. The aggregate reserves-to-assets ratio and the square of that ratio reflect banking system liquidity relative to overall banking intermediation as well as its speed of growth; it can also be interpreted as the common factor in all banks' individual reserves-to-assets ratios. The TGA-to-liabilities provides information on changes in total reserve balances. As a dollar more in the TGA represents a dollar less in reserves, movements in the TGA also affect bank reserves, but movements in the TGA are independent of individual bank reserve-holding choices.[32]

We use a specification analogous to that in Table 5, where the dependent variable equals 1 if the bank borrowed at the discount window and 0 if not, along with the same control variables. We use IV/GMM methods to evaluate our panel linear probability models, and report cluster-robust standard errors consistent with a two-stage approach. Other test statistics use standard cluster-robust techniques, as well. First-stage estimates for each of these instruments are presented in Table A6 of the appendix.

4.3.2 Results

Table 10 displays second-stage parameter estimates. Columns (1) through (4) report estimates for our bank-specific instruments; columns (5) and (6) report estimates for aggregate instruments. Overall, the results are qualitatively similar to our estimates presented in Table 5 where we used no instruments. Specifically, discount window borrowing is associated with lower reserves holdings. For our bank-level instruments, as seen in column (1), the baseline effect of a one standard deviation increase in reserves-to-assets ranges from a decrease in the probability of borrowing of up to 2.7 percentage points.

[32]Using unexpected flows into the TGA as an instrument dates to Hamilton (1997); Judson and Klee (2010) and Correa, Du, and Liao (2020) have also used versions of this instrument.

While this economic magnitude is larger than that in our baseline specifications, it is qualitatively similar, and therefore we gain some comfort in our estimates. Outside of reserve balances, the signs and magnitudes of the coefficients on key liabilities shares remain consistent with our baseline results. Columns (2) and (3) evaluate the same specification, but uses the subsamples of larger banks and smaller banks, respectively. The larger-bank estimated coefficients are not precisely estimated, given the small sample size. However, the smaller-bank coefficients remain consistent with our overall results.

Table 10: Borrowing – Instrumental variable approaches

	Dependent variable: Borrowed ($DW_{it} = 1$)					
	IV: Bank-specific instruments				IV: Aggregate instruments	
	All	2008—Level Larger banks (> $10B)	2008—Level Smaller banks (≤ $10B)	2008—Reserves growth	Reserves growth & growth^2	TGA share
	(1)	(2)	(3)	(4)	(5)	(6)
Reserve balances	-0.574**	0.051	-0.549**	-0.948*	-0.847	-0.698
	(0.218)	(1.450)	(0.213)	(0.470)	(0.886)	(0.807)
Unused commitments (t-1)	0.007*	0.006	0.007*	0.012	0.010	0.008
	(0.003)	(0.038)	(0.004)	(0.007)	(0.012)	(0.011)
Federal funds (t-1)	0.265*	0.531	0.246*	0.261*	0.262*	0.264*
	(0.110)	(0.369)	(0.114)	(0.121)	(0.117)	(0.113)
Repo (t-1)	0.319**	0.188	0.339**	0.288**	0.296**	0.309**
	(0.088)	(0.266)	(0.094)	(0.094)	(0.109)	(0.102)
FHLB advances	0.102**	0.098	0.105**	0.068	0.077	0.091
	(0.036)	(0.138)	(0.036)	(0.051)	(0.083)	(0.077)
Number of observations	73,250	3,104	70,146	73,231	73,250	73,250
Number of banks	2,152	85	2,067	2,145	2,152	2,152
R^2	0.001	0.009	0.002	-0.012	-0.008	-0.002
Weak instrument F−stat	82.24	1.172	86.42	30.58	22.939	62.64
Critical value	11.46	16.38	19.93	16.38	16.38	16.38

Note: This table provides estimates from an instrumental-variable panel linear probability model to control for the possible endogeneity of the reserves-to-assets ratio. The sample is all domestic banks that have borrowed at the discount window or have executed a test loan. Bank-level instruments for the first-stage regression use the bank's ratio of reserves-to-assets as of 2008Q2, interacted with indicator variables or broader aggregate growth rates. Aggregate-level instruments include aggregate growth rates as well as changes in other Federal Reserve balance sheet factors. The specifications include bank balance sheet items and other controls, as described in Table 5. Cluster-robust standard errors are in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

To allow for some differentiation by bank size, but avoid the small number of observations that could contribute to our imprecise estimates in column (2), column (4) presents estimates using bank-specific ratios interacted with the growth rate of reserve balances for each subgroup of banks (larger and smaller). With this instrument, a one standard deviation increase in the reserves-to-assets ratio leads to a fall in the probability of borrowing of roughly 4.5 percentage points, in line with previous results.

For our instruments based on aggregate data, we find that the predictive power of reserves-to-assets for discount window borrowing is eroded, as indicated by the lack of significant coefficients. Still, the coefficients are negative in columns (5) and (6), and in general, our instruments have statistical power. More generally, this result suggests that, during our sample period, bank decisions to borrow from the discount window were not impacted meaningfully by broad, quarterly shifts in reserve balances. Instead, and consistent with our model, bank-specific considerations related to portfolio allocation decisions were the main drivers of borrowing behavior.

