Unintended Consequences of Post-Crisis Liquidity Regulation*

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Abstract

We evaluate the effects of the post-crisis liquidity regulations on the U.S. banking system. Although the new regulations have increased the liquidity buffer held by banks, a significant fraction of the buffer is financed by short-term debt intermediated by a government-sponsored enterprise known as the Federal Home Loan Bank System. Using a model of liquidity regulation, we show that funding a liquidity buffer using government-backed short-term debt compromises the goals of liquidity regulation. Instead of reducing banks' reliance on public liquidity, banks now regularly borrow from a public liquidity backstop. Moreover, the liquidity buffer financed by short-term debt may disappear in times of crisis, making it less effective to deter bank runs. We argue that the fragmented regulatory system in the U.S. allows these unintended consequences to arise.

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1 Introduction

One of the most important lessons from the 2007–09 financial crisis is that private financial institutions may engage in excessive liquidity transformation, which may create massive risks to the economy. When the risk materializes, the government has little choice but to intervene, by either guaranteeing some of banks' liabilities or by acting as a lender of last resort. But these ex-post interventions may expose taxpayers to large credit risks and encourage future moral hazards. Since the 2007–09 crisis, regulators have gone to extraordinary lengths to establish preventative measures to reduce private financial institutions' reliance on public liquidity. For instance, banks are now required, through the Liquidity Coverage Ratio (LCR), to hold enough high-quality liquid assets (HQLAs) to survive 30 days of cash outflows in a stress scenario. Money market funds (MMFs) are required to limit the liquidity rights provided to their investors. Although there is a large body of literature on capital regulation, the effects of these newly introduced liquidity regulations remain largely unknown (Allen and Gale 2017).

We address this gap by investigating the impact of liquidity regulation on the U.S. banking system. On the surface, the new regulations have significantly increased the liquidity buffer held by banks: the aggregate holding of HQLAs by U.S. banks has increased by $1,170 billion from 2012 to 2017. However, a closer empirical examination reveals that the way that the liquidity buffer is financed is potentially problematic. As shown in Figure 1, instead of exchanging illiquid assets for liquid assets, banks borrow from a group of government-sponsored enterprises known as the Federal Home Loan Banks (FHLBs) by pledging their illiquid assets to purchase liquid assets. The FHLBs, in turn, borrow from government money market funds (MMFs) to lend to banks. Each dollar increase in the liquidity buffer is associated with a 20- to 30-cent increase in short-term debt intermediated by the FHLBs. Such transaction allows banks and MMFs to meet liquidity regulations with lower costs because the FHLBs are qualified as a stable funding source for banks and a safe borrower for MMFs. However, it also keeps the illiquid assets in the banking network and increases private financial institutions' reliance on public liquidity, which is inconsistent with the goal of liquidity regulation.

We start our analysis by constructing a theoretical model of liquidity regulation following the canonical model of Diamond and Kashyap (2016). In our model, regulators impose liquidity regulation to reduce banks' reliance on public liquidity backstops in times of crisis as such reliance could be socially costly. However, if public liquidity is not properly priced, banks may borrow from the public liquidity backstop to purchase liquidity assets, which paradoxically increases their reliance on the public liquidity backstop even in normal times. In addition, the effectiveness of liquidity regulation could be further compromised if the public liquidity backstop itself is financed by short-term debt, as is the case with the FHLBs, because investors may stop rolling over the short-term debt in times of crisis, forcing banks to give up liquidity when liquidity is needed most.

We empirically evaluate our model's predictions using a comprehensive database on the balance sheets and lending relationships between banks, FHLBs, and MMFs. A key insight of our model is that any bank liquidity regulation must also simultaneously address the way in which public liquidity is priced. However, we find that this type of coordination between different regulators implied by our model appears to be absent in real life: the cost of borrowing from FHLBs remained unchanged or even became lower since the roll-out of liquidity regulations. This has resulted in a massive expansion of banks' borrowing from the FHLBs. Exploiting the cross-bank exposure to liquidity regulations due to bank size and pre-regulation liquidity position, we show that banks that are more exposed to liquidity regulations increase their borrowing from the FHLBs by a larger amount. The borrowed funds are used to acquire liquid assets to fulfill liquidity requirements, rather than to support real estate lending as the mission of the FHLBs would suggest.

