Unintended Consequences of Post-Crisis Liquidity Regulation*

Suresh Sundaresan
Columbia Business School

Kairong Xiao
Columbia Business School

December 10, 2019

Abstract

We find post-crisis liquidity regulation has unintentionally increased banks' borrowing from an obscure financial intermediary known as the Federal Home Loan Banks (FHLBs), which are not subject to the same liquidity requirements as banks. We show that regulatory arbitrage was an important motive behind banks' increasing reliance on the FHLBs. As liquidity regulation reduces banks' issuance of short-term money-like claims, the unregulated FHLBs increase their issuance and then lend to banks. Using a model of liquidity regulation, we show that this regulatory arbitrage compromises the effectiveness of liquidity regulation to reduce excessive liquidity transformation and creates potential fragilities in the financial system.

JEL Classification Codes: G20, G28

Keywords: liquidity regulation, regulatory arbitrage, money-like claims

*We are grateful to Christa Bouwman (discussant), Sergey Chernenko (discussant), Douglas Diamond, Jennifer Dlugosz (discussant), Mark Flannery, Scott Frame, Edward Golding, Ivan Ivanov (discussant), Raghuram Rajan, Yiming Ma, Christopher Mayer, Patrick McCabe (discussant), Borghan Narajabad, David Scharfstein, Jeremy Stein, Adi Sunderam, Skander van den Heuvel (discussant), and seminar participants at the NBER Summer Institute, New York Fed/NYU Conference on Financial Intermediation, the Conference on Financial Market Regulation Financial at SEC, Financial Stability Conference at Cleveland Fed, the Risk Management and Financial Innovation Conference, the Short-Term Funding Markets Conference, FDIC/JFSR Bank Research Conference, the Indian Institute of Management, BI Oslo, and Columbia Micro Lunch for helpful feedback. We thank Daheng Yang and Zhuoli Wang for excellent research assistance.

1 Introduction

One of the key functions of the banking system is to transform illiquid assets into short-term money-like claims. However, as shown in the 2007–2009 financial crisis, if left regulated, banks tend to engage in excessive liquidity transformation, which makes them vulnerable to runs. When runs occur, the government has no choice but to provide emergency funding to banks, which exposes taxpayers to substantial risk.

In response to this problem, regulators introduced a set of preventative measures to improve banks' liquidity. Banks are now subject to the Liquidity Coverage Ratio (LCR) requirements, which require them to hold high-quality liquid assets (HQLAs) to back their short-term money-like claims. Unlike capital regulation which has received extensive academic scrutiny, liquidity regulation is new and has run ahead of research. As noted by Allen and Gale (2017), "With capital regulation there is a huge literature but little agreement on the optimal level of requirements. With liquidity regulation, we do not even know what to argue about."

In this paper, we try to fill this gap by evaluating the effects of post-crisis liquidity regulation on the U.S. banking system. We document that liquidity regulation has unintentionally led to an expansion of banks' borrowing from an obscure financial intermediary known as the Federal Home Loan Banks (FHLBs). We show that the expansion of banks' borrowing from the FHLBs was driven by a regulatory arbitrage: because the FHLBs are not subject to the LCR, they can issue short-term money-like claims at lower costs and lend to banks in longer-term.[1] We argue that this regulatory arbitrage compromises the effectiveness of liquidity regulation to reduce excessive liquidity transformation and creates potential fragilities in the financial system.

We first develop a model of liquidity regulation to study how liquidity regulation affects the banking system. In the model, there is a demand for short-term money-like claims in the economy. Banks meet this demand by transforming illiquid assets into money-like claims. In the absence of liquidity regulation, banks conduct too much liquidity transformation because they do not internalize the externality of bank runs. To address this market failure, regulators require banks to back short-term debt with liquid assets, which effectively increases the cost of regulated banks to issue money-like claims. However,

[1]Note that the LCR calculates liquidity ratios for a 30-day stress scenario. Therefore, debt with maturities longer than one month could be viewed as long-term in the context of the LCR.

if some banks are not covered by liquidity regulation, then these unregulated banks can issue short-term money-like claims at lower costs and lend to regulated banks in the form of long-term funding. This type of transaction constitutes a regulatory arbitrage because liquidity transformation simply shifts from regulated banks to unregulated banks while the aggregate liquidity mismatch stays unchanged.

We test the model's predictions using a comprehensive database covering banks and the FHLBs. The FHLBs are housing government-sponsored enterprises (GSEs) that provide collateralized loans called "advances" to member financial institutions to promote housing and community development. Although the FHLBs can potentially conduct liquidity transformation as banks, they are not subject to the LCR because of their GSE status. During much of its history, the FHLBs remained in an obscure corner of the financial system. However, from 2013 to 2017, the balance sheets of the FHLBs have rapidly expanded from \$0.7 trillion to \$1.1 trillion—a size comparable to the fourth-largest bank holding company, the Citi Group. The rapid expansion of the FHLB balance sheets is mainly driven by the increase in the borrowing from big and medium banks which are subject to the LCR.

To show that liquidity regulation has indeed led to the expansion of banks' borrowing from the FHLBs, we exploit the variation in regulatory exposure in the cross-section of banks. Specifically, we use banks' balance sheets before the introduction of the LCR to construct the gap between the required liquidity ratio for each bank and its pre-regulation level. This regulatory exposure is predetermined and thus unlikely to be chosen endogenously by banks in response to the LCR. We find that banks that were further away from meeting their liquidity requirements borrowed more from the FHLBs. We examine other important regulatory reforms and policy shocks such as capital regulation, mark-to-market requirements, money market reform, and quantitative easing. We show that they are unlikely to explain the differential increase in the borrowing from the FHLBs for banks subject to the LCR.

We suggest that regulatory arbitrage is an important motive behind banks' borrowing from the FHLBs. Specifically, we estimate how much funding costs that banks can save from this regulatory arbitrage by comparing two alternative funding strategies: (1) banks directly issue short-term money-like claims to the market; and (2) banks use the FHLBs as an intermediary to access the short-term funding market indirectly. Before the LCR, the cost difference between the two strategies is close to zero. After the introduction of

LCR, the cost difference between the two strategies jumped to 80 bps because banks are now required to hold liquidity buffers to back the money-like claims while the FHLBs are not.

The FHLBs are not the only institutions that are not subject to the LCR. Why did banks choose to use them to conduct regulatory arbitrage? Four institutional features make the FHLBs an attractive vehicle to conduct regulatory arbitrage. First, according to the current LCR, holding maturity constant, the FHLB advances receive a favorable treatment compared to other types of banks' funding. Second, the FHLBs can elastically expand their balance sheets because of a unique institutional feature called "activity-based capital". However, other types of intermediaries may run into capital constraint if they were to issue money-like claims and then lend to banks. Third, the FHLBs enjoy implicit government guarantees on their debt, which gives them an additional funding cost advantage over other intermediaries. Finally, banks appear to face no stigma when borrowing from the FHLBs.

We examine the financial stability implications of our empirical findings. Although liquidity regulation has reduced banks' reliance on short-term wholesale funding, the FHLBs have significantly increased their issuance of short-term money-like claims to finance their lending to banks. We find that, in the cross-section of the FHLBs, if more member commercial banks are subject to the LCR in an FHLB district, then the FHLB is likely to issue more money-like claims to finance its lending to member banks compared to other FHLBs. In aggregate, by the end of 2015, the amount of short-term money-like claims issued by the FHLBs has reached $700 billion, surpassing the amount issued by banks. This result suggests the goal of liquidity regulation to reduce aggregate liquidity mismatch may have been compromised.

As the FHLBs increasingly rely on shorter-term debt to finance their lending, their liquidity risks may have increased. As of 2017, around 50% of the FHLB balance sheet is financed by ultra short-term notes with an average maturity of fewer than 40 days. At the same time, the FHLBs' lending has become increasingly concentrated in a few big banks, raising the concern about concentration risk. As banks pledge more collateral to the FHLBs, the recovery rates for unsecured creditors in default may decrease, which makes them more likely to run. The FDIC Deposit Insurance Funds may also suffer greater loss as banks' balance sheets become encumbered. Furthermore, as banks increasingly use the FHLBs as intermediaries to raise funding, inter-dependency and contagion risks in the

financial system may have increased. Finally, the expansion of the FHLB balance sheets increases the reliance of the private banking system on implicit government guarantees. We estimate that the implicit transfer from taxpayers to the FHLBs and banks has increased by 38% from 2012 to 2017.

How should we address this unintended consequence? Imposing tougher liquidity requirements on the FHLBs may suppress this regulatory arbitrage in the short run, but in the long run, liquidity risks may simply migrate to other unregulated intermediaries. This is because the regulation does not resolve the fundamental problem behind this unintended consequence, that is, society needs a large stock of money-like assets, more than can be supplied by other means. Therefore, private financial intermediaries have an incentive to create such assets. If regulated banks are constrained by liquidity regulation, other types of intermediaries will pick up the slack. We suggest an alternative approach, which is to have a central bank facility that provides HQLAs to banks at a price which reflects the externality of liquidity transformation. Such a facility supplies government money-like assets contingent on the aggregate demand for liquidity while equalizing the social marginal benefits and costs of liquidity transformation.

Our paper contributes to four strands of literature. First, we contribute to the literature on liquidity regulation. Unlike capital regulation, which has received extensive academic scrutiny, liquidity regulation is only beginning to attract academic investigation (Allen and Gale 2017). Several recent theory papers study what type of market failure liquidity regulation can address. Calomiris, Heider, and Hoerova (2015) provide a theory of liquidity regulation based on the idea that it is much easier to verify the value of liquidity than other types of capital. Diamond and Kashyap (2016) argue that liquidity regulation can reduce the probability of a run by forcing banks to hold more liquidity. We contribute to this literature by studying the endogenous response of the banking system to liquidity regulation. We show that if liquidity regulation is unevenly implemented in the financial system, then banks may have the incentive to use unregulated entities to circumvent liquidity regulation. We argue the government can mitigate this unintended consequence by increasing the supply safe assets, at a price, on a state-contingent basis.

Our paper also adds to a growing body of empirical works on liquidity regulation. Bai, Krishnamurthy, and Weymuller (2018) propose an index of liquidity mismatch to measure the extent of liquidity transformation of the banking system. Roberts, Sarkar, and Shachar (2018) find that banks subject to liquidity regulation conduct less liquidity transformation.

We show that part of the liquidity transformation has shifted into the FHLBs. Hoerova, Mendicino, Nikolov, Schepens, and Van den Heuvel (2018) and Berger, Black, Bouwman, and Dlugosz (2017) show banks with higher liquidity ratios were less likely to borrow emergency liquidity from the Federal Reserve or the ECB during the 2007-09 crisis. These two papers focus on samples that predate the post-crisis liquidity regulation. In contrast, we focus on the post-regulation period and show that the banking system has devised ways to circumvent liquidity requirements. It is unclear whether liquidity ratios in the post-regulation period can truly reflect the resilience of the banking system as before.

The second strand literature which our paper relates to studies the supply and demand of money-like assets. Holmström and Tirole (1998, 2011) show that when a shortage of government-supplied liquid assets exists, a liquidity premium arises which induces the private sector to conduct liquidity transformation. Gorton and Metrick (2012) show that the run on these money-like claims was one of the key causes of the 2007–09 financial crisis. Krishnamurthy and Vissing-Jorgensen (2012) show that changes in Treasury supply have large effects on liquidity premium in the economy. Sunderam (2014) documents substitutions between public debt and money-like claims issued by shadow banks. We link this literature to liquidity regulation. We show that post-crisis liquidity regulation has exacerbated the shortage of money-like assets by constraining banks' supply. Therefore, other types of intermediaries such as the FHLBs rose to take up the slack.

The third strand literature which our paper relates to studies the role of the FHLBs in the financial system. Flannery and Frame (2006) is one of the early studies on the risk-taking incentive of FHLBs. Ashcraft, Bech, and Frame (2010) highlight the role of the FHLB system in extending liquidity to banks during the 2007–2009 financial crisis. Gissler and Narajabad (2017) and Anadu and Baklanova (2017) document aggregate trends of the FHLBs' balance sheets in the post-crisis period amid the roll-out of the Basel III liquidity requirements. We provide micro-level evidence based on cross-bank exposure to the LCR to identify the causal effect of liquidity regulation. Furthermore, we construct a theoretical model to study the underlying mechanisms of this phenomenon. The model also sheds light on policy remedies for the unintended consequences.

Our paper is also broadly related to the literature which studies the design of financial regulations. Agarwal, Lucca, Seru, and Trebbi (2014) study supervisory decisions of U.S. banking regulators and find that federal regulators are systematically tougher than state supervisors. Acharya, Schnabl, and Suarez (2013) show that banks set up asset-

backed commercial paper conduits before the 2007-09 financial crisis to circumvent capital regulation because these conduits face lower capital requirements. Similarly, Irani, Iyer, Meisenzahl, and Peydro (2018) show that bank capital regulation has led to the prevalence of lightly regulated shadow banks in the U.S. corporate loan market. Our paper shows that a new type of regulatory arbitrage has arisen after the newly introduced liquidity regulation. We study the conditions which make this type of regulatory arbitrage feasible and estimate its economic magnitude.

The rest of the paper is organized as follows. In Section 2, we describe the institutional background of liquidity regulation and the FHLB system. In Section 3, we develop a model of liquidity regulation. In Section 4, we present empirical evidence on how liquidity regulation affects banks' reliance on the FHLBs. Section 5 concludes.

2 Institutional Background

2.1 The Liquidity Coverage Ratio

The LCR was proposed by the Basel Committee on Banking Supervision in December 2010 and finalized in January 2013 as a part of the Basel III regulatory framework. The US version of the LCR was finalized in September 2014. The goal of the LCR was to curb banks' excessive liquidity transformation.[2] The LCR mandates that banks with at least $250 billion in total assets or at least $10 billion in on-balance sheet foreign exposure hold enough HQLA, defined as cash, central bank reserves, Treasuries, and certain types of agency mortgage-backed securities, to cover expected net cash outflow for a 30-day stress scenario. Banks with assets that is between $50 billion to $250 billion are subject to a modified version of LCR that requires HQLA to meet outflows over 21 instead of 30 calendar days in a stress scenario. In the following discussion, we refer these two groups of banks as "full-LCR banks" and "modified-LCR banks" respectively. Banks which are not affected by LCR are referred as "non-LCR banks". Full-LCR banks were required to achieve 80% of LCR by 2015, 90% of LCR by 2016, and 100% by 2017, modified-LCR banks were required to achieve 90% of LCR by 2016, and 100% by 2017.

[2]The other key component of Basel III liquidity standards is the Net Stable Funding Ratio (NSFR) requirement, which is intended to ensure that banks have a robust funding profile over a one-year horizon. The NSFR has not been implemented in the United States as of 2018.

The formula to calculate LCR is the following:

$$\text{LCR} = \frac{\text{High quality liquid asset amount}}{\text{Total net cash outflow amount}}. \tag{1}$$

HQLA in the numerator are calculated by multiplying a liquidity factor to each type of liquid assets and then adding them up. The detailed weights of each type of assets can be found in Table 2. Total net cash outflow in the denominator is calculated as expected cash outflows minus the expected cash inflow within 30 days in a stress scenario. The expected cash outflows is calculated by multiplying a "run-off" rate to the portion of liabilities which matures within the next 30 days. Debt with shorter maturities is penalized more because a large portion of the outstanding amount will mature within the next 30 days. Unstable liabilities such as uninsured deposits face higher "run-off" rate than stable liabilities such as insured deposits. Therefore, for debt with a maturity of τ days and a run-off rate of ρ, the expected cash outflow is $\frac{30}{\max\{\tau,30\}}\rho$. Similarly, the expected cash inflows is calculated by multiplying a inflow rate to receivables within the next 30 days. The detailed weight of each type of liability and receivables can be found in Table 3.