We report specification test statistics in the bottom rows of the table. Overall, the results indicate that the instruments we are using are reasonably effective. The first-stage F-statistics generally exceed typical thresholds, indicating these are not weak instruments. More generally, even though the IV results are not too different in qualitative or economic terms from the reduced form results, the findings suggest endogeneity considerations are worth taking seriously in this context.

5 Conclusions

This paper provides new evidence on the use of the Fed's discount window in normal times. Many banks in the U.S. tap the discount window, even outside of crises. With data on discount window activity kept mostly confidential for most of its history, the conditions that move banks to borrow from the discount window in well-functioning financial markets are not yet well-understood.

In this paper, we show that a bank's discount window activity is tightly related to its holding of reserves balances at the Federal Reserve. Other components of banks' balance sheets, such as wholesale funding activity, are also important for understanding discount window borrowing. The amount and type of collateral pledged at the window is also a factor. We provide theoretical foundations for these links and investigate empirically their prevalence using transaction-level data that only became publicly available in the U.S. after the 2008 financial crisis.

There are multiple policy questions that hinge upon a better understanding of the mechanisms we study in this paper. For example, a long-standing question in central banking policy is whether the discount window should remain open at all times, not just during financial crises. Understanding how banks interact with the discount window outside of crises, as we do here, is a critical component in the search for a convincing answer to that question.

A second example involves monetary policy implementation and the costs and benefits of having a system with ample reserves. In this article, we show that banks' reserves holdings meaningfully affect the way, and the intensity, with which those banks interact with the central bank as provider of back-up liquidity in normal times. This is one aspect that, while not always duly emphasized, should be taken into consideration in any proper assessment of the ample-reserves system.

A final example relates to financial stability and regulatory policy. The speed of the bank runs in March 2023 illustrated the need for banks to be operationally ready to access backstop liquidity, including at the discount window. The results in this paper highlight both theoretical considerations and empirical regularities for banks that choose to gain access to, post collateral at, and, in some instances, borrow from the discount window. Our focus on normal times provides perspective on the incentives and decisions banks face when interacting with the discount window.

References

Ackon, Felix and Huberto M. Ennis (2017). "The Fed's Discount Window: An Overview of Recent Data." Federal Reserve Bank of Richmond *Economic Quarterly* 103, pp. 37–79.

Afonso, Gara, Roc Armenter, and Benjamin Lester (2019). "A Model of the Federal Funds Market: Yesterday, Today, and Tomorrow." *Review of Economic Dynamics* 33, pp. 177–204.

Armantier, Olivier et al. (2015). "Discount Window Stigma During the 2007 - 2008 Financial Crisis." *Journal of Financial Economics* 118(2), pp. 317–335.

Armenter, Roc and Benjamin Lester (2017). "Excess Reserves and Monetary Policy Implementation." *Review of Economic Dynamics* 23, pp. 212–235.

Ashcraft, Adam, Morten L. Bech, and Scott Frame (2010). "The Federal Home Loan Bank System: The Lender of Next-to-Last Resort?" *Journal of Money, Credit and Banking* 42(4), pp. 551–583.

Barr, Michael (2023). "The Importance of Effective Liquidity Risk Management." Speech at the ECB Forum on Banking Supervision, Frankfurt, Germany on December 1.

Bech, Morten L. and Elizabeth Klee (2011). "The Mechanics of a Graceful Exit: Interest on Reserves and Segmentation in the Federal Funds Market." *Journal of Monetary Economics* 58, pp. 415–431.

Belloni, Alexandre, Victor Chernozhukov, and Christian Hansen (Nov. 2013). "Inference on Treatment Effects after Selection among High-Dimensional Controls." *The Review of Economic Studies* 81(2), pp. 608–650.

Berentsen, Aleksander, Sebastien Kraenzlin, and Benjamin Mueller (2018). "Exit Strategies for Monetary Policy." *Journal of Monetary Economics* 99, pp. 20–40.

Berger, Allen N. et al. (2017). "Bank Loan Supply Responses to Federal Reserve Emergency Liquidity Facilities." *Journal of Financial Intermediation* 32, pp. 1–15.

Bernanke, Ben S. (2008). "Liquidity Provision by the Federal Reserve." Speech at the Federal Reserve Bank of Atlanta Financial Markets Conference on May 13.

Bertrand, Marianne et al. (June 2018). "Breaking the Glass Ceiling? The Effect of Board Quotas on Female Labour Market Outcomes in Norway." *The Review of Economic Studies* 86(1), pp. 191–239.

Bianchi, Javier and Saki Bigio (2022). "Banks, Liquidity Management, and Monetary Policy." *Econometrica* 90(1), pp. 391–454.

Carpenter, Seth et al. (2015). "The Federal Reserve's Balance Sheet and Earnings: A Primer and Projections." *International Journal of Central Banking* 11(2), pp. 237–283.

Clouse, James A. (2000). "Monetary Policy when the Nominal Short-Term Interest Rate is Zero." FEDS Working Paper 2000-51.