The other major component of the post-crisis liquidity regulation, the Money Market Reform, reinforces this trend by increasing the supply of short-term funding to the FHLBs. The Money Market Reform restricts liquidity rights that prime MMFs, whose assets were primarily private debt, can provide to their investors. This has resulted in a massive shift of deposits out of prime MMFs into government MMFs. Exploiting the pre-reform differences in the fraction of prime fund assets within each fund family, we find that the fund families that have more exposure to the reform substantially increase their lending to the FHLBs. The economic magnitude is large: the aggregate holdings of the FHLB debt *quadrupled* after the reform, and the MMF industry has become the single largest creditor of the FHLBs.

Taken together, the post-crisis liquidity regulations have increased the banking system's reliance on the FHLBs. Banks increasingly borrow from the FHLBs to meet LCR while MMFs increasingly lend to the FHLBs as a result of the Money Market Reform. The balance sheet size of the FHLBs rapidly expanded-by nearly 50%-from 2012 to 2017 and reached 1.1 trillions at the end of 2017, a level that was only reached shortly after the onset of the financial crisis of 2008. The FHLBs increasingly fund themselves using ultra short-term debt from MMFs: the average maturity of loans from MMFs to FHLBs fell below 40 days as of 2017.

The increasing role of the FHLBs in liquidity transformation compromises the goals of liquidity regulation. Instead of reducing banks' reliance on public liquidity, banks now rely on publicly supplied liquidity from the FHLB system on a regular basis, even in normal times. In addition, using FHLB funding to meet liquidity regulations appears to be a deviation from the stated mission of the FHLBs, which is to support the real estate lending. We estimate the subsidy associated with the implicit government guarantee on the FHLBs and find that it is increasingly captured by banks rather than being passed through to the borrowers in the housing market. Finally, because the FHLBs themselves are increasingly funded by ultra short-term debt, the liquidity buffer built by the regulations may not be effective to deter bank runs because the funding source of the liquidity buffer may quickly disappear in times of crisis.

We argue that the fragmented regulatory system in the U.S. has allowed these unintended consequences to arise. In the U.S., regulation of the financial system is divided among separate regulatory agencies with different mandates.[1] In our context, the regulator of FHLBs did not raise the cost for banks to borrow from the FHLBs in response to liquidity regulation because it views the lending of FHLBs to banks as part of their mandate of promoting housing lending. In fact, such funding is mainly used by banks to fulfill liquidity requirements. The regulators of commercial banks treat the FHLBs as a stable source of funding without necessarily recognizing that the FHLBs themselves are largely financed by unstable funding.[2] The regulator of MMFs aims to improve the liquidity and safety of MMFs but unintentionally makes the funding structure of the FHLBs more fragile. In such a fragmented regulatory system, each regulator focuses on their narrowly defined jurisdictions. This lack of coordination allows financial institutions to tap into public liquidity to meet liquidity requirements.

We discuss potential policy remedies. The first approach is to impose strict leverage requirements on the FHLBs. We show, however, that leverage requirements may be ineffective because of a unique institutional feature of the FHLBs, known as activity-based

[1]Commercial banks are primarily regulated by the Federal Deposit Insurance Corporation (FDIC), the Federal Reserve Board, or the Office of the Comptroller of the Currency (OCC). MMFs are regulated by the SEC. The FHLBs are regulated by the Federal Housing Finance Agency (FHFA).

[2]Borrowing from FHLBs has low "run-off" rates in the LCR calculation. The "run-off" rates are expected rates of draw-down for each category of bank liabilities in a distress scenario.

capital, which allows the FHLBs to obtain capital automatically when they lend to banks. The second approach would be to adjust the regulatory treatment of FHLB funding in the calculation of banks' LCR. The downside of this approach is that the compliance cost of liquidity regulation may become quite high if liquid assets become scarce in the economy, which may incentivize banks to seek other ways to evade regulations. The third approach is to use a price-based mechanism similar to the Committed Liquidity Facility (CLF) used in Australia. In this approach, banks pay a commitment fee to obtain a loan commitment from the public liquidity backstop. Regulators set the commitment fees to reflect the social cost of supplying public liquidity and count the *unused* loan commitment as HQLAs in the LCR. The advantage of the price-based mechanism is that banks do not have to purchase liquid assets to meet LCR as such purchases may exacerbate the shortage of liquid assets.

Related Literature

In this section, we review the relevant literature and summarize our paper's contributions. First, our paper contributes 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). A number of recent theory papers have focused on how liquidity requirements affect bank runs. 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. We contribute to this literature by introducing the institutional feature that banks have access to public liquidity backstops, such as the central bank discount window or the FHLBs, which allows us to analyze interactions between liquidity regulation of banks and public liquidity backstops, an issue emphasized by Stein (2013) in a speech at the Federal Reserve Bank of Richmond. We show that any bank liquidity regulation must also simultaneously address the way in which government-supplied liquidity is priced.