Using the banks' balance sheet data from Call reports and FR Y-9C, we construct the LCR measure for each bank. Figure 1 plots the average LCR for full-LCR banks and the modified-LCR banks over time. As a reference, we also plot the minimum requirement phased in each year. Notice that the minimum requirement on the modified-LCR banks is only 70% of that for full-LCR banks. At the start of the sample, the average liquidity coverage ratio of full-LCR banks is only around 0.8, which is 20% lower than the required level when the regulation becomes fully effective. Over this period, the full-LCR banks substantially increase their LCR. By the end of the 2017, the average full-LCR banks are compliant with the requirement. In comparison, the LCR is less constraining for the modified-LCR banks, although there are large cross-bank heterogeneity in their liquidity position leading up to the roll-out of LCR. Banks can improve their liquidity ratios in two ways. First, they can hold more liquid assets on the asset side, which increases the numerator of the LCR. Second, they can issue fewer short-term money-like claims and borrow more longer term funding on the liability side, which reduces the denominator of the LCR.

2.2 The Federal Home Loan Bank System

The FHLB system, which was established in 1932, is a large government-sponsored enterprise (GSE) whose mission is to assist its member financial institutions to finance housing and certain types of community development lending. Membership in the FHLB is voluntary and restricted to federally insured depository institutions, insurance companies, and Community Development Financial Institutions (CDFIs). There were 12 regional FHLBs but one failed after the 2007-2009 crisis. As of June 2018, the FHLBs have over 6,900 members in total. The collateralized loans that the FHLBs provide to banks are called "advances" and their maturities range from overnight to 30 years.[3]

Figure 2 plots the aggregate amount of the FHLB advances borrowed by different groups of banks. Traditionally, small banks were the main borrowers of the FHLB advances because they did not have access to alternative funding sources. During the 2007–2009 financial crisis, the FHLBs became an important provider of liquidity to banks in first half of 2007 because they offered "stigma-free" funding with favorable pricing compared to the discount window of the Federal Reserve. However, the FHLBs' lending to banks also drew sharp criticism because the loans often had weak collateral standards and were concentrated in big banks (Gaberlavage 2017). For example, Senator Charles Schumer criticized advances made to Countrywide Bank by the FHLB of Atlanta stating that the bank was serving as Countrywide's "personal ATM." Following heightened concerns about the financial health of Fannie Mae and Freddie Mac in the second quarter of 2008, the FHLB system found itself "guilty by association" and saw its borrowing costs and advance rates rise (Ashcraft, Bech, and Frame 2010). One of the twelve original FHLBs, the Seattle FHLB, failed in part due to the failure of its largest member, Washington Mutual, and was forced to merge with the Des Moines FHLB. In response to these problems, the 2011 joint report by the Department of Treasury and HUD recommended limiting the level of advances and reducing portfolio investments of the FHLBs as part of the broad housing market reform.[4]

After the crisis, the borrowing from the FHLBs started to revert to its pre-crisis level. However, such a trend reversed after the roll-out of the LCR. Banks started to expand their borrowing from the FHLBs again and most of the demand seemed to come from big banks.

[3]We provide a more detailed description of the key institutional features of the FHLB system In the Online Appendix.

[4]See "Reforming America's Housing Finance Market: A Report to Congress", February (2011), U.S. Department of Treasury and the Department of Housing and Urban Development.

This is unusual because big banks did not borrow substantially from the FHLBs except in the crisis times. As a result of increasing demand for FHLB advances, the balance sheets of the FHLBs rapidly expanded by 46% from 2013 to 2017 and reached $1.1 trillion.

To finance their lending to banks, the FHLBs have increased the issuance of short-term money-like claims. Figure 3 plots the money-like claims issued by banks and the FHLBs. Money-like claims issued by banks include federal funds purchased, repurchase agreements, trading liabilities, and brokered deposits with maturities less than one year.[5] Money-like claims issued by the FHLBs include FHLB discount notes and FHLB bonds with maturities less than one year. Following the roll-out of liquidity regulation, money-like claims issued by banks have substantially decreased. However, at the same time, money-like claims issued by the FHLBs have significantly increased. In 2016, the amount of money-like claims issued by the FHLBs has surpassed that of banks. This is striking because the total assets of the FHLBs is less than 7% of the total assets of banks.

Because FHLB advances have relatively longer maturities than the money-like claims issued to finance them, the expansion in the FHLB advances may have led to an increase in liquidity mismatch in FHLBs' balance sheets. Figure 4 shows the maturity composition of the FHLB balance sheets. We estimate the average maturity of the FHLB bonds using the FHLBs' filings to the SEC. Because MMFs are the main holders of the FHLB discount notes, we use MMF N-MFP filings to estimate the average maturity of the FHLB notes. On the asset side, around 60% of the advances have maturities longer than one year. In contrast, on the liability side, around 50% of the FHLB balance sheets is financed by ultra short-term discount notes from MMFs with an average maturity of less than 40 days as of 2017; 20% is financed by bonds with maturities less than one year.

The rapid expansion of the FHLBs coincides the roll-out of the LCR, raising the concern that liquidity regulation could be an underlying driving force.[6] In particular, unlike banks, the FHLBs are not subject to the LCR because they are regulated as housing GSEs. It is possible that the uneven liquidity regulation on banks and the FHLBs may create an regulatory arbitrage opportunity. In the following section, we will propose a theoretical model to study the effect of an uneven liquidity regulation on the banking system.

[5]Note that retail deposits have short maturities but they are stable source funding because of deposit insurance.

[6]For instance, see "Recent Trends in Federal Home Loan Bank Advances to JPMorgan Chase and Other Large Banks", FHFA-OIG report, April 16, 2014.

3 Model

In this section, we introduce a theoretical model to study how the banking system will respond to liquidity regulation. Although our empirical exercise focuses on the FHLBs in the US, the model abstracts away from specific institutional details of the FHLBs such as the super-lien status. Instead, the FHLBs are modeled as as a generic type of unregulated financial intermediaries and FHLB advances a type of term loans between unregulated banks and regulated banks. This allows us to draw general lessons for liquidity regulation.

We first describe the setting of the model. Then, we study a case in which all the intermediaries are subject to liquidity regulation. Finally, we allow some intermediaries to be unregulated and study the implication for liquidity regulation.

3.1 Aggregate Demand and Supply of Money-like Claims

We assume that there is an aggregate demand for money-like claims. For simplicity, we assume a linear demand function:

$$m^d(y) = \phi(y_0 - y),$$

where y is the equilibrium liquidity premium, y_0 is the liquidity premium of the first dollar of money-like claims; ϕ is the slope of the demand for money-like claims.

On the supply side, banks can create money-like claims by conducting liquidity transformation. By doing so, banks can reduce their funding costs by the amount of liquidity premium, y. Formally, suppose there is a continuum of banks with an aggregate mass of 1. Each bank is indexed by its cost of issuing money-like claims, c. Without loss of generality, we assume the issuance cost follows a uniform distribution, $c \sim U[0, 1]$. Note that banks may need to hold some liquid assets to back these claims. Therefore, the net liquidity creation of each bank is $m(c) - l(c)$, where $m(c)$ is the money-like claims issued by bank c and $l(c)$ is the liquid assets held by bank c. In addition to banks' supply, the government can issue m_g units of money-like claims. They come in two forms: the fiscal authority issues high quality liquid claims (i.e., government risk-free securities) and the monetary authority provides central bank reserves. In summary, the aggregate supply of

money-like claims is given by the following:

$$m^s(y) = \int (m(c) - l(c))dc + m_g.$$

3.2 Banks

Now we describe banks' technology to create money-like claims. Figure 5 presents the timeline of the model. There are three dates, $T = 0$, 1, and 2. At date 0, banks decide the asset and liability composition. Banks can hold i units of illiquid asset that generates a constant return of R_i at date 2. Note that banks have finite lending opportunities so the maximum amount of illiquid assets each bank can invest is 1. Banks can also hold l units of liquid asset that generates an endogenous return, R_l, at date 2. The difference between the liquid and illiquid assets is liquidity premium, $y = R_i - R_l$, which is endogenously determined in the equilibrium. The early liquidation value is 1 for liquid assets and 0 or illiquid assets.[7]

On the liability side, banks can issue money-like claims to finance their assets. Because money-like claims carry the liquidity premium, y, issuing money-like claims allow banks to reduce their funding costs:

$$r_m = R_i - y.$$

Issuing money-like claims, however, makes banks susceptible to runs. Specifically, there are two states of the world at date 1, $s = G, B$, which realize at date 1 with exogenous probabilities of $1 - p$ and p respectively. In the good state, G, no depositors want to withdraw early. In the bad state, B, a fraction of holder of the money-like claims, Δm, want to withdraw early. If the liquidity buffer is less than the early withdrawals, $l < \Delta m$, then a run will occur and the bank will fail. Define f_s as the amount of early withdrawals in state s

$$f_s = \begin{cases} 0, & \text{if } s = G \\ \Delta m, & \text{if } s = B. \end{cases}$$

Banks can also finance their assets with long-term funding from outside capital market, b. We assume that the long-term capital market is competitive so that the long-term funding cost equals to the return of illiquid assets $r_b = R_i$. Note that the LCR seeks to

[7]The results are robust to any positive liquidation value less than 1 for the illiquid assets.

discourage banks from issuing claims with maturities shorter than 30 days. Therefore, the long-term funding here should be interpreted as term funding with maturity longer than 30 days, which is the length of stress scenario defined in the LCR. Banks

In addition to borrowing long-term from outside capital market, banks can also borrow long-term funding from other banks. The FHLB advances can be interpreted as a type of long-term funding among banks. Note that we do not study the short-term inter-bank loans here because short-term inter-bank loans do not help banks to relax liquidity constraint. Define a as the amount of term lending among banks. By convention, $a > 0$ means that a bank is a borrower while $a < 0$ means a bank is a lender. We assume the amount of long-term funding that banks can borrow or lend to each other is bounded, $|a| < \alpha$. α is equivalent to a leverage constraint.

At date 0, banks choose asset composition and liability structure to maximize the equity value. The objective of banks is the following:

$$\max_{i,l,m,b,a} \mathbb{E}\left[(iR_i + lR_l - m(r_m + c) - br_b - ar_a)\,\mathbb{1}_{[l \geq f_s]}\right]$$
$$\text{subject to } i + l = m + b + a$$

where i is illiquid assets; l is liquid assets; m is money-like claims; b is long-term funding from outside capital market; a is long-term funding from other banks; R_i is the return of illiquid assets; R_l is the return of liquid assets; r_m is the interest rate of money-like claims; r_b is the interest rate of the long-term funding from outside capital market; r_a is the interest rate of long-term funding market among banks; $\mathbb{1}_{[l \geq f_s]}$ is an indicator function that takes a value of one if the bank has enough liquidity to cover the unexpected withdrawals f_s in state s, and zero otherwise.

3.3 Equilibrium

Banks take the equilibrium liquidity premium, y, as given, and choose their balance sheets accordingly. The equilibrium is defined as optimal choices of banks, i, l, m, a, b, and an equilibrium liquidity premium, y, such that the supply of short-term money-like claims equals to the demand

$$\int (m(c) - l(c))dc + m_g = \phi(y_0 - y)$$

and the equilibrium interest rate of the long-term funding market among banks, r_a, such that the supply equals to the demand

$$\int a(c)dc = 0.$$

We use liquidity mismatch index proposed by Bai, Krishnamurthy, and Weymuller (2018) to measure the liquidity risk in the model economy. This measure captures the aggregate liquidity shortage of the banking system in a stress scenario in which money-like claims suffer from early withdraw before the illiquid assets mature:

$$LMI = \Delta \int m(c)dc - \int l(c)dc.$$

3.4 Equilibrium without Liquidity Regulation

We first consider a laissez-faire economy in which banks do not face liquidity regulation. In the short-term funding market, only banks with issuance cost c below the equilibrium liquidity premium y issues money-like claims:

$$m(c) = \begin{cases} 1+\alpha, & \text{if } c < y \\ 0, & \text{if } c \geq y. \end{cases}$$

Because the issuance cost is uniformly distributed between 0 and 1. The total amount of money-like claims issued by the banking system is

$$\int m(c)dc = (1+\alpha)y$$

Banks with issuance cost c below the equilibrium liquidity premium y lend α units of long-term funding. Banks with issuance cost c above the equilibrium liquidity premium y borrow $\frac{y}{1-y}\alpha$ units of long-term funding from other banks and finance the remaining balance sheets with long-term funding from the capital market outside of the banking system:

$$a(c) = \begin{cases} -\alpha, & \text{if } c < y \\ \frac{y}{1-y}\alpha, & \text{if } c \geq y. \end{cases}$$

Given the liability structure, each bank chooses how much liquidity buffer to hold. For banks which do not issue money-like claims, they have no need to hold liquid assets because they face no early withdrawal. For banks which do have money-like claims, however, they face the following trade-off: if they hold liquid buffer of Δ, they will earn lower returns on average but survive the bad state; if they do not hold liquid buffer, then they will earn higher returns in the good state but fail in the bad state. If the probability of the bad state, p, is low enough, then even banks financed by money-like claims will hold 0 liquidity buffer.

Proposition 1. *In the laissez-faire economy, if the equilibrium liquidity premium is higher than the following threshold,*

$$y^* \geq \frac{pR_i}{\Delta(1+\alpha)},$$

then banks hold no liquidity buffer

$$l^*(c) = 0,$$

and the aggregate amount of liquidity mismatch is

$$LMI^* = \Delta \frac{1+\alpha}{1+\alpha+\phi}(\phi y_0 - m_g)$$

Proof: See Appendix.

In the laissez-faire equilibrium, bank runs occur in the bad state of the world. However, this equilibrium may not be socially optimal because the social externality of bank runs could be quite large and it would socially optimal to prevent runs in both states. The market failure that leads to this inefficient outcome is that banks' shareholders do not internalize the social cost of bank run because they are protected by limited liability in the event of bankruptcy. Therefore, the privately optimal liquidity buffer is too low to prevent socially costly bank runs in the bad state of the world. In another words, there is excessive liquidity transformation in the economy.

One way to address the liquidity crisis is that the government can provide emergency lending to banks which experience liquidity problems. However, as Stein (2013) argues, using government emergency lending to address bank runs may be socially costly. First, in practice, it is often impossible to differentiate illiquid banks from insolvent banks, so lending to troubled banks may expose taxpayers to large credit risks. Second, using government emergency lending to support banks when they get into trouble can lead to moral

hazard problems. If the social costs of providing emergency government lending is high, then it may be socially optimal to requires banks to hold a liquidity buffer by themselves to meet unexpected withdrawals.

3.5 Equilibrium with Liquidity Regulation

A high social cost of government emergency lending motivates preventative liquidity regulation, which requires banks to hold liquidity buffers ex ante to reduce their reliance on government funding. Regulators can require financial institutions to hold as least ρ units of liquid assets per unit of money-like claims issued at date 0. ρ is also known as the "run-off rate" in LCR. We first consider the equilibrium where all banks are subject to the same liquidity regulation. The problem of banks is the following:

$$l \geq \rho m$$

where ρ is the required liquidity ratio for banks. Note that the bank loans a are long term, so banks do not need to hold liquidity buffer to back them.

Liquidity regulation essentially increases the effective funding cost of short-term money-like claims. For each unit of money-like claims, banks need to hold ρ units of liquid assets, which imposes an opportunity cost of ρy. Therefore, the effective funding cost of money-like claims becomes:

$$\hat{r}_m = r_m + \rho y. \tag{2}$$

This opportunity cost of holding liquid assets reduces the cost advantage of money-like claims from y before the regulation to $y(1-\rho)$ after the regulation. This makes money-like claims less attractive. As a result, fewer banks issue money-like claims:

$$m(c) = \begin{cases} 1+\alpha, & \text{if } c < y(1-\rho) \\ 0, & \text{if } c \geq y(1-\rho). \end{cases}$$

Proposition 2. *If all banks are subject to the same liquidity regulation, then a tightening in liquidity requirement reduces the aggregate liquidity mismatch:*

$$\frac{\partial LMI^*}{\partial \rho} < 0. \tag{3}$$

Proof: See Appendix.