Correa, Ricardo, Wenxin Du, and Gordon Y. Liao (July 2020). *U.S. Banks and Global Liquidity.* NBER Working Papers. National Bureau of Economic Research, Inc.

Drechsler, Itamar et al. (2016). "Who Borrows from the Lender of Last Resort?" *Journal of Finance* 71, pp. 1933–74.

Ennis, Huberto M. (2018). "A Simple General Equilibrium Model of Large Excess Reserves." *Journal of Monetary Economics* 98(50-65), pp. 601–616.

Ennis, Huberto M. (2019). "Interventions in Markets with Adverse Selection: Implications for Discount Window Stigma." *Journal of Money, Credit and Banking* 51(7), 1737–1764.

Ennis, Huberto M., Sara Ho, and Elliot Tobin (2019). "Recent Borrowing from the U.S. Discount Window: Some Cases." Federal Reserve Bank of Richmond *Economic Quarterly* 105, pp. 251–271.

Ennis, Huberto M. and Todd Keister (2008). "Understanding Monetary Policy Implementation." Federal Reserve Bank of Richmond *Economic Quarterly* 94(3), pp. 235–263.

Ennis, Huberto M. and Elizabeth Klee (2021). "The Fed's Discount Window in 'Normal' Times." Federal Reserve Bank of Richmond *Working Paper*(21-01R).

Ennis, Huberto M. and David A. Price (2015). "Discount Window Lending: Policy Trade-offs and the 1985 BoNY Computer Failure." Federal Reserve Bank of Richmond *Economic Brief* 15-05.

Ennis, Huberto M. and David A. Price (2020). "Understanding Discount Window Stigma." Federal Reserve Bank of Richmond *Economic Brief* 20-04.

Ennis, Huberto M. and John A. Weinberg (2013). "Over-the-counter loans, adverse selection, and stigma in the interbank market." *Review of Economic Dynamics* 16(4), pp. 601–616.

Ennis, Huberto M. and John A. Weinberg (2016). "The Role of Central Bank Lending in the Conduct of Monetary Policy." Federal Reserve Bank of Richmond *Economic Brief* 16-12.

Ennis, Huberto M. and Alexander L. Wolman (2015). "Large Excess Reserves in the U.S.: A View from the Cross-Section of Banks." *International Journal of Central Banking* 11(1), pp. 251–288.

Fischer, Stanley (2016). "The Lender of Last Resort Function in the United States." Speech at the Committee on Capital Markets Regulation on February 10.

Friedman, Milton (1960). *A Program for Monetary Stability*. Fordham University Press.

Gauthier, Celine et al. (2015). "Emergency Liquidity Facilities, Signaling, and Funding Costs." Staff Working Paper 2015-44, Bank of Canada.

Gerlach, Jeffrey R. and Mehdi Beyhaghi (2020). "Discount Window Lending and Bank Performance." manuscript.

Gilbert, R.A. et al. (2012). "Federal Reserve Lending to Troubled Banks During the Financial Crisis, 2007-2010." Federal Reserve Bank of St. Louis *Review* 94, pp. 221–242.

Gissler, Stefan and Borghan Narajabad (2017). "The Increased Role of the Federal Home Loan Bank System in Funding Markets." *FEDS Notes* Board of Governors of the Federal Reserve System.

Goldsmith-Pinkham, Paul, Isaac Sorkin, and Henry Swift (2020). "Bartik Instruments: What, When, Why, and How." *American Economic Review* 110(8), pp. 2586–2624.

Goodfriend, Marvin and Robert G. King (1988). "Financial Deregulation, Monetary Policy, and Central Banking." Federal Reserve Bank of Richmond *Economic Review* 88(1), pp. 3–22.

Hamilton, James (1997). "Measuring the Liquidity Effect." *American Economic Review* 87(1), pp. 80–97.

Hu, Yunzhi and Hanzhe Zhang (2021). "Overcoming borrowing stigma: The design of lending-of-last-resort policies." *manuscript*.

Humphrey, Thomas M. (1989). "Lender of Last Resort: The Concept in History." Federal Reserve Bank of Richmond *Economic Review* 75(2), pp. 8–16.

Judson, Ruth A. and Elizabeth Klee (2010). "Whither the liquidity effect: The impact of Federal Reserve open market operations in recent years." *Journal of Macroeconomics* 32(3), pp. 713–731.

Kasriel, Paul L. and Randall C. Merris (1982). "Reserve Targeting and Discount Policy." Federal Reserve Bank of Chicago *Economic Perspectives* 6(3), pp. 15–25.

Keane, Michael, Sonya Krutikova, and Timothy Neal (2022). "Child Work And Cognitive Development: Results From Four Low To Middle Income Countries." *Quantitative Economics* 13(2).

Klee, Elizabeth (2019). "The First Line of Defense: The Discount Window during the Early Stages of the Financial Crisis." *International Journal of Central Banking* (Forthcoming).

Kleymenova, Anya (2016). "Consequences of Mandated Bank Liquidity Disclosures." Chicago Booth Research Paper No. 16-04.

Li, Mei, Frank Milne, and Junfeng Qiu (2020). "The LOLR Policy and Its Signaling Effect in a Time of Crisis." *Journal of Financial Services Research* 57, pp. 231–252.