Our paper relates to the literature that 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 2007–09 financial crisis. Gissler and Narajabad (2017) and Anadu and Baklanova (2017) document aggregate trends of the FHLB advances in the post-crisis period amid the roll-out of the Basel III liquidity requirements and the Money Market Reform. Our paper provides systematic evidence supporting this strand of research by exploiting the variations in the exposure to the liquidity regulations across different banks and MMF families. Our paper also relates to Narajabad and Gissler (2018), which finds that banks use FHLB advances as a substitute for deposit financing. We show that the use of the FHLB advances differs across banks with different exposures under the liquidity requirements. Most importantly, our paper provides a conceptual framework to study the interaction between the FHLBs and liquidity regulation and the policy remedies for the unintended consequences.

Our paper adds to a growing body of literature on the effect of the Money Market Reform. McCabe, Cipriani, Holscher, and Martin (2013) and Hanson, Scharfstein, and Sunderam (2015) systematically evaluate different MMF reform proposals. Cipriani, La Spada, and Mulder (2017) use the MMF reform as a quasi-natural experiment to estimate the convenience of having stable Net Asset Values (NAVs). Baghai, Giannetti, and Jäger (2017) study how the reform changes the risk-taking behavior for the prime money market funds. Our paper shows that the 2016 Money Market Reform unintentionally funnels extensive amounts of short-term funding to FHLBs. This, in turn, enables FHLBs to help banks to meet their liquidity requirements through their advances to banks. More broadly, our paper also contributes to the literature on the systemic risks of MMFs (Kacperczyk and Schnabl 2013; Chernenko and Sunderam 2014; Schmidt, Timmermann, and Wermers 2016; La Spada 2018).

Finally, our paper contributes to the literature on the design of financial regulations. The recent financial crisis has led to substantial surge in interest in this area. Most of the debate has been about which financial activities should be regulated, while the discussion on reforming the regulatory structure itself has been less active (Agarwal, Lucca, Seru, and Trebbi 2014). At a theoretical level, we show how a change in bank liquidity regulations by bank regulators can incentivize banks to draw liquidity from the credit line at the FHLBs, unless the regulator of FHLBs also simultaneously increases the cost of accessing the credit line or the bank regulators increase the "run-off" rates on FHLB advances. We provide empirical evidence that such regulatory coordination appears to be absent in fragmented regulatory structure in the U.S..

2 Institutional Background

2.1 Post-crisis Liquidity Regulations

The first main post-crisis liquidity regulation which we examine is the Liquidity Coverage Ratio requirement (LCR). The LCR was initially proposed by the Basel Committee on Banking Supervision Committee in December 2010 and finalized in January 2013 as a part of the Basel III regulatory framework.[3] In the U.S., the Federal Reserve carried out its first ever system-wide stress test of bank liquidity for the largest U.S. banks in November 2012, which marked the beginning of liquidity regulation on banks in the U.S.[4] 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 reserves, Treasuries, and certain types of agency MBS, to cover expected net cash outflow for a 30-day stress scenario. Banks with assets below $50 billion are not required to meet LCR requirement.[5] We define banks which are covered by the LCR as "LCR banks" and banks which are not covered by LCR as "non-LCR banks."[6] The goal of the LCR was to curb banks' excessive liquidity transformation and reduce their reliance on the public liquidity backstop in stressed times.

The second main liquidity regulations which we examine is the Money Market reform. MMFs transform money market instruments with maturities ranging from several months to one year into daily liquidity. During the crisis, the Reserve Primary Fund "broke the buck" which triggered a massive run on the MMF industry. In 2014, 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 MMF reform mainly affected the prime funds which hold private debts while government funds are exempted from some of the most stringent regulations such as the floating NAV requirement.

[3]The U.S. version of LCR was finalized in 2014.

[4]Note that the liquidity stress testing considers multiple stress scenarios in addition to the 30-day scenario considered by LCR. Therefore, our results should be viewed as due to liquidity regulations on banks generally, rather than solely to LCR.

[5]In our sample, we have 8 banks which satisfy this criteria in November 2012.

[6]Banks with between $50 billion and $250 billion in assets are subject to a modified LCR, which is less stringent than the full rule. In the Online Appendix, we find that the modified LCR does not seem to be binding in our sample period.