3.6 Equilibrium with Uneven Liquidity Regulation

Suppose there is a fraction μ of banks which are not subject to liquidity regulation. We define this set of banks as $\mathbb{U}$. For simplicity, assume the issuance costs of money-like claims for unregulated banks follow the same uniform distribution. Liquidity regulation reduce the incentive for regulated banks to issue money-like claims and only banks with issuance cost $c < y(1-\rho)$ will issue money-like claims. However, unregulated banks with $c < y$ can issue money-like claims and lend to regulated banks with $c > y(1-\rho)$. We define A as the amount of loans that unregulated banks lend to regulated banks

$$A = \int_{c \in \mathbb{U}} |a| \mathbb{1}_{[c \leq y]} dc = \mu \alpha y.$$

Proposition 3. *Tightening liquidity regulation increases unregulated banks' lending to regulated banks,*

$$\frac{\partial A^*}{\partial \rho} > 0.$$

Proof: See Appendix.

Our final question is how the presence of unregulated banks affects the effectiveness of liquidity regulation to reduce the aggregate liquidity mismatch. Formally, we have

Proposition 4. *The effectiveness of liquidity regulation is decreasing to the fraction of the unregulated banks.*

$$\frac{\partial}{\partial \mu} \left(\frac{\partial LMI^*}{\partial \rho} \right) > 0.$$

Proof: See Appendix.

Figure 6 presents the main results of the model. Panel (a) is the aggregate supply and demand of money-like claims. Panel (b) and (c) are the supply of money-like claims from regulated and unregulated banks, respectively. A tightening in liquidity regulation decreases the supply from regulated banks, which drives up the equilibrium liquidity premium. An increase in the liquidity premium, however, increase the supply of money-like claims by unregulated banks. Since unregulated banks are not required to hold liquidity buffers to back their money-like claims, an increase in their issuance of money-like claims

compromises the effectiveness of liquidity regulation to reduce the aggregate liquidity mismatch.

4 Empirical Evidence

In this section, we will empirically test three model predictions. We first describe the data. Then, we test whether post-crisis liquidity regulation has caused the expansion of banks' borrowing from the FHLBs. Next, we discuss alternative explanations of our findings. Finally, we discuss the implications of our findings for financial stability.

4.1 Data

We combine several data sources to analyze the linkages between commercial banks and FHLBs. The summary statistics are reported in Table 1. We first use the Call Reports and FR Y-9C for balance sheet information of U.S. banks and bank-holding companies (BHCs) from 2011 to 2017. Because the LCR applies to both bank level and BHC level and some banks belong to BHCs and some do not, we use the highest level ownership as the unit of observation. In other words, if a bank is a standalone bank, we include it as an observation; if a bank belongs to a BHC as a subsidiary, we only include the BHC but not the subsidiary bank.[8] In the following discussion, we simply call our observations as banks. We follow the methodology of Hong, Huang, and Wu (2014) to calculate the liquidity coverage ratio for banks. The average LCR is 1.08 but there is considerable heterogeneity across banks. On average, 2.5% of the balance sheets is financed by FHLB advances.

Second, we manually compile a unique data set on the balance sheets of the FHLBs. We collect the balance sheets and income statements from SEC filings with quarterly frequency. The FHLBs are highly levered. The average capital ratio is 5%. The FHLBs issue both long-term and short-term debt to capital markets. On the asset side, 55% of the total assets of the FHLBs are advances, which are secured loans that the FHLBs make to member financial institutions. The maturity ranges from overnight to 30 years. Finally, the LCR-bank ratio is the fraction of member commercial banks that are subject to the

[8]The result is robust if we use only bank-level or BHC-level data.

LCR weighed by assets. For an average FHLB, 30% of the their member commercial banks are subject to the LCR requirements.

We obtain information on the collateral pledged by member banks to the FHLBs from Federal Housing Finance Agency. Most of the collateral are mortgage related. On average, 70% of the collateral is mortgage loans, 14% is mortgage-backed securities (MBS), 15% is other real estate related collateral (ORERC) is 16%, community financial institution (CFI) loans is 1%. Most of these collaterals are highly illiquid, and are generally not accepted as collateral in the private repo market.

We complement the balance sheet data of the FHLBs with pricing data collected from the websites of FHLB Boston, FHLB Dallas, FHLB Des Moines, the FHLB Office of Finance, and the Mergent Fixed Income Securities Database (FISD). We obtain benchmark yields of money market instruments from the FRED database of the Federal Reserve Bank of St. Louis. Finally, we obtains the maturity composition of the FHLB debts held by MMFs using iMoneyNet.

4.2 Methodology

We try to identify the causal effect of the LCR on banks' usage of FHLB advances using a difference-in-differences (DID) specification:

$$Advances_{i,t} = \beta Post_t * Exposure_i + \gamma X_{i,t} + \tau_t + \tau_i + \epsilon_{i,t}.$$

where $Advances_{i,t}$ is the amount of FHLB advances borrowed by bank i at quarter t normalized by the total assets of this bank; $Post_t$ is a dummy variable which equals to 1 after 2013Q1, the quarter in which the Basel Committee finalized the LCR, and 0 otherwise;[9] $Exposure_i$ is the predetermined exposure of bank i to the LCR. We construct three different measures of exposure: (1) *Full-LCR*, a dummy variable which equals to 1 if a bank or a bank holding company is subject to the full LCR requirement; (2) *Modified-LCR*, a dummy variable which equals to 1 if a bank or a bank holding company is subject to the modified LCR requirement; (3) *LCR Gap*, a continuous variable which measures the distance for a bank to meet its LCR requirement. Notice that the *LCR Gap* is constructed using banks' balance sheets before the liquidity regulation was introduced. Therefore, this exposure is not endogenously chosen by banks in response to liquidity regulation.

[9]We consider alternative event dates in the Online Appendix and results are robust.

The vector of control variable, $X_{i,t}$, includes lagged log assets, lagged deposit ratios, and lagged capital ratio. We also include bank fixed effects to absorb time-invariant bank characteristics, time fixed effects to absorb aggregate economic shocks. The sample period starts from 2011Q1 to exclude the influence of the crisis, and ends in 2017Q4. The standard errors are clustered at both bank and time level.

4.3 Parallel Trends Assumption

We first verify the parallel trend assumption is satisfied for the DID research design. Panel A of Figure 7 plots the advances normalized by assets for the treatment group and the control group. Consistent with our prior, before the regulation, the non-LCR banks borrow significantly more advance compared to the LCR banks. Despite the difference in the level, importantly, the advances of the full-LCR banks and the non-LCR banks move in tandem, which is consistent with the parallel trend assumption. After the regulation, the advances of the treatment group substantially increases while the advances of the control group stay roughly the same. This suggests that the liquidity regulation induces full-LCR banks to increase their borrowing from the FHLBs. Overall, the average full-LCR banks have increased their borrowing from the FHLBs by around 1.25% of their assets.

4.4 Banks' Borrowing from the FHLBs

Table 4 presents the estimation results using the discrete variables, *Full-LCR* and *Modified-LCR*, as measures of LCR exposure. We find that full-LCR banks have significantly increased their advances by around 2% of the total assets during the post period compared to the control group. The results are robust to including bank fixed effects and time fixed effects. The effect on the modified-LCR banks are smaller: they increase their advances by around 1%. This reflects the fact that their liquidity requirements are less stringent. We multiply the estimated coefficients with the total amount of assets of these two groups of banks and find that these two estimates imply that the LCR has increase banks' borrowing from the FHLBs by $200 billion as of 2017. The increase in advances borrowing from LCR-banks accounts for more than 50% of the expansion of the FHLBs from 2013 to 2017. We also examine the raw changes in the advances of these two groups of banks and find the magnitude is quite similar.

One potential concern on the results of Table 4 is that LCR banks are quite different from the non-LCR banks. For instance, it is possible that some non-LCR banks do not have much mortgage lending business. Therefore, they do not have collateral to borrow from the FHLBs even if they want to do so. To alleviate this concern, in Table 5, we use the the fraction of mortgage loans in the total assets before the regulation to construct a matched sample. We also match deposit ratio, capital ratio, and liquidity ratio. We repeat our analysis in the match sample and find our results are robust to this alternative specification.

To further sharpen our identification, we use the gap to meet liquidity requirements to measure banks' exposure to the LCR. As discussed above, this measure is constructed using banks' balance sheets before the introduction of the LCR. Therefore, it is unlikely to be endogenously chosen by banks in response to the regulation. Table 6 presents the results. We find that banks which are further away to meet liquidity requirement ends up borrowing more from the FHLBs, consistent with our hypothesis. The results are robust to including bank fixed effects and time fixed effects.

4.5 Why did LCR increase banks' borrowing from the FHLBs?

So far we have documented that post-crisis liquidity has led to an expansion of banks' borrowing from the FHLBs. In this section, we investigate the underlying mechanism which drove this unintended consequence.

Our model shows that if some intermediaries are subject to liquidity regulation but some are not, then there exists an arbitrage opportunity between the regulated and the unregulated intermediaries. The FHLBs are not subject the LCR because they are regulated as GSEs instead of as commercial banks. As shown in Panel B of Table 1, the FHLBs hold very little liquidity buffer. The average cash holding is around 2.4% of the total assets in the whole sample and 2.9% for the post LCR period.[10] Therefore, the FHLBs can issue short-term money-like claims and lend to banks at longer maturity. This transaction effectively allows banks to issue short-term debt through the FHLBs. This evidence is consistent with the predictions of our model.

[10]Only a small fraction of the FHLBs' investment portfolio is Treasury securities. Treasury securities only account for 0.6% of the total assets as of 2017.

Informed by our model, we compare the effective funding costs for banks to issue short-term debt directly with the effective funding costs for banks and the FHLBs to issue money-like claims. As shown in equation 2 of our model, the effective funding costs consists of the direct interest costs and the opportunity costs of holding liquid assets. In the baseline model, banks only need to hold liquidity buffers for short-term funding but not long-term funding. In reality, however, banks also need to hold liquidity buffers the fraction of long-term funding which matures within the next 30 days. In this section, we generalize the effective funding cost formula for fundings with an arbitrary maturity τ:

$$\hat{r}_b^\tau = r_b^\tau + \frac{30}{\max[\tau, 30]}\rho y \tag{4}$$

where r_b^τ is the direct interest costs of borrowing with maturity τ days; $\frac{30}{\max[\tau,30]}$ is the fraction of the debt that matures within the next 30 days; ρ is the run-off rates; y is the liquidity premium. We measure the direct funding costs of banks using the spreads of 1-month asset-backed commercial paper (ABCP) yields over 1-month Treasury yields.[11] We measure the direct finding costs of the FHLBs using the spreads of FHLB discount note yield over 1-month Treasury yields. We measure the liquid premium y using the difference between AAA bond yields and the Treasury yield following Krishnamurthy and Vissing-Jorgensen (2012). Figure 8 shows the results. Before the LCR, it would not make sense for banks to borrow through the FHLBs because the effective funding costs for banks to issue short-term debt were quite low.[12] The FHLBs have some funding advantages compared to banks due to their GSE status but the arbitrage profits for banks to borrow through the FHLBs is closed to zero once we take into account the operating expenses of the FHLBs. After the LCR, however, the spreads between the effective short-term funding costs between banks and the FHLBs widened to 80-120 bps, which creates an arbitrage opportunity in which the FHLBs can issue money-like claims and lend to banks in longer-term.

To verify that the LCR has indeed made it relatively cheaper for banks to borrow from the FHLBs, we compare the effective costs of borrowing from the capital markets versus to the effective costs of borrowing from the FHLBs, which is measured by the FHLB advance

[11]The reason why we use the ABCP spreads is that the FHLB advances are secured lending. The result still holds if we use other measure of other measures of wholesale funding costs such as LIBOR. Note that the ABCP spreads are unavailable for the 12-month maturity. We impute this spread using the LIBOR rates adjusting for the spreads between secured and unsecured funding.

[12]Some small banks still borrowed from the FHLBs because their costs to access the wholesale funding market were quite high.

rates plus an opportunity cost of holding liquid assets. We construct the effective costs for maturities ranging from 1 month to 12 months.

Figure 9 presents the results. Before the LCR, banks' funding costs are increasing to maturities because short-term money-like claims generate a liquidity premium for investors. Furthermore, at the very short term, it is cheaper for banks to borrow from the capital markets than to borrow from the FHLBs. Therefore, before the LCR, banks did not use much of the FHLB advances and preferred to issue ultra-short-term debt directly to the market. After the LCR, banks face the additional opportunity costs of holding liquid assets. The opportunity costs is higher for the short-term funding because a larger fraction of the funding will mature in the next 30 days. This gives incentive for banks to term out their funding. Note that at longer maturity, the effective funding costs of borrowing from the FHLBs become lower than those of borrowing from the private market. Therefore, banks increasingly borrow term funding from the FHLBs after the LCR.

The above results show that the uneven liquidity regulation between banks and the FHLBs creates an arbitrage opportunity. However, the FHLBs are not the only financial intermediaries that are not subject to liquidity requirements. Why did banks seem to mainly increase their borrowing from the FHLBs? We argue that three institutional features of the FHLBs make them an attractive vehicle to conduct regulatory arbitrage. First, as shown in equation 4, the amount of liquidity buffers that banks need to hold not only depends on the maturities of the funding, it also depends on "run-off rates", which measure the perceived stability of the funding source. According to the current LCR, the FHLB advances receive a favorable run-off rate of 25%. In contrast, other types of wholesale funding receive a run-off rate of 100%. This makes the FHLBs a more attractive source of funding. Note that the favorable run-off rate alone would not lead to the regulatory arbitrage. If the FHLBs themselves are subject to the LCR, then it still would not be profitable for the FHLBs to issue money-like claims and lend to banks. Second, other types of counterparty may run into capital constraint if they issue money-like claims and then lend to banks. However, the FHLBs are able to elastically grow their balance sheets because of an unique institutional feature called "activity-based capital". Specifically, when banks borrow from the FHLBs, they need to contribute additional capital to the FHLBs, which allows the FHLBs to relax their capital constraints when they lend to banks. Finally, the FHLBs enjoy implicit government guarantees on their debt which further reduce their funding costs.

4.6 Money-like Claims Issued by the FHLBs

To finance the advance lending to banks, the FHLBs have increased their issuance of money-like claims. As shown in Figure 3 the amount of short-term short-term money-like claims issued by the FHLBs has surpassed that of banks in 2016. Given the total assets of the FHLBs is less than 7% of the total assets of banks, the magnitude of money-like claims issued by the FHLBs is truly striking.

To provide causal evidence that the increase in the FHLBs' short-term money-like claims is indeed driven by the LCR, we take advantage of an unique institutional feature of the FHLB system. The FHLB system divides into 12 (now 11) districts and commercial banks can only borrow from the FHLB from the district where banks are chartered.[13] This leads to cross-section variation in the exposure to the LCR across FHLBs. If there are more LCR-banks in an FHLB district, then this FHLB is likely to face more demand for advances. To finance these advances, this FHLB may issue more short-term money-like claims. Formally, we estimate the following regression:

$$\textit{Short-term debt}_{i,t} = \beta \textit{Post}_t * \text{LCR-bank ratio}_{i,t} + \tau_t + \tau_i + \epsilon_{i,t},$$

where $\textit{Short-term debt}_{i,t}$ is the short-term money-like claims issued by FHLB i in quarter t normalized by lagged assets; $\textit{Post}_t$ is a dummy variable which equals to 1 after 2013Q1; LCR-bank ratio$_{i,t}$ is the fraction of member commercial banks that are subject to the LCR weighted by assets; τ_t and τ_i are time and FHLB fixed effects, respectively.

The result is presented in Table 8. Consistent with our hypothesis, FHLBs which are more exposed the LCR have significantly increased their issuance of short-term money-like claims. The economic magnitude is large as well. The LCR increases the issuance of the short-term money-like claims by 2.1% of the assets for an FHLB which has the sample average LCR exposure of 0.3.[14] This result is consistent with our model prediction that a tightening in liquidity regulation may drive the issuance of short-term money-like claims from the regulated banks to the unregulated FHLBs. As a result, the effectiveness of the liquidity regulation to reduce aggregate liquidity mismatch may be compromised.

[13] If a bank-holding company has multiple subsidiary banks chartered in multiple FHLB districts, it is possible that it can borrow from multiple FHLBs. To control for this possibility, we assign subsidiary banks' assets to regional FHLBs based on where the location of the subsidiaries instead of the location of the headquarters of their bank-holding companies.