Nelson, Bill (2019). "Design Challenges for a Standing Repo Facility." Bank Policy Institute Blog, pp. 1–4.

Poole, William (1968). "Commercial Bank Reserve Management in a Stochastic Model: Implications for Monetary Policy." *Journal of Finance* 23(5), pp. 769–791.

Rodnyansky, Alexander and Olivier M. Darmouni (June 2017). "The Effects of Quantitative Easing on Bank Lending Behavior." *The Review of Financial Studies* 30(11), pp. 3858–3887.

Schwartz, Anna J. (1992). "The Misuse of the Fed's Discount Window." Federal Reserve Bank of St. Louis *Review* 74(5).

Selgin, George (2017). "Reforming Last-Resort Lending: The Flexible Open-Market Alternative." In *Prosperity Unleashed: Smarter Financial Regulation* edited by Norbert J. Michel. The Heritage Foundation.

Stevenson, Betsey (2010). "Beyond the Classroom: Using Title IX to Measure the Return to High School Sports." *The Review of Economics and Statistics* 92(2), pp. 284–301.

Appendix - Collateral "stickiness"

Table A1 displays results from a simple regression of the share of a type of collateral on its lags, from the discount window transaction data. The results suggest significant persistence, with a coefficient on the first lag of collateral of around 0.7. Results should be interpreted with care, as the sample reflects only those institutions that have at least three separate instances of test loans or borrowing at the discount window in our sample.

Table A1: Posted collateral over time

Dependent variable Share of total collateral	Liquid securities	Other securities	Real estate	Business and household
First lag	0.671 **	0.7695 **	0.724 **	0.784 **
	(0.05)	(0.07)	(0.04)	(0.03)
Second lag	0.138 **	0.155 *	0.121 **	0.0478
	(0.05)	(0.08)	(0.04)	(0.04)
Third lag	0.106	0.0058	0.0763 **	0.0771 **
	(0.06)	(0.05)	(0.02)	(0.03)
Intercept	0.0590 **	0.0488 **	0.0519 **	0.0674 **
	(0.02)	(0.01)	(0.01)	(0.01)
R^2	0.929	0.943	0.942	0.942
Number of banks	254	306	710	494
Number of observations	1,760	2,450	5,968	4,142

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: This table reports the results of a unbalanced panel regression of the collateral type as a share of total collateral on its first, second, and third lags. An observation is a discount window loan (test or borrowing) for a bank on a specific day. Cluster-robust standard errors in parentheses.

Appendix - Further heterogeneity results—Foreign Banking Organizations

Foreign branch decisions to borrow at the discount window do not appear to be driven by the same factors as those for domestic banks. Although the sample size is small (fewer than 100 institutions), table A2 illustrates that neither the share of reserves nor most other balance sheet characteristics significantly predict foreign branch discount window borrowing. These observations support our choice to concentrate on domestic banks for our analysis.

Table A2: Foreign banking organizations and discount window borrowing

Dependent variable:	$DW_{it} = \{0, 1\}$					
	(1)	(2)	(3)	(4)	(5)	(6)
Reserve balances	-0.015	-0.004	0.008	-0.023	-0.018	-0.004
	(0.019)	(0.020)	(0.025)	(0.018)	(0.018)	(0.019)
Treasury securities (t-1)				0.025	0.022	-0.059
				(0.081)	(0.087)	(0.056)
Agency debt (t-1)				-0.082	-0.089	-0.123**
				(0.063)	(0.063)	(0.041)
Agency MBS (t-1)				-0.144**	-0.151**	-0.079
				(0.044)	(0.046)	(0.062)
Residential (t-1)				-0.146	-0.146	-0.011
				(0.216)	(0.219)	(0.769)
CRE (t-1)				0.069	0.064	-0.012
				(0.266)	(0.269)	(0.226)
C & I (t-1)				0.009	0.011	-0.028
				(0.033)	(0.034)	(0.041)
Federal funds (t-1)				0.098	0.093	0.112
				(0.076)	(0.078)	(0.097)
Repo (t-1)				-0.029	-0.028	0.027
				(0.030)	(0.030)	(0.051)
Log(assets) (t-1)				0.001	0.001	0.016**
				(0.006)	(0.006)	(0.004)
Total collateral to assets				0.000	0.000	0.000
				(0.000)	(0.000)	(0.000)
Bank FE	N	N	Y	N	N	Y
Year-quarter FE	N	Y	Y	N	Y	Y
R^2	0.002	0.011	0.148	0.006	0.016	0.153

Notes: The number of observations is 3,104 and the number of Foreign Banking Organizations (FBOs) is 85. This table provides estimates from evaluating a linear probability model of the effects of selected bank characteristics on the probability of borrowing at the discount window as described in equation 11. Sample is an unbalanced panel of FBOs and is restricted to those FBOs that executed at least a test loan. The dependent variable is an indicator that equals one if an FBO borrowed at the discount window in a quarter and zero otherwise. An observation is a bank-quarter. FBO-level cluster-robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix - Results by Federal Reserve District

Column (5) of table A3 provides some evidence suggesting that borrowing behavior differs by Federal Reserve District. Reasons for this range from potential stigma from the ability to identify institutions by District in Federal Reserve reporting, differences in credit risk management across Reserve Banks, or unobserved bank heterogeneity that predicts borrowing that is correlated with Reserve District, but is otherwise neither economically or qualitatively meaningful. Our results framework cannot distinguish between possible explanations for the differences.