2.2 The Federal Home Loan Bank System

The FHLB system, which was established in 1932, is a large government-sponsored enterprise (GSE) with a mission of assisting 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). As of June 2018, the FHLB system has eleven regional banks and over 6,900 members. The loans that the FHLBs provide to banks are called "advances", whose maturity ranges from overnight to 30 years.[7]

During the 2007–09 financial crisis, the FHLBs became an important provider of liquidity to banks in first half of 2007 because of favorable pricing and less stigma compared to discount window of the Federal Reserve. 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). In this period, weak collateral standards and concentrated lending to big banks drew sharp criticism (Gaberlavage 2017).[8] In response to these problems, the 2011 joint report by the Department of Treasury and HUD recommends limiting the level of advances and reducing portfolio investments of the FHLBs as part of the broad housing market reform.[9]

3 Model

In this section, we introduce the institutional feature that banks have an access to a public liquidity backstop such as the central bank discount window or the FHLBs into the Diamond and Kashyap (2016) model of liquidity regulation. We keep the framework sparse to develop sharp predictions and hypotheses for our empirical tests.[10] The goals of

[7]In the appendix, we provide a more detailed description of the key institutional features of the FHLB system.

[8]For example, Sen. Charles Schumer criticized advances made to Countrywide Bank by the FHLBs of Atlanta stating that the bank was serving as Countrywides "personal ATM". Based on a study by Federal Housing Finance Agency (FHFA) 34.5% of the collateral was subprime, nontraditional and Alt-A loans and subprime private-label and Alt-A MBS at the end of 2007.

[9]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.

[10]We abstract away capital regulation as it has received extensive study in the prior literature. Kashyap, Tsomocos, and Vardoulakis (2017) proposes a model which studies the interaction between liquidity and capital regulation.

this model are the following: First, we want to understand how changes in the liquidity regulations might affect banks' demand for public liquidity. Second, we want to study how the cost of public liquidity should be adjusted to prevent banks from using public liquidity backstops to meet liquidity regulation. Third, we want to explore how the predictions of canonical banking models such as Diamond and Kashyap (2016) concerning the role of liquidity buffers in mitigating the risk of runs may be affected when banks have access to public liquidity backstops.

3.1 Setting

As in the baseline model of Diamond and Kashyap (2016), there are three dates, $T = 0$, 1, and 2. For a unit investment at date 0, the bank offers a demand deposit which pays either per period return of r_1 at date 1 or r_2 at date 2. The bank can invest in two assets with constant returns to scale. One is a liquid asset that returns $R_1 > 1$ per unit invested in the previous period. The other is an illiquid asset for which a unit investment at date 0 generates a per period return $R_2 > R_1$ but the investment only matures at date 2. For simplicity, we assume the premature liquidation value of the illiquid asset is zero. The results are robust to a positive liquidation value. We also assume that banking is profitable even if the bank invests exclusively in the liquid asset, so that $r_1 \leq R_1$ and $r_2 \leq R_1$.

We denote by α the fraction of bank's assets held as liquid assets. We define f_1 as the total amount of early withdrawals. If the liquidity buffer is less than the withdrawals, $\alpha R_1 - f_1 r_1 < 0$, then a bank run will occur and the bank will be insolvent. The amount of early withdrawals at $T = 1$ depends on the states of the world at $T = 1$. We assume that there are two states of the world at $T = 1$, $s = G, B$ with probability $1 - p$ and p respectively. In the good state, G, a fraction t of depositors want to withdraw at date 1 and $1 - t$ want to withdraw at date 2. In the bad state, B, a fixed number Δ of the patient depositors see a sunspot and decide to run. The total amount of early withdrawal is $f_1 = t + \Delta$ in the bad state.

3.2 Equilibrium without Liquidity Regulation

At date 0, the bank chooses the amount of liquid asset and illiquid asset to maximize the equity value.

$$\max_{\alpha} \mathbb{E}\left[\left((1-\alpha)R_2^2 + (\alpha R_1 - f_1 r_1)R_1 - (1-f_1)r_2^2\right)\mathbb{1}_{[\alpha R_1 - f_1 r_1 \geq 0]}\right] \tag{1}$$

where $\mathbb{1}_{[\alpha R_1 - f_1 r_1 \geq 0]}$ is an indicator function which takes a value of one if the bank has enough liquidity to cover the early withdrawals, and zero otherwise. If the available liquidity is lower than the early withdrawals, a bank run will occur which leads to a large externality, l, to the rest of the economy. The social welfare is the following

$$\mathbb{E}\left[(1-\alpha)R_2^2 + \alpha R_1^2 - \mathbb{1}_{[\alpha R_1 - f_1 r_1 < 0]} l\right] \tag{2}$$