[14] The treatment effect for an FHLB with LCR exposure of 1 is 7%. The sample average LCR exposure is 0.3. Therefore, the treatment effect for an FHLB with average LCR exposure is 0.3×7%=2.1%.

4.7 Implications for Financial Stability

This section discusses the implications of our findings for financial stability. We first evaluate whether banks' borrowing from the FHLBs has compromised the efficacy of liquidity regulation to limit aggregate liquidity mismatch. Then we evaluate the impact of FHLB advances on the FDIC. Finally, we examine how the FHLBs' lending concentration has changed following liquidity regulation.

4.7.1 Aggregate liquidity mismatch

An important goal of liquidity regulation is to reduce the aggregate liquidity mismatch in the banking system. On the surface, post-crisis liquidity regulation seems to have achieved this goal: banks hold more HQLAs and issue fewer money-like claims. As a result, the liquidity ratios of banks have substantially improved as shown in Figure 1. However, as shown in Section 4.6, some of the liquidity transformation has shifted into the FHLBs. This outcome compromises the effectiveness of the liquidity regulation to reduce aggregate liquidity mismatch.

4.7.2 Liquidity risks of the FHLBs

As the FHLBs issue more short-term money-like claims, liquidity risk borne by the FHLBs may have increased. As shown in Panel B of Table 1, the FHLBs hold very little liquidity buffers: cash and Treasury securities only accounts for 3% of the assets. Most of the assets are illiquid investments or advances backed by highly illiquid collateral.[15] In contrast, the liabilities of the FHLBs mainly consist of short-term money-like claims. As shown in Figure 4, 50% of the FHLB balance sheets is financed by ultra short-term discount notes from MMFs with an average maturity of less than 40 days as of 2017. Furthermore, because the FHLBs are regulated as GSEs instead of banks, they are ineligible to borrow from the Federal Reserve Bank's discount window, nor do they have daylight overdraft privileges at a Federal Reserve Bank. Therefore, the same amount of liquidity mismatch would have greater impacts on the FHLBs than banks.

Liquidity risks not only affects the FHLBs, it may spillover to banks as well. Consider the following hypothetical scenario: if there is unexpected shock that triggers short-term

[15]The collateral composition of the FHLB advances is shown in Panel C of Table 1.

creditors to withdraw their funding to MMFs, MMFs will be forced to withdraw funding to the FHLBs. The FHLBs in turn will be forced to withdraw funding to banks. Banks will have significantly less liquidity to meet the withdrawals of other creditors. There are historical episodes that resemble the scenario described above. Ashcraft, Bech, and Frame (2010) document that in the first half of 2017, the FHLBs provided substantial amount of emergency funding to troubled banks acting as a "lender of next-to-last resort." However, following heightened concerns about the financial health of Fannie Mae and Freddie Mac during the summer of 2008, the FHLBs found themselves "guilty by association" and saw their borrowing costs rise, which forced them to shrink their lending to banks. Were similar events to happen, the unraveling could be more severe because now the FHLBs rely on short-term debt more heavily than in the previous episode.

4.7.3 Lending Concentration of the FHLBs

During the 2007-09 financial crisis, some FHLBs provided concentrated funding to banks engaging in unsound business practices (Gaberlavage, 2017). The Seattle FHLB was forced to merge with the Des Moines FHLB, in part due to the failure of its largest member, Washington Mutual. The concentrated lending during the crisis attracted a lot of criticism and led to regulatory efforts to reduce the lending concentration and shift the lending to small- and medium-sized financial institutions.[16] However, as the liquidity regulations increase the demand for advances among the biggest banks, the lending of FHLBs may have become more concentrated in the largest banks, which bear the brunt of liquidity regulation.

We systematically examine the lending concentration of the FHLB system. Figure 10 plots the average Herfindahl-Hirschman Index (HHI) of the advance lending for the FHLB system over time.[17] We can see that since the roll-out of liquidity regulation in late 2012, lending concentration has risen rapidly, from 12% to 18%. To show that liquidity regulation is indeed driving the increase in concentration, we construct a counterfactual HHI assuming that LCR banks' advance-to-asset ratio stays constant after 2013Q1. We find the counterfactual HHI stays almost flat, suggesting the rise in concentration is indeed driven by LCR banks. This result is consistent with anecdotal evidence that some of the

[16]See "Reforming America's Housing Finance Market: A Report to Congress," by the Department of the Treasury and the Department of Housing Development and Urban Development.

[17]We match regional FHLBs to commercial banks based on the location of the headquarters of commercial banks.

largest banks dominate in some FHLBs' lending portfolios, an issue which raised concern among market participants.[18] Such development is inconsistent with the regulatory effort to reduce the FHLBs' lending concentration.

4.7.4 Externality to FDIC Deposit Insurance Fund

One may argue that the FHLBs may not suffer much losses from bank defaults because advances have a "super lien" status, which means that the FHLBs are able to claim the collateral before all the other creditors in the event of default. However, the "super lien" status only transfers the loss from the FHLBs to another government agency, the FDIC Deposit Insurance Fund because the more collateral claimed by the FHLBs, the lower liquidation value that the FDIC Deposit Insurance Fund can recover from failed banks. Furthermore, the "super lien" status does not insulate the FHLBs from liquidity risks because, unlike other types of secured lending such as repurchase agreements, the FHLB advances are backed by extremely illiquid collateral as shown in Panel C of Table 1. If the failures of the FHLBs' borrowers prompt the FHLBs' short-term creditors to withdraw their funding, the FHLBs would have to sell these collaterals at fire-sale discount to meet the redemptions. A small loss could easily bankrupt the FHLBs because of their thin capital cushion (5% as shown in Panel B of Table 1). Finally, an expansion of the FHLB advances also impose an externality for unsecured creditors as well. As banks' assets are pledged to the FHLBs, the recovery rate for unsecured creditors in the event of bank failure becomes lower, which make them more prone to run ex ante. This may compromise the effectiveness of liquidity regulation to deter bank runs.

4.7.5 Reliance on implicit government guarantee

Another important goal of liquidity regulation is to reduce the banking system's reliance on implicit government guarantees. However, with the balance sheets of the FHLBs rapidly expanding after the liquidity regulation and with liquidity and concentration risks creeping up, taxpayers may have greater exposure if the FHLBs run into trouble. To get a quantitative sense of magnitude of the subsidy from the taxpayers to the FHLBs, we estimate

[18]For instance, an article in American Banker on April 28, 2017, reported that Wells Fargo's borrowings accounted for nearly 59% of Des Moines FHLB's total advances at the end of 2017.

the following formula:

$$\text{Implicit subsidy} = \sum_{\tau}(\text{FHLB funding costs}^{\tau} - \text{Private funding costs}^{\tau}) \times \text{Debt outstanding}^{\tau}$$

where τ is the maturity of the debt issued by the FHLBs.

We first calculate the funding advantage of the FHLBs compared to private borrowers with highest credit rating. We find that the FHLBs enjoy a funding advantage of around 20–50 basis points compared to private borrowers with highest credit rating. Next, we multiply the funding advantage with the corresponding dollar amount of outstanding debt and then sum across maturities. We find that, by the end of 2017, the FHLBs received an annual transfer of $3.9 billion from taxpayers, which is a 38% increase from the level in 2012. These subsidies benefit banks in the form of low advance rates, which makes the FHLBs more attractive regulatory arbitrage vehicles.

One may argue that the implicit government guarantee on the FHLB debt is not necessarily bad because the FDIC also offers guarantee on banks' deposits. However, there are three distinctions between the two. First, banks need to pay a premium for the FDIC guarantee. In contrast, the implicit government guarantee on the FHLB is not priced. It is a pure transfer from taxpayers to the FHLBs and banks. Second, the premium that banks need to pay for the FDIC guarantee is increasing to banks' risk, which alleviates the moral hazard problem created by the guarantee. In contrast, the implicit government guarantee is unpriced. This may encourage moral hazard of the FHLBs because the funding costs of the FHLBs would remain low no matter what the FHLBs do so long as the market believes the government will bailout the FHLBs. Finally, the FDIC guarantee on bank deposits is explicit while the government guarantee on the FHLB debt is implicit. Were investors ever in doubt on this implicit promise, as what they did in the summer of 2008, the FHLBs could see their funding costs rising.

4.8 Alternative Explanations

In above discussion, we document that banks that are subject to the LCR have significantly increased their borrowing from the FHLBs. In this this section, we discuss alternative explanations for this result.

4.8.1 Capital regulation

One may worry that Basel III accord not only introduced new liquidity requirement, it also tightened the existing capital requirement. It is possible that banks use the borrowing from the FHLBs as a loss-absorbing capacity to meet the increased capital requirements. We argue that this alternative hypothesis is unlikely to explain our findings. According to the Basel III capital requirements, for any debt to be counted as loss-absorbing capacity, it has to be unsecured. However, banks' borrowing from the FHLB is 100% secured. Therefore, borrowing more from the FHLBs cannot help banks to improve their capital ratios or loss-absorbing capacity.

Relatedly, the US banking regulators have also installed the Supplementary Leverage Ratio (SLR) regulation which requires banks to maintain a certain amount of common equity capital relative to banks' total non-risk weighted assets. We argue the SLR is unlikely to drive banks to borrow advances from the FHLBs because the FHLB advances are not counted as tier 1 capital for banks. Therefore, banks cannot improve their SLR by swapping other types of liabilities with the FHLB advances.

4.8.2 Mark-to-market accounting

Another important regulatory change in Basel III introduced together with LCR is the mark-to-market accounting requirement for available-for-sale security holdings, which incentivizes banks to reclassify available-for-sale assets as held-to-maturity. Since this requirement mainly affected banks which were also subject to the LCR, one may worry that it may drive some of our empirical results. We argue that this is unlikely. First, conceptually, mark-to-market accounting requirements only affect banks' choices in the asset side. It is unclear how it affects banks' usage of the FHLB advances, which are on the liability side. Second, the LCR treats available-for-sale and held-to-maturity assets with the same liquidity weights. Therefore, banks cannot affect their liquidity ratios if they change the composition of available-for-sale and held-to-maturity assets.

4.8.3 Heterogeneous demand shock

Another possibility is that LCR banks experienced a positive demand shock for real estate loans in the post-LCR period. Therefore, they borrowed advances to lend to housing mar-

ket. It is difficult to test this alternative explanation by examining the *static* composition of banks' balance sheets in the cross section of banks because money is fungible. Instead, we examine the *dynamic* adjustment of the balance sheet within the same bank over time. The idea is the following. If a bank uses advances borrowed from the FHLBs to lend in the real estate market, we would expect to see the increase in the borrowing from the FHLBs is associated with a contemporaneous increase in the real estate lending. In contrast, if the bank simply hoards liquidity to meet liquidity requirement, then we would expect to see a contemporaneous increase in the HQLAs. Specifically, we estimate the following regression model

$$\Delta Advances_{i,t} = \beta_1 Post_t * \Delta HQLA_{i,t} + \beta_2 Post_t * \Delta Loans_{i,t} + \gamma X_{i,t} + \tau_t + \tau_i + \epsilon_{i,t},$$

where $\Delta Advances_{i,t}$ is the annual changes in FHLB advances borrowed by the bank i at quarter t; $Post_t$ is a dummy variable which equals to 1 after 2013Q1, the quarter in which the Basel Committee finalized the LCR, and 0 otherwise; $\Delta HQLA_{i,t}$ is the annual changes in HQLAs held by the bank; $\Delta Loans_{i,t}$ is the real estate loans held by the bank; $X_{i,t}$ is a vector of control variable including lagged log assets, lagged deposit ratios, and lagged capital ratio; τ_t and τ_i are time fixed effects and bank fixed effects, respectively.

We estimate the regression model separately for three groups of banks. Table 7 presents the result. We find that, before the liquidity regulation, banks' behaviors are similar across these three groups: an increase in the borrowing from FHLBs is usually associated with an increase in real estate lending. This suggests that banks' use of advances was consistent with the FHLBs' mandate to promote the housing market. However, banks' behavior started to diverge after the LCR: LCR banks became more likely to hoard the liquidity borrowed from the FHLBs instead of lending it out compared to non-LCR banks. This result suggests that the increase in the borrowing from FHLBs is not driven by an increase in loan demand because banks are not actually lend out the liquidity borrowed from the FHLBs.[19] This also suggest that the FHLBs' lending to big banks to meet the LCR requirements appears to be at odds with the main mission of the FHLB system, which is to promote housing and community investment.

[19]One possibility is that banks may hold the liquidity for some time and lend it out later. However, it is unclear why LCR-banks would increase the delay after the LCR relative to non-LCR banks.

4.8.4 Money market reform

The last part of our sample overlaps with 2016 money market reform. MMFs are important provider of short-term funding to banks and FHLBs. During the crisis, some funds took excessive credit and liquidity risk and "broke the buck", which triggered a massive run on the MMF industry. After the crisis, the SEC adopted a set of new liquidity regulations on MMFs, including redemption fees, redemption gates, and floating NAV requirements, with an implementation deadline of October 2016. The money market reform mainly affected the prime funds, which hold private debts; government funds are exempted from some of the most stringent regulations such as the floating NAV requirement.

The 2016 money market reform has resulted in a massive shift of deposits out of prime MMFs into government MMFs. The upper panel of Figure 11 plots the aggregate assets held by MMFs by fund types. The light area represents government funds, which can only hold treasury or agency debt. The dark area represents prime funds, which can also hold riskier private debt, such as bank commercial paper. The red vertical line indicates the implementation deadline of October 2016. We can see that almost $1 trillion deposits shifted from prime funds to government funds leading up to the implementation deadline.[20] As more deposits shifted from prime funds to government funds, the demand for government and agency debt may increase. Therefore, money market reform may lower the funding costs of the FHLBs, which further increases their lending to banks.

Although the 2016 money market reform may contribute to the overall increase in the *supply* of FHLB funding to banks, it cannot explain the increase in the *demand* of FHLB funding by the LCR banks relative to the non-LCR banks. In our difference-in-differences regressions, this supply effect should be absorbed by the time fixed effects thus would not drive our results. Furthermore, as shown in Figure 7, the increase in LCR banks' borrowing from the FHLBs occurred right after the introduction of the LCR in 2013. In contrast, the shifts of deposits from prime funds to government funds occurred mainly in 2016 before the compliance deadline of the money market reform. Therefore, it is unlikely that the money market reform has caused the increase in banks' borrowing from the FHLBs in 2013.

[20]The shift of deposits from prime funds to government funds is also documented in Cipriani, La Spada, and Mulder (2017) and Narajabad and Gissler (2018).

4.8.5 Quantitative easing

Finally, our sample overlaps with the third round of quantitative easing (QE3), which was announced on 13 September 2012. One may worry that QE may drive our results because it supplies more liquid reserves to the system. Although it is true that QE makes it easier for the banking system as whole to meet liquidity requirements by increasing the supply of liquid assets, the aggregate supply of liquid assets is absorbed by time fixed effects in our DID regression. If QE had driven our results, it had to have heterogeneous effects on banks' demand for the FHLB advances in a way that lines up with their cross-section exposure to LCR, which was highly unlikely. The parallel trends between banks that are exposed to LCR and banks that not exposed to LCR shown in Figure 7 further alleviate such concern. If anything, by increasing the aggregate supply of liquid assets, QE reduces banks' need to borrow from the FHLBs, which can only bias against finding any significant results.[21]

4.9 Potential Policy Remedies

In this section, we consider potential policy remedies to the unindented consequences documented above.

4.9.1 Tightening liquidity requirements on the FHLBs

We first consider a policy which tightens liquidity requirements on the FHLBs. As shown in our model, the key reason that leads to the liquidity arbitrage is the uneven liquidity requirements on banks and the FHLBs. The FHLBs are able to issue a large amount of short-term money-like claims without holding much liquidity buffer. Therefore, homogenizing liquidity requirements across banks and the FHLBs will help to reduce this regulatory arbitrage. Specifically, if the FHLBs are required to hold more liquidity buffer when they issue short-term money-like claims, they will shift toward costlier longer-term funding. This will increase the advance rates for banks and make it less profitable to conduct the regulatory arbitrage. The regulator of the FHLBs, the FHFA, has impose the new liquidity requirements on the FHLBs in July 2018, which leads to an increases

[21] Formally, in our model an increase in the aggregate supply in liquid assets will reduce the liquidity premium, y, which reduces the amount of advances borrowed in the equilibrium.

in the holding of US Treasury notes from 1.5% to 5.2% of the assets from 2018 to 2019 as shown in the FHLB Office of Finance 2019 consolidated report. However, it remains unclear whether the new liquidity requirements on the FHLBs is sufficient to eliminate the regulatory arbitrage.