Table A3: Borrowing, conditional on access

Dependent variable:	$DW_{it} = \{0,1\}$					
	Reserve balances			Other balance sheet items		
	(1)	(2)	(3)	(4)	(5)	(6)
Asset composition (share of assets)						
Reserve balances	-0.229**	-0.228**	-0.252 **	-0.164 **	-0.177 **	-0.242 **
	(0.020)	(0.020)	(0.023)	(0.030)	(0.032)	(0.025)
Treasury securities (t-1)				-0.003	0.007	0.019
				(0.052)	(0.052)	(0.038)
Agency debt (t-1)				0.040	0.042	0.1004*
				(0.029)	(0.029)	(0.046)
Agency MBS (t-1)				0.008	0.010	0.034
				(0.024)	(0.025)	(0.023)
Residential (t-1)				-0.026	-0.021	0.021
				(0.016)	(0.019)	(0.028)
CRE (t-1)				-0.014	-0.015	0.009
				(0.018)	(0.019)	(0.020)
C & I (t-1)				0.030	0.030	0.031
				(0.031)	(0.032)	(0.029)
Consumer (t-1)				-0.057*	-0.055*	-0.006
				(0.025)	(0.026)	(0.030)
Unused commitments (t-1)				0.000	0.001	0.002
				(0.003)	(0.003)	(0.001)
Liability composition (share of liabilities)						
Uninsured deposits (t-1)				0.030*	0.037**	0.019
				(0.013)	(0.014)	(0.015)
Federal funds (t-1)				0.209*	0.223*	0.275**
				(0.090)	(0.089)	(0.104)
Repo (t-1)				0.190**	0.186**	0.333**
				(0.073)	(0.072)	(0.087)
FHLB advances				0.087**	0.090**	0.127**
				(0.021)	(0.022)	(0.030)
Other characteristics						
Log(assets) (t-1)				0.002*	0.002	-0.001
				(0.001)	(0.001)	(0.004)
Tier 1 capital ratio (t-1)				-0.004	-0.003	0.035
				(0.019)	(0.021)	(0.023)
ROA				0.650**	0.635**	-0.142
				(0.217)	(0.224)	(0.247)
Total collateral to assets				0.107**	0.096**	0.021
				(0.026)	(0.026)	(0.030)
Selected Federal Reserve Districts						
3					0.013*	
					(0.005)	
6					0.016**	
					(0.006)	
7					0.013**	
					(0.005)	
10					-0.001	
					(0.005)	
12					0.012*	
					(0.005)	
Bank FE	N	N	Y	N	N	Y
Year-quarter FE	N	Y	Y	N	Y	Y
R^2	0.003	0.004	0.157	0.012	0.015	0.159

Notes: The number of observations is 73,250 and the number of banks is 2,152. This table provides estimates from evaluating a linear probability model of the effects of selected bank characteristics on the probability of borrowing at the discount window as described in equation 11. Sample is an unbalanced panel of commercial banks and is restricted to those banks that executed at least a test loan. The dependent variable is an indicator that equals one if a bank borrowed at the discount window in a quarter and zero otherwise. An observation is a bank-quarter. Bank-level cluster-robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix - Regional banks

Table A4 provides an additional robustness test relative to table 6, and explores the borrowing decisions of regional banks. Column (2) shows that the determinants of discount window borrowing for regional banks—defined as those with assets between $10 billion and $100 billion—are similar to those for larger banks. One exception is that the coefficient on reserves-to-assets is only significant at the 10 percent level of confidence. Inspection of the individual independent variables suggest significant collinearity of reserves-to-assets with unused commitments-to-assets at the bank level. Dropping unused commitments from the specification strengthens the significance of the point estimate. That said, these results should still be interpreted with care, reflecting the smaller number of banks relative to time periods in this subsample.

Table A4: Robustness

Robustness strategy:	Subsamples				Access		Definition of borrowing		
Dependent variable:	$DW_{it} = 1$						$DW_{it} = 1$ and $\text{loan}_{it} > \$10M$	Number of borrowings	Amount borrowed to total liabilities
Bank sample:	Larger (>$10B)	Regional (>$10B & <$100B)	Smaller (≤$10B)	Traded	Assuming access for >$50B	All banks	Access	Access	Borrowing
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Share of assets									
Reserve balances	-0.179*	-0.189$^+$	-0.248 **	-0.272**	-0.242**	-0.081**	-0.061**	-0.563**	0.649
	(0.081)	(0.095)	(0.026)	(0.052)	(0.025)	(0.009)	(0.013)	(0.080)	(0.488)
Agency debt (t-1)	0.144	0.198	0.097*	0.353	0.101*	0.016	0.012	0.264**	-0.009
	(0.119)	(0.116)	(0.048)	(0.215)	(0.046)	(0.010)	(0.013)	(0.092)	(0.046)
Agency MBS (t-1)	0.021	-0.013	0.032	0.106*	0.034	0.007	0.003	0.141	0.003
	(0.093)	(0.105)	(0.024)	(0.046)	(0.023)	(0.007)	(0.011)	(0.073)	(0.051)
Unused commitments (t-1)	-0.001	-0.004	0.003	-0.001	0.002	0.000	-0.001	0.013	0.038
	(0.008)	(0.008)	(0.001)	(0.008)	(0.001)	(0.000)	(0.001)	(0.009)	(0.047)
Share of liabilities									
Uninsured deposits (t-1)	0.024	0.025	0.017	0.046	0.019	0.003	-0.001	0.063	0.028
	(0.045)	(0.052)	(0.015)	(0.033)	(0.015)	(0.005)	(0.009)	(0.050)	(0.038)
Federal funds (t-1)	0.507	0.530	0.254*	0.389	0.274**	0.070*	0.050	0.946**	0.323
	(0.369)	(0.414)	(0.108)	(0.235)	(0.104)	(0.028)	(0.044)	(0.322)	(0.236)
Repo (t-1)	0.206	0.162	0.349**	0.447**	0.332**	0.160**	0.026	0.604*	0.045
	(0.241)	(0.314)	(0.093)	(0.135)	(0.086)	(0.047)	(0.036)	(0.246)	(0.065)
FHLB advances	0.072	0.091	0.128**	0.1708*	0.127**	0.048**	0.024	0.330**	0.029
	(0.148)	(0.162)	(0.031)	(0.087)	(0.030)	(0.011)	(0.015)	(0.085)	(0.069)
Other characteristics									
Log(assets) (t-1)	-0.029	-0.020	0.001	-0.014	-0.002	-0.001	0.003	0.006	-0.021**
	(0.017)	(0.018)	(0.005)	(0.009)	(0.004)	(0.002)	(0.002)	(0.017)	(0.004)
Tier 1 capital ratio (t-1)	0.059	0.053	0.037	0.020	0.034	0.007	0.010	0.177*	-0.114
	(0.082)	(0.091)	(0.024)	(0.047)	(0.023)	(0.005)	(0.013)	(0.090)	(0.119)
Total collateral to assets	-0.232*	-0.229	0.032	0.038			0.018	0.025	0.283**
	(0.111)	(0.122)	(0.034)	(0.082)			(0.015)	(0.073)	(0.081)
Number of observations	3,104	2,496	70,146	15,087	73,250	239,834	73,250	73,250	1,739
Number of banks	85	69	2,067	466	2,152	7,557	2,152	2,152	648
R^2	0.083	0.088	0.162	0.162	0.159	0.170	0.136	0.149	0.194

Note: This table provides estimates from a fixed effects panel linear probability model of the effects of selected bank characteristics on the probability of borrowing at the discount window (columns (1) through (7)) and from fixed effects panel regression models of the effects of selected bank characteristics on the number of instances and amount of borrowing at the discount window (columns (8) and (9)). Except for column (6), all samples are restricted to those banks that executed at least a test loan. In all cases, an observation is a bank-quarter. Columns (1), (2), and (3) evaluate equation 11 on large, regional, and small-banks subsamples, respectively. The dependent variable is an indicator that equals one if a bank borrowed at the discount window in a quarter. Column (4) evaluates the model on all publicly-traded commercial banks, and column (5) assumes banks with greater than $50B in assets have discount window access. Column (6) incorporates all commercial banks, regardless of access considerations. Column (7) increases the loan threshold to $10M, column (8) evaluates the number of loans in a quarter, and column (9) explores the dollar value of loans relative to total liabilities. Robust standard errors (shown in parentheses) are clustered at the bank level. $^+$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Evaluating the LCR: D-I-D and event study approaches

Dependent variable	$DW_{it} = \{0, 1\}$	
	D-I-D	Event study
Treatment	0.014	
	(0.009)	
After 2014		-0.004
		(0.005)
$> \$10B$ & after 2014		0.005
		(0.007)
Reserve balances	-0.242 **	-0.266**
	(0.025)	(0.027)
$> \$10B$ & reserve balances		0.103
		(0.081)
After 2014 & reserve balances		0.055
		(0.033)
$> \$10B$ & after 2014 & Reserve balances		-0.115
		(0.072)
Number of observations	73,250	73,250
Number of banks	2,152	2,152
R^2		0.006

Appendix - Further FHLB results

Our results reported in Table 7 indicate a nonlinear relationship between FHLB advances and discount window borrowing, when evaluating a bank's discount window borrowing decisions based on its own distribution of FHLB advance usage. There is also the question of the cross-sectional distribution of FHLB advances-to-liabilities. Column (7) of Table A5 suggests that banks with relatively little FHLB advance capacity, as measured by FHLB advances to liabilities, are more likely to borrow from the discount window. By contrast, banks with substantial FHLB capacity do not borrow from the discount window. This result points to the important of the pecking order in bank funding decisions, as well as the potential for FHLB borrowing constraints to influence discount window use.