Relatedly, banking regulators can also adjust the run-off rates of the FHLB advances when calculating liquidity ratios for banks. As we discussed above, the current LCR gives preferential run-off rates on the FHLB advances. By eliminating this preferential treatment, banking regulators can also reduce banks' incentive to use the FHLB advances for regulatory arbitrage.

Both policy proposals may help to suppress the regulatory arbitrage in the short run. However, in the long run, liquidity transformation may simply migrate to other unregulated intermediaries after we impose more stringent regulations on the FHLBs. Therefore, more regulation is unlikely to fundamentally resolve the risks associated with private liquidity transformation. The root of the problem is that the society needs a large stock of money-like assets. If the supply of government money-like assets does not saturate the demand, then a liquidity premium arises which induces the private sector to conduct liquidity transformation.

4.9.2 Contingent provision of money-like assets by the central bank

Given more liquidity regulation is unlikely to fundamentally eliminate the risks associated with private liquidity transformation, an alternative way to address this problem is to increase the government's supply of liquid assets such as central bank reserves. A higher supply of government liquid assets will significantly dampen the incentives for the private supply of short-term money-like claims, thereby reducing the risks of bank runs.

While the amount of government debt is largely determined by the fiscal policy, the central bank can elastically supply safe assets according to the liquidity demand. In fact, such a policy has been implemented in Australia. Specifically, the Australian central bank provides the committed liquidity facility which allows banks to obtain a loan commitment with a fee. The *unused* capacity of the loan commitment from the central bank is counted as HQLAs required by the LCR. Therefore, by giving the loan commitment, the central bank creates government liquid assets to the economy.

Figure 12 shows the aggregate supply and demand curves of money-like assets under the committed liquidity facility. The commitment fee acts as an upper bound for the equilibrium liquidity premium. If liquidity demand turns out to be quite low, the liquidity premium y will fall below the commitment fee k and banks will hold liquid assets to meet liquidity regulations. In contrast, if liquidity demand turns out to be quite high, then banks will pay the commitment fee to obtain the loan commitment from the CLF and issue money-like claims against it. The central bank can set the commitment fee to reflect the social cost of issuing money-like claims. Therefore, when banks purchase the loan commitment to back their money-like claims, they internalize the externality of issuing money-like claims.

The committed liquidity facility, by using a price-based mechanism, has an important advantages over the current quantity-based liquidity regulation in the US. Under the current liquidity regulation in the US, banks are forced to hold a certain amount of liquid assets regardless of the costs of doing so. If liquidity demand turns out to be extremely high, the quantity-based mechanism may lead to a high compliance cost for banks, which induce banks to conduct regulatory arbitrage. In contrast, the price-based mechanism put a cap on the compliance cost for banks. This advantage is important because liquidity demand turns to fluctuate over time. For instance, rates for overnight loans surged as high as 10% around the third quarter end of 2019 because of an unexpected spike in demand for liquidity.[22] Many blame liquidity regulation for freezing liquidity inside of the banking system.[23] Such volatility in liquidity premium would not have occurred in a price-based mechanism because the supply of government money-like assets would have automatically adjusted to the demand shock.

There are two important differences between the committed liquidity facility and the FHLBs. First, the cost of borrowing from FHLBs is subsidized by implicit government guarantee, which distorts banks' incentives. In contrast, under the committed liquidity facility, banks pay a Pigovian tax which forces banks to internalize the externality of liquidity transformation. Second, the FHLBs are highly levered private institutions. Therefore, their lending capacity depends on their ability to access capital markets, which could be unstable in times of crisis. In contrast, the committed liquidity facility is backed by the

[22]See the Oct 7th, 2019 article in the *Wall Street Journal* "Wild Swings in Repo Rates Raise Concerns About Bond Markets Liquidity".

[23]See the Sep 24th, 2019 article in the *American Bankers Association Banking Journal* "Bank Liquidity and the Repo Market".

central bank's ability to print money. Therefore, its the lending capacity is unlimited and stable.

5 Conclusion

In this paper, we provide a timely evaluation of the effects of liquidity regulation on the U.S. banking system. On the surface, we find that post-crisis liquidity regulation seems to achieve its goal: the liquidity ratio of the banking system has substantially improved since the introduction of the LCR. However, digging deeper, we find that banks have increasingly borrowed from the FHLBs as a way to circumvent liquidity requirements. This outcome is at odds with the goal of liquidity regulation to reduce aggregate liquidity mismatch and may create potential fragilities in the financial system. Using a model of liquidity regulation, we show that this phenomenon is driven by inconsistent liquidity requirements between banks and the FHLBs. To address this unintended consequence, more regulation may not be the best solution. Instead, increasing the supply of government money-like assets could help to alleviate the risks associated with private liquidity transformation.

References

Acharya, V. V., P. Schnabl, and G. Suarez, 2013, "Securitization without risk transfer," *Journal of Financial economics*, 107(3), 515–536.

Agarwal, S., D. Lucca, A. Seru, and F. Trebbi, 2014, "Inconsistent regulators: Evidence from banking," *The Quarterly Journal of Economics*, 129(2), 889–938.

Allen, F., and D. M. Gale, 2017, "How Should Bank Liquidity Be Regulated?," .

Anadu, K., and V. Baklanova, 2017, "The Intersection of US Money Market Mutual Fund Reforms, Bank Liquidity Requirements, and the Federal Home Loan Bank System," .

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

Bai, J., A. Krishnamurthy, and C.-H. Weymuller, 2018, "Measuring liquidity mismatch in the banking sector," *The Journal of Finance*, 73(1), 51–93.

Berger, A. N., L. K. Black, C. H. Bouwman, and J. Dlugosz, 2017, "Bank loan supply responses to Federal Reserve emergency liquidity facilities," *Journal of Financial Intermediation*, 32, 1–15.

Calomiris, C., F. Heider, and M. Hoerova, 2015, "A theory of bank liquidity requirements," .

Cipriani, M., G. La Spada, and P. Mulder, 2017, "Investors appetite for money-like assets: the money market fund industry after the 2014 regulatory reform," .

Diamond, D. W., and A. K. Kashyap, 2016, "Liquidity requirements, liquidity choice, and financial stability," in *Handbook of macroeconomics*. Elsevier, vol. 2, pp. 2263–2303.

Flannery, M., and S. Frame, 2006, "The federal home loan bank system: The" other" housing GSE," *Economic Review-Federal Reserve Bank of Atlanta*, 91(3), 33.

Gaberlavage, G., 2017, "The Federal Home Loan Bank System: A Chronological Review and Discussion of Key Issues," .

Gissler, S., and B. Narajabad, 2017, "The Increased Role of the Federal Home Loan Bank System in Funding Markets," *FEDS Notes*.

Gorton, G., and A. Metrick, 2012, "Securitized banking and the run on repo," *Journal of Financial economics*, 104(3), 425–451.

He, Z., A. Krishnamurthy, and K. Milbradt, 2019, "A model of safe asset determination," *American Economic Review*, 109(4), 1230–62.

Hoerova, M., C. Mendicino, K. Nikolov, G. Schepens, and S. Van den Heuvel, 2018, "Benefits and costs of liquidity regulation," .

Holmström, B., and J. Tirole, 1998, "Private and public supply of liquidity," *Journal of political Economy*, 106(1), 1–40.

——— , 2011, *Inside and outside liquidity*. MIT press.

Hong, H., J.-Z. Huang, and D. Wu, 2014, "The information content of Basel III liquidity risk measures," *Journal of Financial Stability*, 15, 91–111.

Irani, R. M., R. Iyer, R. R. Meisenzahl, and J.-L. Peydro, 2018, "The rise of shadow banking: Evidence from capital regulation," .

Kacperczyk, M. T., C. Perignon, and G. Vuillemey, 2017, "The private production of safe assets," .

Krishnamurthy, A., and A. Vissing-Jorgensen, 2012, "The aggregate demand for treasury debt," *Journal of Political Economy*, 120(2), 233–267.

Narajabad, B., and S. Gissler, 2018, "Supply of Private Safe Assets: Interplay of Shadow and Traditional Banks," .

Roberts, D., A. Sarkar, and O. Shachar, 2018, "Bank liquidity provision and Basel liquidity regulations," .

Stein, J., 2013, "Liquidity Regulation and Central Banking," *Speech at 2013 Credit Markets Symposium sponsored by the Federal Reserve Bank of Richmond*.

Sunderam, A., 2014, "Money creation and the shadow banking system," *The Review of Financial Studies*, 28(4), 939–977.

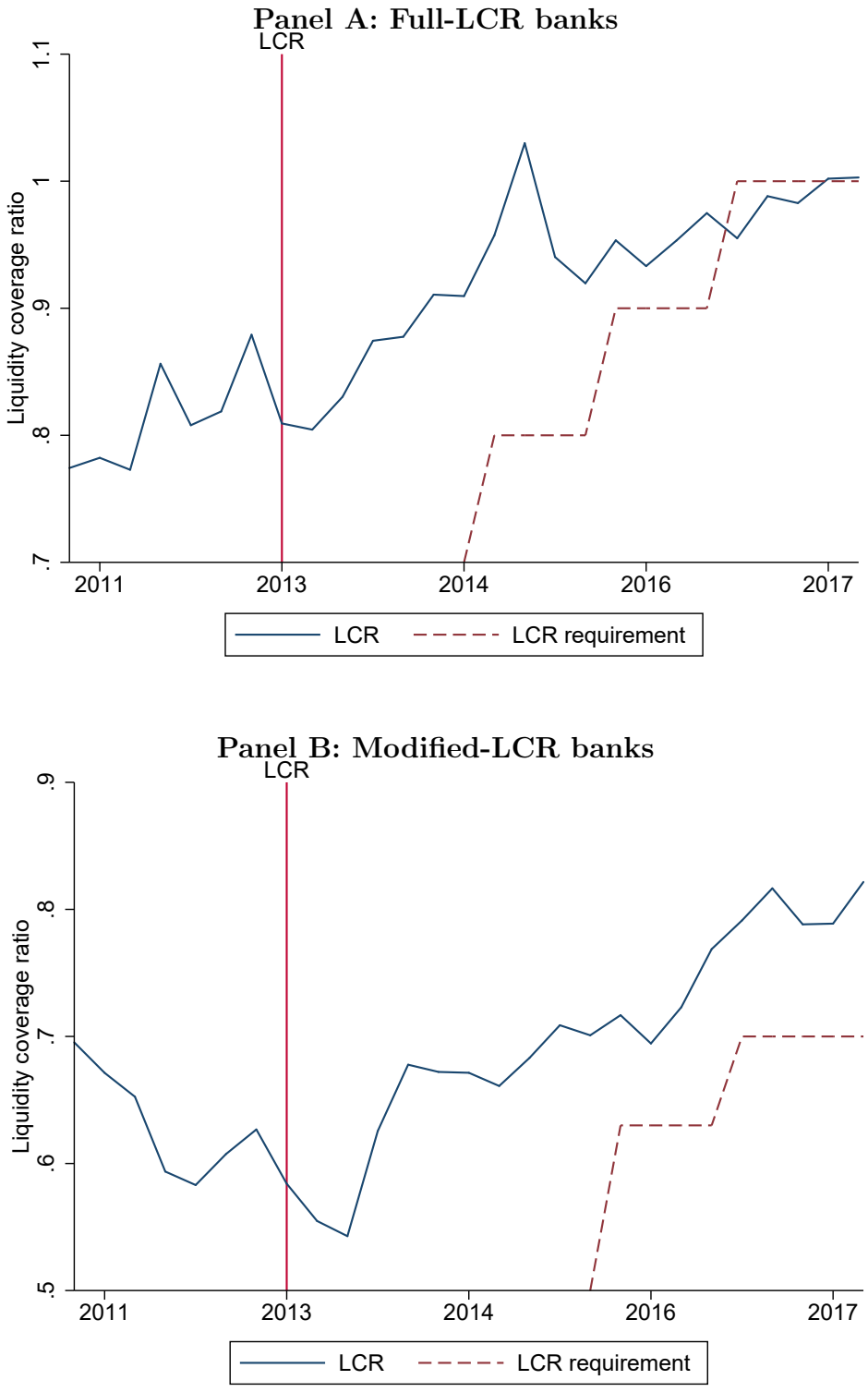


Figure 1: Liquidity Coverage Ratio of US Banks

This figure plot the average liquidity coverage ratios and the compliance requirements over time. The sample period is from 2011 to 2017. Data source: Call Report, FRY9C.

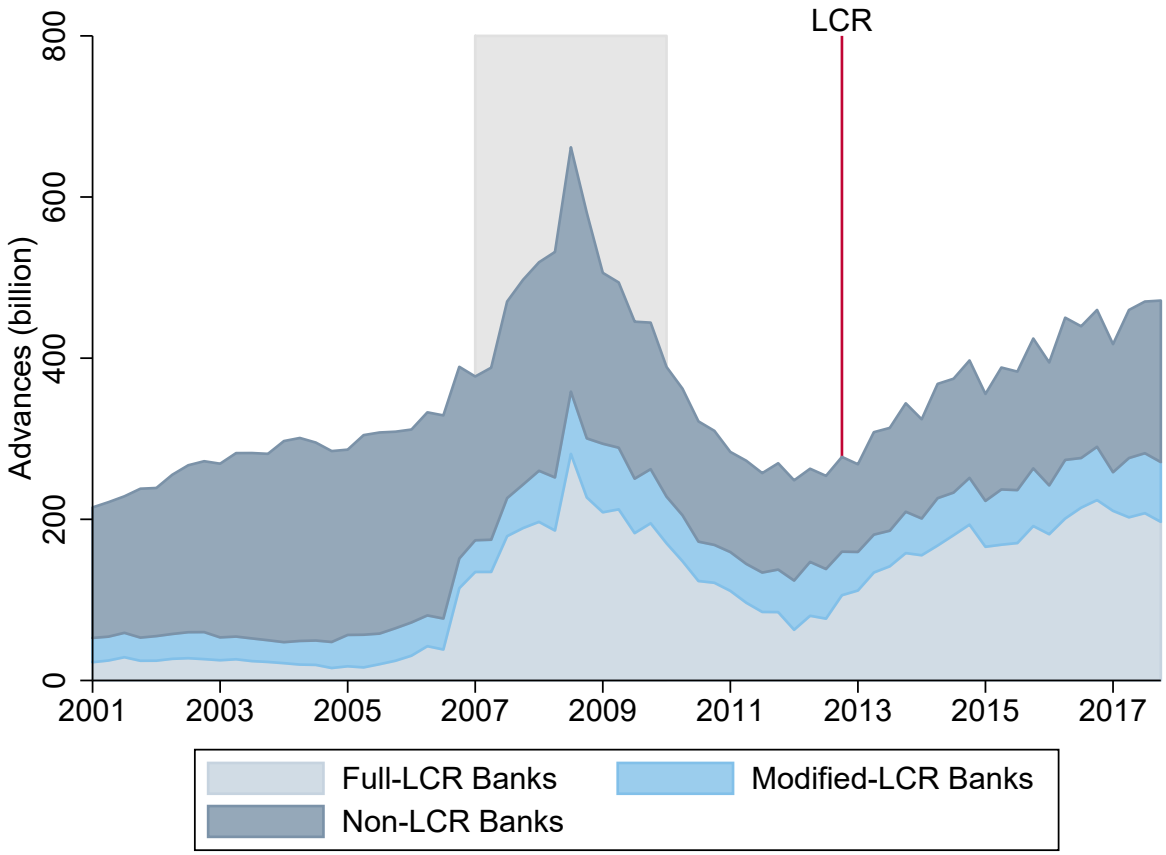


Figure 2: FHLB Advances Borrowed by Banks

This figure plots the FHLB advances borrowed by banks. The sample period is from 2001 to 2017. Data source: Call Report, FRY9C.