Table A5: Borrowing, conditional on access – The role of FHLB advances

Dependent variable	$DW_{it} = 1$						
	All		Larger banks (> \$10B)		Smaller banks (< \$10B)		All
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Reserve balances	-0.240**	-0.239**	-0.171*	-0.166*	-0.248**	-0.246**	-0.238**
	(0.024)	(0.024)	(0.076)	(0.075)	(0.026)	(0.025)	(0.024)
FHLB advances	0.120 **	0.087**	0.069	0.020	0.122**	0.090**	
	(0.030)	(0.032)	(0.149)	(0.143)	(0.031)	(0.033)	
"Top 5" FHLB advances		0.006*		0.010		0.006*	
		(0.002)		(0.013)		(0.003)	
FHLB advances usage: Spline approx.							
First segment (0)							0.171**
							(0.038)
Second segment (0.11,.)							-0.173
							(0.089)
Third segment (0.22,.)							0.110
							(0.206)
Fourth segment (0.33,.)							0.509
							(0.562)
Fifth segment (0.44,.)							-1.883*
							(0.754)
Federal funds$_{t-1}$	0.247*	0.246 *	0.443	0.432	0.230*	0.230*	0.247*
	(0.105)	(0.105)	(0.360)	(0.361)	(0.109)	(0.109)	(0.105)
Repo$_{t-1}$	0.314**	0.313**	0.175	0.174	.3327 **	0.332**	0.311**
	(0.086)	(0.086)	(0.239)	(0.240)	(0.092)	(0.092)	(0.086)
Number of banks	2,149	2,149	85	85	2,064	2,064	2,149
Number of observations	73,239	73,239	3,104	3,104	70,135	70,135	73,239
R^2	0.159	0.160	0.097	0.097	0.163	0.163	0.160

Cluster-robust standard errors in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: This table provides estimates from a linear panel model of the effects of selected bank characteristics on the probability of borrowing at the discount window. Sample is restricted to those banks we classified as having access. The dependent variable is an indicator that equals one if a bank borrowed at the discount window in a quarter. An observation is a bank-quarter. A linear spline approximation for FHLB advances to total liabilities is included in Column (7), with knots evenly spaced throughout the range of the data and coefficients presented as marginal effects.

Appendix - First-stage results

This table presents first-stage results for the instrumental variables used in the second-stage estimation results presented in table 10. The independent variable $R_{i,2008}$ indicates the bank's reserves-to-assets ratio in June 2008. This ratio is interacted with a range of year indicators from 2009 to 2019. All specifications include the same controls as in column (6) of table 5.

Table A6: First-stage for IV specification (Table 10)

Instrument	Dependent variable: R_{it}					
Bank-level instruments						
$R_{i,2008} * 2010$	0.314	-0.376	0.266			
	(0.193)	(1.570)	(0.190)			
$R_{i,2008} * 2011$	.9532 **	0.441	.9193 **			
	(0.213)	(1.410)	(0.220)			
$R_{i,2008} * 2012$	1.102 **	-0.518	1.123 **			
	(0.247)	(1.260)	(0.255)			
$R_{i,2008} * 2013$	.724 **	-0.437	.7603 **			
	(0.257)	(0.934)	(0.264)			
$R_{i,2008} * 2014$	0.308	-0.461	0.341			
	(0.214)	(0.766)	(0.219)			
$R_{i,2008} * 2015$	0.307	-0.935	0.342			
	(0.204)	(0.625)	(0.208)			
$R_{i,2008} * 2016$	0.259	-0.204	0.287			
	(0.174)	(0.483)	(0.177)			
$R_{i,2008} * 2017$	-0.111	0.291	-0.106			
	(0.116)	(0.433)	(0.117)			
$R_{i,2008} * 2018$	-0.236 *	0.548	-0.2439 *			
	(0.095)	(0.312)	(0.097)			
$R_{i,2008}*$Reserves growth by bank size				0.008**		
				(0.002)		
Aggregate instruments						
Reserves growth					0.006 **	
					(0.002)	
Reserves growth^2					-.01106 **	
					(0.002)	
$\frac{TGA}{Reserves}$						-0.017 **
						(0.005)
Number of observations	73,250	3,104	70,146	73,231	73,250	73,250
Number of banks	2,152	85	2,067	2,152	2,152	2,152

Note: This table provides first-stage estimates from a instrumental variables linear panel model of the effects of selected bank characteristics on the probability of borrowing at the discount window. Sample is restricted to those banks we classified as having access. The dependent variable is an indicator that equals one if a bank borrowed at the discount window in a quarter. The potential endogenous variable is reserves-to-assets. The table presents the parameter estimates on the instruments for the second-stage results presented in table 10. An observation is a bank-quarter.

Instrumental variable approaches and the LCR

	Full sample			LCR period		
	All	Larger banks	Smaller banks	All	Larger banks	Smaller banks
	(1)	(2)	(3)	(4)	(5)	(6)
Reserve balances	-0.535*	0.355	-0.517*	0.259	-0.323	0.267
	(0.214)	(1.350)	(0.208)	(0.205)	(0.329)	(0.221)
N	73,250	3,104	70,146	43,712	1,915	41,797
Number of banks	2,152	85	2,067	2,016	85	1,931
R^2	0.002	-0.005	0.003	-0.002	0.005	-0.002

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Appendix - Discount Window Access

In general, the decision to gain access to the discount window also responds to basic cost-benefit evaluations. If the costs of gaining access to the discount window were zero, banks exposed to liquidity shocks would choose to have access (or be indifferent about it). However, there are some costs that a bank incurs when gaining access to the discount window, stemming from, for example, setting up the systems and collateral-pledging processes. In this appendix, we investigate further how access interacts with other decisions of the bank and in particular with the decision to hold bank reserves.

Suppose that bank i has a cost c_i^{DW} from gaining access to the discount window. Going back to expression (9), we have that bank i will choose to gain access to the discount window whenever

$$\widehat{V}_{iA} - c_i^{DW} \geq \widehat{V}_{iN},$$

where $\widehat{V}_{iA}$ is the optimized value of $\widehat{V}_i$ in expression (9) (when the bank has access to the discount window) and $\widehat{V}_{iN}$ is the optimized value of $\widehat{V}_i$ when the bank has no access to the discount window, as in Section 3.3.2. It is important here to realize that the choice of reserves (and securities) depends on whether the bank obtains access to the discount window. Corollary 5.1 illustrates this point.

Continuing with our leading example, we know from propositions 4 and 5 that the choice of reserves depends on the level of the interest rate on deposits relative to other relevant interest rates. For example, when $r_D \in (r^{T_1}, r^{T_2})$ we have that the bank would set the level of reserves to equal Δ_2 regardless of whether it has access to the discount window. In fact, the bank will not need to use the discount window or overnight overdraft in such case. When the cost $c_i^{DW} > 0$, the bank will choose not to pay it and hence will not have ready access to the discount window.

A more interesting case ensues when $r_D \in (r^{T_2}, r^{T_2'})$. In this case, a bank with access to the discount window would set its level of reserves equal to Δ_1, and a bank without access to the discount window would instead choose reserves equal to Δ_2 (see Figure 5). This, in turn, implies that the bank without access will not need central bank funding, while the bank with access to the discount window will borrow from the central bank when the shock is large (equal to Δ_2). Based on these patterns, after some algebra, it can be shown that the bank will choose to have access to the discount window if

$$(r_D - r^{T_2})(\Delta_2 - \Delta_1) \geq c_i^{DW}. \tag{14}$$

The interpretation of this condition is simple. When a bank chooses to not have access to the discount window, it chooses to hold $\Delta_2 - \Delta_1$ extra reserves at a cost of r_D. A bank that chooses to have access, instead, would decide to hold lower reserves but would have to borrow from the interbank market or the discount window (by and amount $\Delta_2 - \Delta_1$) according to the probability that the interbank market is open (q), or not $(1 - q)$, at the time when the bank needs the funds (this average funding cost is exactly reflected in the formula for r^{T_2}). When the differential funding cost associated with the two alternatives is greater than the cost of obtaining access, the bank will choose to gain access.

A second interesting case is when $r_D \in (r^{T_2'}, r^{T_3})$. In this case, both the bank with access to the discount window and the one without it would choose the same level of reserves Δ_1. In that way, both banks would experience the same liquidity needs with the same probabilities. In particular, when the shock equals Δ_2 and the bank does not have access to interbank markets, it will need to seek funding from the central bank. Having access to the discount window lowers the cost of that funding (by avoiding a more expensive overdraft). Hence, whenever

$$(1 - q)p_2(r_o - r_{DW})(\Delta_2 - \Delta_1) \geq c_i^{DW}, \tag{15}$$

bank i will choose to obtain access to the discount window by paying the cost c_i^{DW}.

The rest of the cases (for higher values of r_D) are similar, with the bank saving in funding costs by lowering the cost of central bank liquidity in some contingencies (when the shock is large) even if in some cases the choice of lower reserve levels increases exposure to that liquidity risk.

With the set of interest rates taken as given by the bank, equations (14) and (15) (and their counterparts for the other cases) capture the factors that determine whether a bank will choose to gain access to the discount window. For example, banks with lower c^{DW} are more likely to choose to gain access to the discount window. These differences in cost may originate, for example, on a differential treatment of discount window requirements across Federal Reserve districts in the U.S.

Furthermore, banks facing different shock processes will, in principle, make different access decisions. The difference in shock process is reflected not only on the support of possible values of Δ, but also on the probabilities over those values and the probability that the bank could face the shock when the interbank market is closed (these probabilities determine r^{T_2} in equation (14)).

For a given structure of the shock, the model suggests that a bank choosing to obtain access to the discount window would choose to hold no more reserves than a bank not choosing to have such access. However, note that the decision to gain access is driven (among other things) by the differential between values of Δ (the variability on the size of the shock) while the level of reserves chosen by the bank depends on the *level* of the different values of Δ (the size of the shocks). For this reason, when banks are heterogeneous over the shock process they face, some of those banks can be choosing to gain access to the discount window and also hold relatively high levels of reserves compared with other banks that face smaller and less variable shocks and choose to not have access to the discount window. With this in mind, we restrict the sample in some cases to banks with access to the discount window, to partially control for patterns of unobserved heterogeneity.