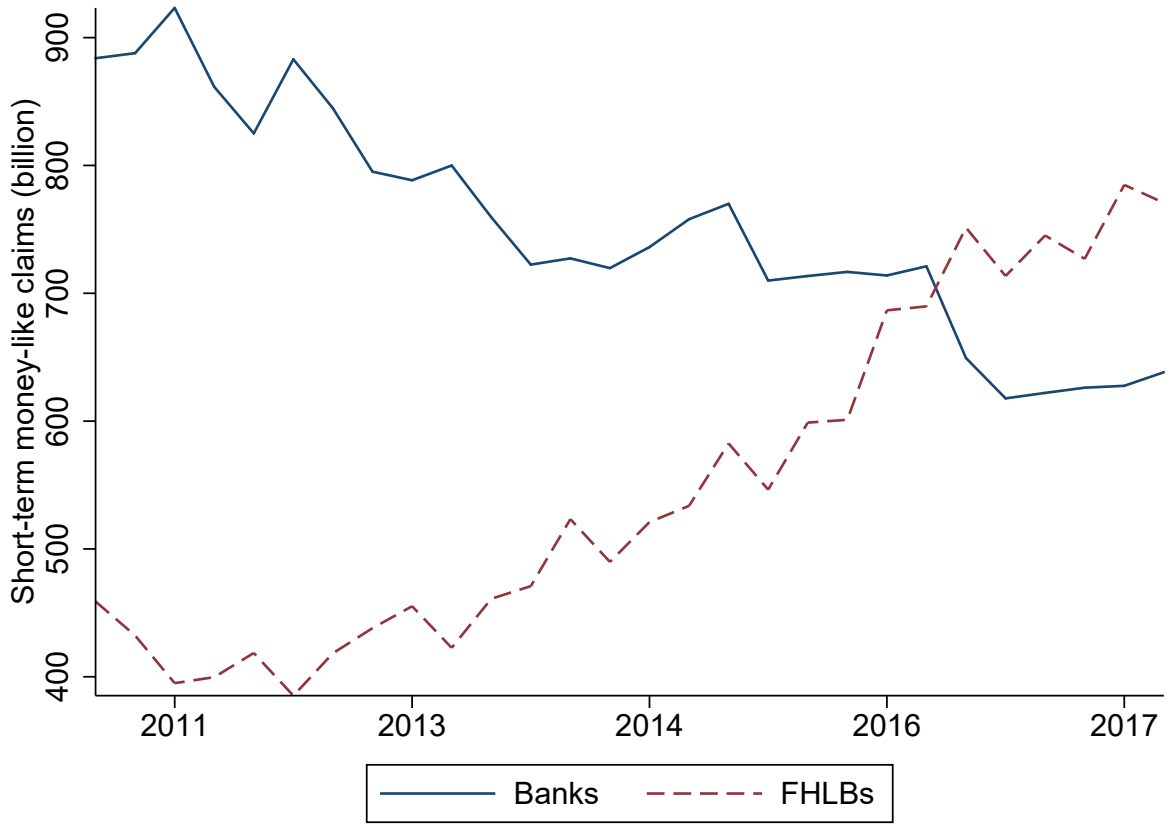


Figure 3: Short-term Money-like Claims

This figure plots the amount of short-term money-like claims issued by banks and the FHLBs. Short-term money-like claims issued by banks include federal funds purchased, repurchase agreements, trading liabilities, and uninsured brokered deposits with maturities less than one year. Short-term money-like claims issued by the FHLBs include FHLB discount notes and FHLB bonds with maturities less than one year. The sample period is from 2011 to 2017. Data source: Call Report, FRY9C.

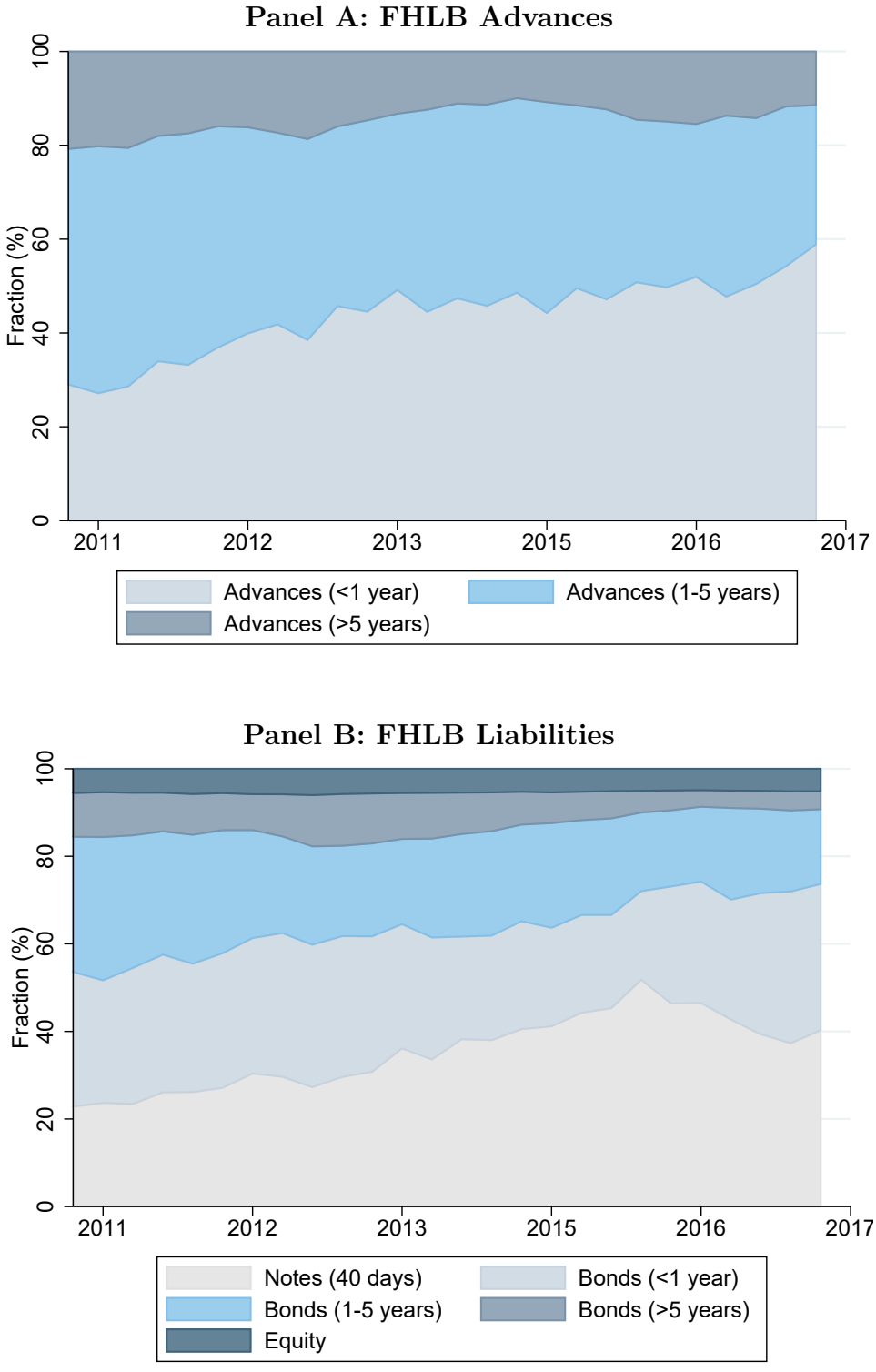


Figure 4: The Balance Sheets of the FHLB System

This figure plots the maturity composition of the FHLB balance sheets from 2011 to 2017. Panel A is the FHLBs advances and Panel B is liabilities. Data source: 10-K filings of FHLBs, iMoneyNet.

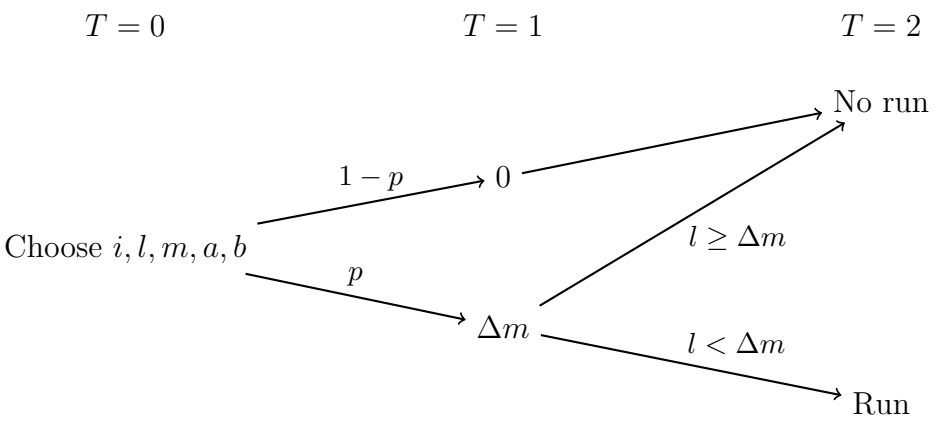


Figure 5: Timeline of the Model

This figure plots the timeline of the model. i is illiquid assets. $R_i - R_l$ is liquid assets. m is short-term money-like claims. b is long-term funding from private capital market. a is FHLB advances. Δ is the fraction of short-term creditors who withdraw their funding early at the bad state, which occurs with probability p.

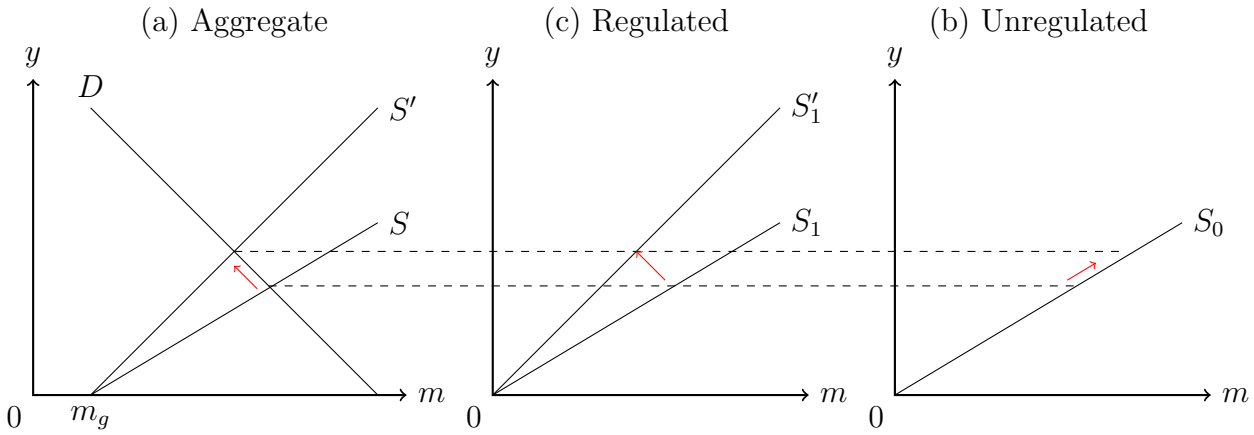


Figure 6: Demand and Supply of Money-like Assets

This figure plots the demand and supply of money-like assets. Panel (a) is the aggregate supply and demand. Panel (b) and (c) are the supply money-like claims from regulated and unregulated banks, respectively.

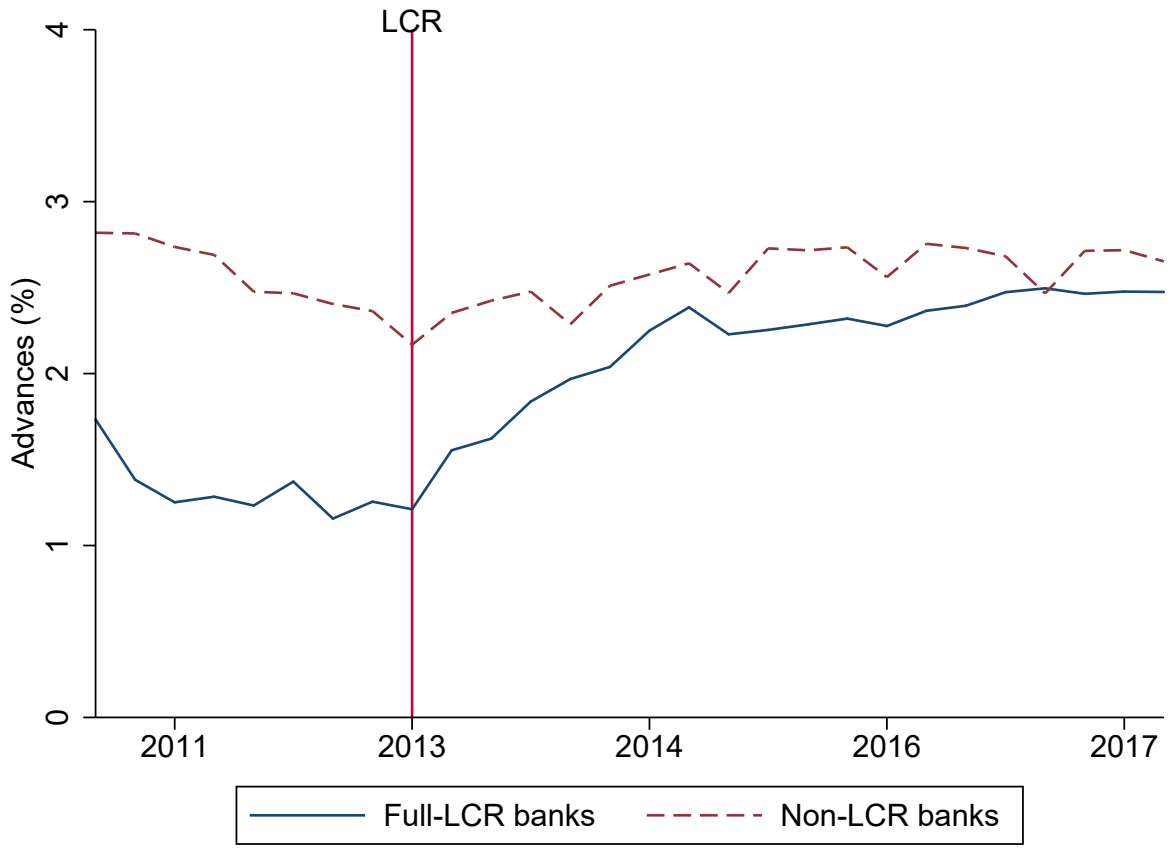


Figure 7: FHLB Advances of Full-LCR Banks vs. Non-LCR Banks
This figure plots the FHLB advances of US banks over assets. The solid line shows the full-LCR banks. The dashed line shows the non-LCR banks. The sample period is from 2011 to 2017. Data source: Call Report, FRY9C.

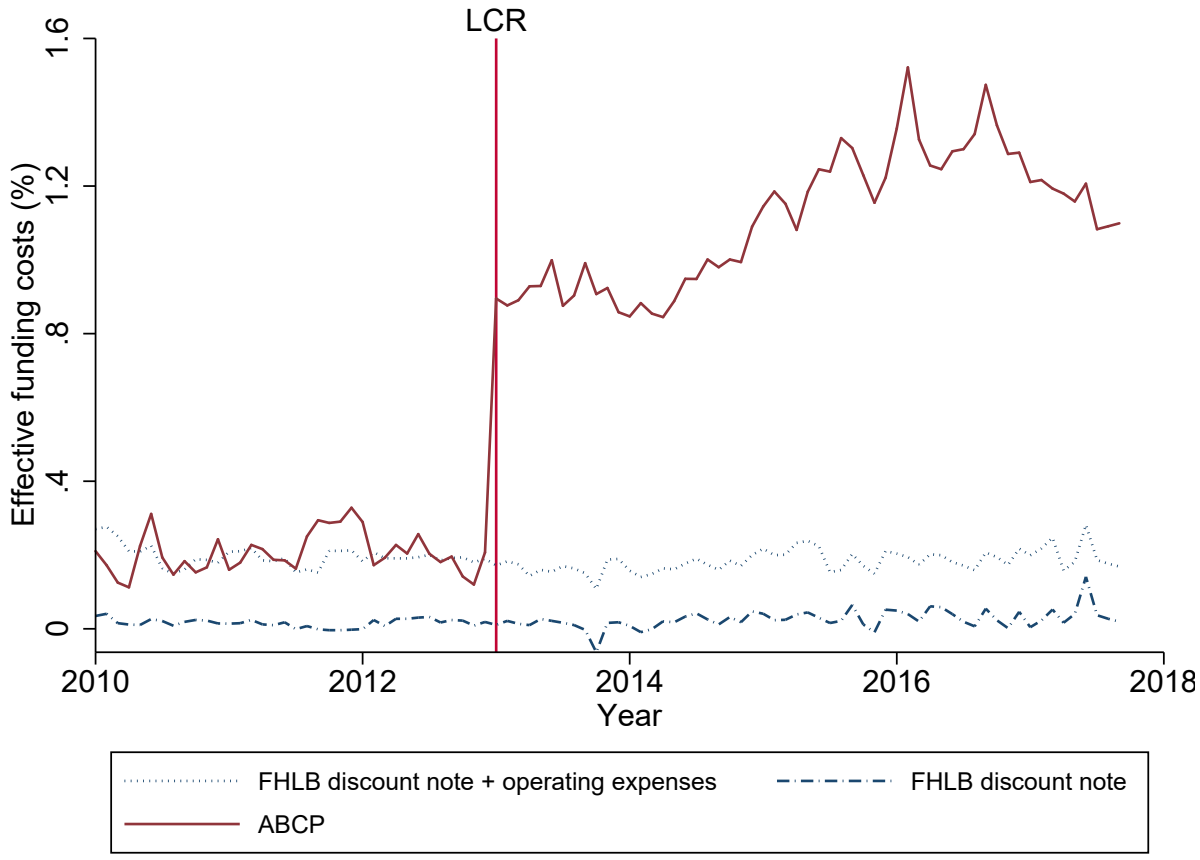


Figure 8: Effective Funding Costs of Money-like Claims: Banks vs. FHLBs
This figure plots funding costs of the FHLBs and banks from 2011 to 2017. Banks' secured funding costs are measured by 1-month ABCP spread over 1-month Treasury. FHLBs' funding costs are measured by 1-month FHLB discount note spread over 1-month Treasury. Data source: FHLB Office of Finance and Federal Reserve Bank of St. Louis.

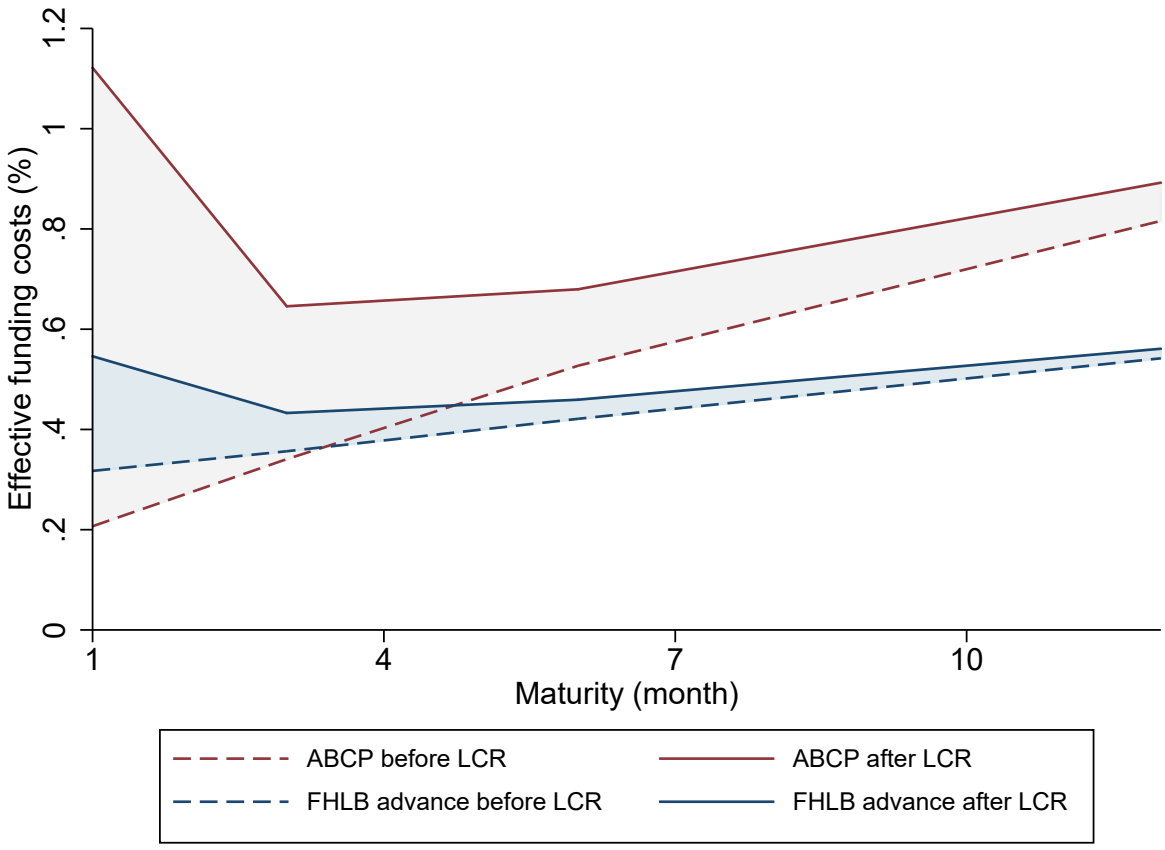


Figure 9: Effective Funding Costs for Banks

This graph plots average banks' effective funding costs over the sample period of 2013 to 2017 across different maturities. Funding costs are defined as spreads over 1 month Treasury yields. Data source: FHLB Boston, Dallas, and Des Moines; Federal Reserve Bank of St. Louis.

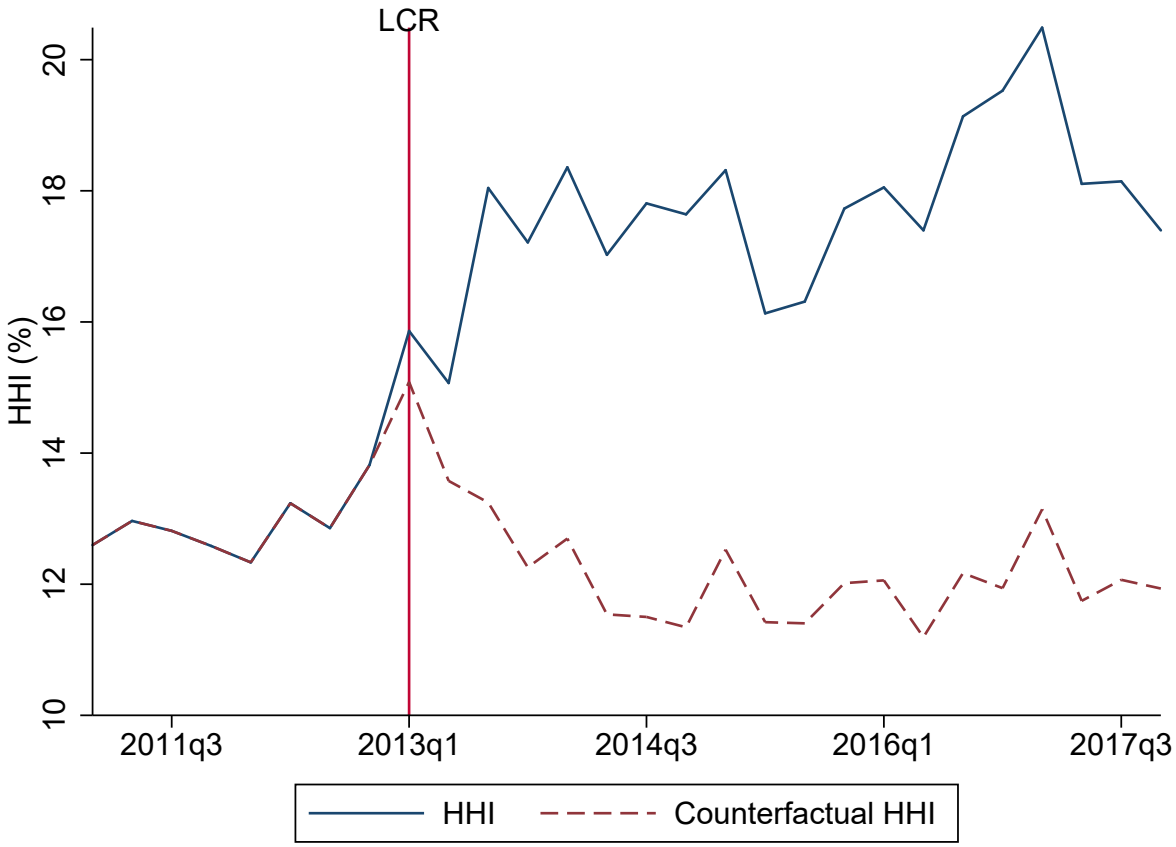


Figure 10: The Herfindahl-Hirschman Index (HHI) of FHLB Lending
This figure plots the HHI of FHLB lending. The counterfactual HHI is computed assuming that the LCR banks' advance-to-asset ratio stays constant after 2013Q1. Data source: Call Report, FRY9C.

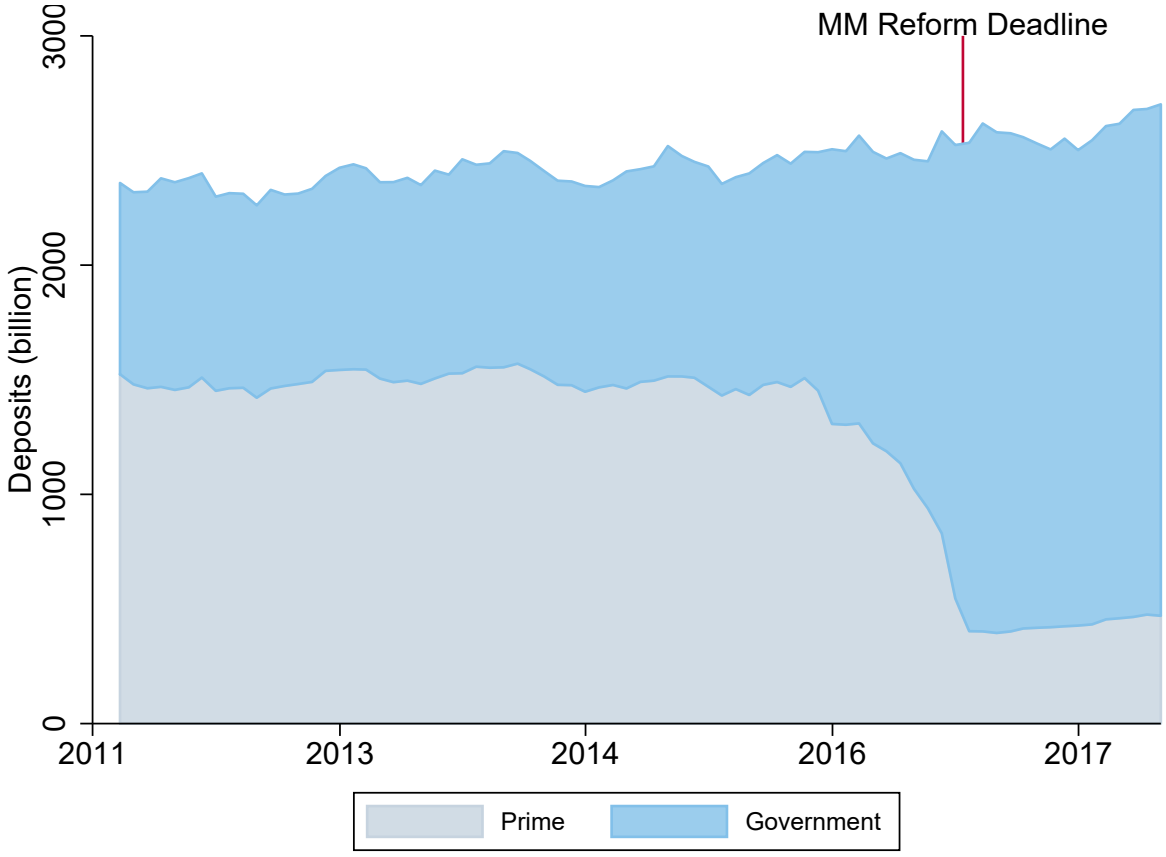


Figure 11: MMF Deposits

This figure plots the amount of deposits of prime and government money market funds respectively. The sample period is from 2011 to 2017. Data source: iMoneyNet.

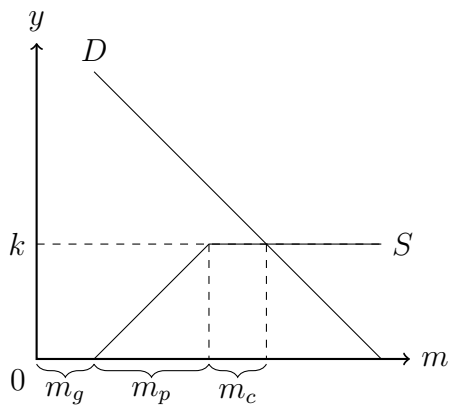


Figure 12: Committed Loan Facility

This figure plots the demand and supply of money-like assets with committed ;oan facility. k is the fee for loan commitment charged by the central bank. m_g is the outstanding government debt and central bank reserves; m_p is the money-like assets created by the private banking sector; m_c is the loan commitment provided by the central bank.

Table 1: Summary Statistics

Panel A: Banks

	N	mean	sd	p5	p25	p50	p75	p95
HQLAs	148063	18.404	12.420	3.955	9.321	15.561	24.370	42.988
LCR	148063	2.207	2.416	0.285	0.778	1.503	2.792	6.489
Advances	148063	2.562	3.478	0.000	0.000	0.623	4.271	11.213
Wholesale funding	148063	1.002	2.295	0.000	0.000	0.000	0.950	5.397
Size	148063	19.188	1.359	17.331	18.317	19.041	19.852	21.552
Deposits	148063	84.429	6.111	73.477	81.657	85.694	88.588	91.222
CapitalRatio	148063	11.096	3.312	7.522	9.238	10.509	12.268	16.670
Real estate loans	148063	42.800	15.273	14.113	31.551	43.776	54.606	68.355

Panel B: FHLBs

	N	mean	sd	p5	p25	p50	p75	p95
Log Assets	237	17.954	0.462	17.322	17.509	17.936	18.386	18.647
Advances	237	54.717	14.470	25.309	49.218	54.378	66.138	74.435
Cash and cash equivalents	237	2.389	2.683	0.004	0.438	1.301	3.559	8.369
Investments	237	25.968	10.463	12.081	17.710	24.845	32.147	48.324
Mortgage loans	237	7.060	6.013	0.340	1.507	6.238	13.256	17.445
FHLB notes	237	32.711	13.233	13.510	22.322	32.261	42.353	58.741
FHLB bonds	237	58.650	12.465	34.607	50.452	59.633	67.210	77.540
Capital	237	5.318	0.979	3.475	4.823	5.254	5.786	6.984
Other liabilities	237	1.654	1.706	0.353	0.630	1.092	2.166	5.257
LCR-bank ratio	237	0.287	0.322	0.000	0.000	0.061	0.610	0.813

Panel C: Advance Collateral

	N	mean	sd	p5	p25	p50	p75	p95
Mortgage	85	69.576	14.489	38.300	60.000	70.700	80.500	88.600
MBS	85	13.975	8.097	4.200	6.800	12.577	20.900	27.400
ORERC	85	14.913	11.827	1.000	5.400	11.900	21.200	36.400
CFI	85	1.484	3.546	0.000	0.000	0.100	1.000	8.500

Table 2: The Regulatory Weights of LCR: Assets

Description	**Factor**
Level 1 HQLA	
Cash / Reserve	100%
U.S. Government Securities	
GNMA MBS	100%
Non-GSE Agency Debts	100%
Foreign Sovereign Debt Securities	100%
Level 2a HQLA	
GSE Debts	85%
GSE MBS	85%
Agency CMBS	85%
Level 2b HQLA	
Investment grade corporate bonds	50%
Russell 1000 equities	85%
Investment grade municipal bonds	50%
Non-HQLA	
Loans	0%

Table 3: The Regulatory Weights of LCR: Liabilities

Description	Factor
Expected Cash Outflows	
Deposits	
Stable foreign deposits with a remaining maturity of one month or less	5%
Less stable foreign deposits with a remaining maturity of one month or less	25%
Stable large time deposits with a remaining maturity of one month or less	20%
Less stable large time deposits with a remaining maturity of one month or less	40%
Stable small time deposits with a remaining maturity of one month or less	3%
Less stable small time deposits with a remaining maturity of one month or less	10%
Stable wholesale transaction deposits	5%
Less stable wholesale transaction deposits	25%
Stable retail transaction deposits	3%
Less stable retail transaction deposits	10%
Stable wholesale saving deposits	20%
Less stable wholesale saving deposits	40%
Stable saving deposits	3%
Less stable retail saving deposits	10%
Wholesale Funding	
Secured by level 1 liquid assets	0%
Secured by level 2A liquid assets	15%
Secured by level 2B liquid assets	50%
Secured by other assets (with sovereigns and GSEs as counterparty)	25%
Secured by other assets (with other counterparty)	100%
Unsecured borrowing	100%
Loan commitment	
Negative fair value of derivatives	100%
Unused commitments for securities underwriting	100%
Unused commitments of commercial real estate	10%
Unused commitments of credit cards	5%
Unused commitments of home equity line of credit	5%
Other unused commitments	5%
Letters of credit	5%
Repo	30%
Repo Offset	30%
Securities Lent	30%
Expected Cash Inflows	
50% of loans with a remaining maturity less than one month	100%
Positive fair value of derivatives	100%
Securities Borrowed	30%
Reverse Repo	30%

Table 4: Effect of the LCR on FHLB Advances

	(1) Advances	(2) Advances	(3) Advances
Post*Full-LCR bank	1.869***	1.865***	1.683***
	[0.465]	[0.467]	[0.377]
Post*Modified-LCR bank	1.272***	1.270***	0.841**
	[0.298]	[0.298]	[0.321]
Log assets	-0.107***	-0.111***	0.852***
	[0.029]	[0.029]	[0.093]
Deposit ratio	-0.629***	-0.630***	-0.471***
	[0.009]	[0.009]	[0.016]
Capital ratio	-0.716***	-0.718***	-0.436***
	[0.015]	[0.015]	[0.021]
Bank F.E.	No	No	Yes
Time F.E.	No	Yes	Yes
Observations	149,891	149,891	149,886
Adj. R-squared	0.620	0.622	0.853

Note: This table shows the impact of the LCR regulations on the amount of FHLB advances borrowed by U.S. commercial banks. The sample includes all the U.S. banks from 2011Q1 to 2017Q4. The dependent variable, *Advances*, is the amount of FHLB advances normalized by assets. *Post* is a dummy variable that equals 1 if the time is after 2013Q1. *Full-LCR Bank* is a dummy variable that equals 1 if a bank is covered by the full LCR rule in 2013Q1, and 0 otherwise. *Modified-LCR Bank* is a dummy variable that equals 1 if a bank is covered by the modified LCR rule in 2013Q1, and 0 otherwise. *Post*, *Full-LCR Bank*, and *Modified-LCR Bank* are included in the regression when corresponding fixed-effects are not included. For control variables, *Log Asset* is the log of the total assets of the bank; *Deposit Ratio* is the ratio of core deposits as a percentage of total deposits of all membership banks; *Capital Ratio* is the ratio of equity as a percentage of total assets of all membership banks; Time and bank fixed effects are added to the regressions as shown in the table. Standard errors shown in parentheses are clustered at the quarter level. ***, **, * represent 1%, 5%, and 10% significance levels, respectively.

Table 5: Effect of the LCR on FHLB Advances: Matched Sample

	(1) Advances	(2) Advances	(3) Advances
Post*Full-LCR bank	1.523***	1.525***	0.952**
	[0.395]	[0.402]	[0.383]
Post*Modified-LCR bank	0.743**	0.745**	-0.057
	[0.315]	[0.317]	[0.375]
Log assets	-0.390	-0.411	1.298***
	[0.311]	[0.314]	[0.389]
Deposit ratio	-0.444***	-0.451***	-0.260***
	[0.075]	[0.077]	[0.057]
Capital ratio	-0.439***	-0.438***	-0.274**
	[0.149]	[0.149]	[0.106]
Bank F.E.	No	No	Yes
Time F.E.	No	Yes	Yes
Observations	1,564	1,564	1,564
Adj. R-squared	0.383	0.382	0.866

Note: This table shows the impact of the LCR regulations on the amount of FHLB advances borrowed by U.S. commercial banks. The sample includes banks which are subject to the LCR and a one-to-one matched sample of banks which are not subject to the LCR from 2011Q1 to 2017Q4. The matched characteristics include deposit ratio, capital ratio, and liquidity ratio in 2013Q1, the quarter before the introduction of LCR. The dependent variable, *Advances*, is the amount of FHLB advances normalized by assets. *Post* is a dummy variable that equals 1 if the time is after 2013Q1. *Full-LCR Bank* is a dummy variable that equals 1 if a bank is covered by the full LCR rule in 2013Q1, and 0 otherwise. *Modified-LCR Bank* is a dummy variable that equals 1 if a bank is covered by the modified LCR rule in 2013Q1, and 0 otherwise. *Post*, *Full-LCR Bank*, and *Modified-LCR Bank* are included in the regression when corresponding fixed-effects are not included. For control variables, *Log Asset* is the log of the total assets of the bank; *Deposit Ratio* is the ratio of core deposits as a percentage of total deposits of all membership banks; *Capital Ratio* is the ratio of equity as a percentage of total assets of all membership banks; Time and bank fixed effects are added to the regressions as shown in the table. Standard errors shown in parentheses are clustered at the quarter level. ***, **, * represent 1%, 5%, and 10% significance levels, respectively.

Table 6: Gap to Meet LCR Regulation and FHLB Advances Borrowing

	(1) Advances	(2) Advances	(3) Advances
Post*Gap	2.015**	2.007**	1.432*
	[0.852]	[0.855]	[0.830]
Log assets	-0.139***	-0.143***	0.861***
	[0.031]	[0.031]	[0.095]
Deposit ratio	-0.629***	-0.630***	-0.472***
	[0.009]	[0.009]	[0.016]
Capital ratio	-0.715***	-0.718***	-0.437***
	[0.015]	[0.014]	[0.021]
Bank F.E.	No	No	Yes
Time F.E.	No	Yes	Yes
Observations	148,063	148,063	148,063
Adj. R-squared	0.619	0.621	0.852

Note: This table shows the impact of the LCR regulations on the amount of FHLB advances borrowed by U.S. commercial banks. The sample includes all the U.S. banks from 2011Q1 to 2017Q4. The dependent variable, *Advances*, is the amount of FHLB advances normalized by assets. *Post* is a dummy variable that equals 1 if the time is after 2013Q1. *Gap* is a continuous variable which measures the distance for a bank to meet its LCR requirement. *Post* and *Gap* are included as control when the corresponding fixed-effects are not included. For control variables, *Log Asset* is the log of the total assets of the bank; *Deposit Ratio* is the ratio of core deposits as a percentage of total deposits of all membership banks; *Capital Ratio* is the ratio of equity as a percentage of total assets of all membership banks; Time and bank fixed effects are added to the regressions as shown in the table. Standard errors shown in parentheses are clustered at the quarter level. ***, **, * represent 1%, 5%, and 10% significance levels, respectively.

Table 7: Effect of the LCR Regulation on the Usage of FHLB Advances

	(1) Full-LCR banks	(2) Modified-LCR banks	(3) Non-LCR banks
Δ HQLA	-0.066**	0.024**	-0.015***
	[0.029]	[0.010]	[0.002]
Δ HQLA*Post	0.117**	-0.029	-0.002
	[0.046]	[0.019]	[0.002]
Δ Loans	0.165***	0.098	0.033***
	[0.059]	[0.079]	[0.004]
Δ Loans*Post	-0.249*	-0.159*	-0.004
	[0.133]	[0.089]	[0.005]
Log assets	-0.137*	0.262**	-0.005
	[0.076]	[0.124]	[0.004]
Deposit ratio	-0.020**	-0.035***	-0.006
	[0.009]	[0.010]	[0.007]
Capital ratio	-0.038	-0.021	0.005
	[0.043]	[0.022]	[0.011]
Bank F.E.	Yes	Yes	Yes
Time F.E.	Yes	Yes	Yes
Observations	218	604	148,516
Adj. R-squared	0.092	0.017	0.015

Note: This table examines the relationship between the amount of FHLB advances borrowed by banks and the contemporaneous changes in HQLAs and real estate loans. The sample period is 2011Q1-2017Q4. The dependent variable, $\Delta Advances$, is annual changes in the FHLB advances normalized by assets. $\Delta HQLA$ is annual changes in high-quality liquid assets. $\Delta Loans$ is annual changes in real-estate loans. *Post* is a dummy variable that equals 1 if the time is after 2013Q1. The sample in Column 1, 2, and 3 includes full-LCR banks, modified-LCR banks, and non-LCR banks respectively. For control variables, *Log Asset* is the log of the total assets of the bank; *Deposit Ratio* is the ratio of core deposits as a percentage of total deposits of all membership banks; *Capital Ratio* is the ratio of equity as a percentage of total assets of all membership banks; Time and bank fixed effects are added to the regressions as shown in the table. Standard errors shown in parentheses are clustered at the quarter level. ***, **, * represent 1%, 5%, and 10% significance levels, respectively.

Table 8: Effect of the LCR Regulation on FHLBs' Short-term Debt

	(1)	(2)	(3)
	Short-term debt	Short-term debt	Short-term debt
Post*LCR-bank ratio	7.630**	7.836**	6.757**
	[3.120]	[3.090]	[3.190]
LCR-bank ratio	0.883	0.908	
	[2.530]	[2.506]	
Post	9.673***		
	[2.666]		
FHLB F.E.	No	No	Yes
Time F.E.	No	Yes	Yes
Observations	237	237	237
Adj. R-squared	0.171	0.297	0.524

Note: This table shows the impact of the LCR regulations on the issuance of consolidated notes by the FHLBs. The sample includes all the FHLBs from 2011Q1 to 2015Q4. The dependent variable, *Short-term debt*, is the amount of FHLB notes normalized by lagged assets. *Post* is a dummy variable that equals 1 if the time is after 2013Q1. *LCR-bank ratio* is the fraction of member commercial banks that are subject to the LCR weighed by assets. Time and FHLB fixed effects are added to the regressions as shown in the table. Standard errors shown in parentheses are clustered at the quarter level. ***, **, * represent 1%, 5%, and 10% significance levels, respectively.

Appendix

Proof of Proposition 1

Proof:

Suppose $\underline{y}$ is liquidity premium which makes banks indifferent between (1) holding Δ liquidity buffer for each dollar of money-like assets and being solvent in both states of the world and (2) holding zero liquidity buffer and defaulting in the bad state of the world. We have

$$R_i - \Delta(1+\alpha)\underline{y} = (1-p)R_i$$

If the equilibrium liquidity premium is higher than $\underline{y} = \frac{pR_i}{\Delta(1+\alpha)}$, then banks would prefer to hold zero liquidity buffer and default in the bad state of the world.

In the long-term funding market, the equilibrium interest rate adjusts to make banks indifferent between borrowing from other banks or borrowing from the capital markets

$$r_a = r_b$$

In the equilibrium, denote $\overline{c}$ as the marginal bank which is indifferent between issuing money-like claims or using long-term funding. The indifference condition is

$$y = r_b - r_m = \overline{c}.$$

Because c follows a uniform distribution, the aggregate supply of money-like claims by banks is

$$\int m(c)dc = y(1+\alpha).$$

The liquidity premium adjusts to clear the short-term funding market:

$$y(1+\alpha) = \phi(y_0 - y) - m_g$$

We can solve the equilibrium amount of liquidity premium is

$$y^* = \frac{1}{1+\alpha+\phi}(\phi y_0 - m_g).$$

The aggregate amount of liquidity mismatch is

$$LMI^* = \Delta \int m^*(c)dc - \int l^*(c)dc = (1+\alpha)y^* = \Delta \frac{1+\alpha}{1+\phi+\alpha}(\phi y_0 - m_g).$$

□

Proof of Proposition 2

Proof: In the equilibrium, denote $\overline{c}$ as the marginal bank which is indifferent between issuing money-like claims or using long-term funding. The indifference condition is

$$y(1-\rho) = \overline{c}.$$

Because c follows a uniform distribution, the aggregate supply of money-like claims by banks is

$$\int m(c)dc = y(1-\rho)(1+\alpha).$$

The liquidity premium adjusts to clear the short-term funding market:

$$y(1-\rho)(1+\alpha) - y(1-\rho)(1+\alpha)\rho = \phi(y_0 - y) - m_g$$

We can solve the equilibrium amount of liquidity premium is

$$y^* = \frac{1}{(1+\alpha)(1-\rho)^2 + \phi}(\phi y_0 - m_g).$$

The aggregate amount of liquidity mismatch is

$$\begin{aligned} LMI^* &= \Delta \int m^*(c)dc - \int l^*(c)dc \\ &= (\Delta - \rho) \int m(c)dc \\ &= (\Delta - \rho)(1-\rho)(1+\alpha)y^* \\ &= \frac{\Delta - \rho}{1-\rho} \frac{(1-\rho)^2}{(1+\alpha)(1-\rho)^2 + \phi}(\phi y_0 - m_g) \end{aligned}$$

Take derivative with respect to ρ:

$$\frac{\partial LMI^*}{\partial \rho} < 0$$

for $\rho < \Delta$. $\square$

Proof of Proposition 3

Proof: Because c follows a uniform distribution, the aggregate supply of money-like claims by regulated banks is

$$\int_{\mathbb{U}^c} m(c)dc = y(1-\rho)(1+\alpha)(1-\mu).$$

the aggregate supply of money-like claims by unregulated banks is

$$\int_{\mathbb{U}} m(c)dc = y(1+\alpha)\mu.$$

The liquidity premium adjusts to clear the short-term funding market:

$$y(1-\rho)(1+\alpha)(1-\mu) + y(1+\alpha)\mu = \phi(y_0 - y) - m_g$$

We can solve the equilibrium liquidity premium is

$$y^* = \frac{1}{(1+\alpha)\left[(1-\rho)^2(1-\mu)+\mu\right]+\phi}(\phi y_0 - m_g).$$

The equilibrium liquidity premium is increasing to the liquidity requirement:

$$\frac{\partial y^*}{\partial \rho} > 0.$$

The amount of loans that unregulated banks supply is

$$A^* = \mu\alpha y^* = \frac{\mu\alpha}{(1+\alpha)\left[(1-\rho)^2(1-\mu)+\mu\right]+\phi}(\phi y_0 - m_g).$$

Because the equilibrium liquidity premium is increasing to the liquidity requirement, we have

$$\frac{\partial A^*}{\partial \rho} > 0.$$

$\square$

Proof of Proposition 4

Proof: The aggregate amount of liquidity mismatch is

$$
\begin{aligned}
LMI^* &= \Delta \int m^*(c)dc - \int l^*(c)dc \\
&= (1-\mu)(\Delta-\rho)(1-\rho)(1+\alpha)y^* + \mu\Delta(1+\alpha)y^*
\end{aligned}
$$

The first term is the liquidity mismatch of the regulated banks, which is decreasing to ρ as shown in 2. The second term is the liquidity mismatch of the unregulated banks, which is increasing to ρ. The effectiveness of liquidity regulation is decreasing to the fraction of the unregulated banks.

$$
\frac{\partial}{\partial \mu}\left(\frac{\partial LMI^*}{\partial \rho}\right) > 0.
$$

□