where $(1-\alpha)R_2^2 + \alpha R_1^2$ is the output of the economy, $\mathbb{1}_{[\alpha R_1 - f_1 r_1 < 0]}$ is an indicator function that a bank run occurs, and l is the social cost of bank runs. If the social cost of the run l is large enough, it is socially optimal to prevent runs in both states. However, the market failure here is that the bank does not internalize the social cost of bank runs, l, because it can simply declare financial distress and allow itself to be shut down by the closure authorities. Therefore, the privately optimal liquidity buffer is too low to prevent socially costly bank runs. Formally, if the following condition holds, the bank chooses a lower liquidity buffer $\alpha_L = \frac{tr_1}{R_1}$ which only prevents runs in the good state and allow runs in the bad state

$$p\left((1-\alpha_H)R_2^2 + (\alpha_H R_1 - (t+\Delta)r_1)R_1 - (1-f_1)r_2^2\right) < (1-p)(\alpha_H - \alpha_L)(R_2^2 - R_1^2) \tag{3}$$

where $\alpha_H = \frac{(t+\Delta)r_1}{R_1}$. The left-hand side is the expected profit if the bank does not fail in the bad state, and the right-hand side is the opportunity cost to hold the extra liquidity. Intuitively, if the probability of the bad state is sufficiently small, the bank finds it unprofitable to hold the extra liquidity, although it is beneficial for the society to do so.

One way to prevent bank runs is to allow banks to borrow from a public liquidity backstop. For now, we can think about the public liquidity backstop as the discount window of the central bank which has unlimited lending capacity. Later we consider the case of the FHLBs in which the lending capacity may be binding.[11] Denote β_0 and β_1 as

[11] In reality, even the lending capacity of the discount window could also be binding due to the insufficiency of eligible collateral and potential stigma effects.

the quantity of loan drawn from the credit line at date 0 or 1 respectively and c as the cost of borrowing.[12] The bank's optimization problem becomes

$$\max_{\alpha,\beta_0,\beta_1} \mathbb{E}\big[\big((1+\beta_0-\alpha)R_2^2+(\alpha R_1+\beta_1-f_1r_1-\beta_0c)R_1-(1-f_1)r_2^2-\beta_1c\big) \mathbb{1}_{[\alpha R_1+\beta_1-f_1r_1-\beta_0c\geq 0]}\big] \tag{4}$$

It is clear that accessing to the public liquidity backstop can prevent bank runs because the bank can borrow $\beta_1 = \Delta r_1$ from the public liquidity backstop to meet the withdrawal in the bad state. However, as Stein (2013) argues, relying on public liquidity to address bank runs may be socially costly because of two reasons. First, it is often impossible to differentiate illiquid banks from insolvent banks. Therefore, lending to troubled banks may expose taxpayers to large credit risks. Second, using public liquidity to support banks when they get into trouble can lead to moral hazard problems. These concerns motivate the preventative measures such as liquidity regulation which requires banks to hold more liquidity ex ante so that the bank would not borrow from the public liquidity backstop when the bad state occurs.

3.3 Equilibrium with Liquidity Regulation

Suppose the regulator requires the bank to hold as least $\alpha \geq \rho$ units of liquid assets at date 0. The problem of the bank becomes the following:

$$\max_{\alpha,\beta_0,\beta_1} \mathbb{E}\big[\big((1+\beta_0-\alpha)R_2^2+(\alpha R_1+\beta_1-f_1r_1-\beta_0c)R_1-(1-f_1)r_2^2-\beta_1c\big) \mathbb{1}_{[\alpha R_1+\beta_1-f_1r_1-\beta_0c\geq 0]}\big] \quad \text{st. } \alpha \geq \rho \tag{5}$$

Regulators choose the liquidity requirement ρ and the cost of accessing public liquidity c to maximize the social welfare:

$$\max_{\rho,c} \mathbb{E}\left[(1-\alpha)R_2^2+\alpha R_1^2-\mathbb{1}_{[\alpha R_1+\beta_1-f_1r_1-\beta_0c<0]}l-(\beta_0+\beta_1)w\right] \tag{6}$$

where w is the social cost of supplying public liquidity.

[12]The cost c captures both the pecuniary cost of borrowing at a penalizing rate and the stigma associated with borrowing from the public liquidity backstops.

Diamond and Kashyap (2016) considers the optimal liquidity regulation in the case where the bank does not have access to public liquidity, $\beta_0 = \beta_1 = 0$. In this case, the bank has to exchange illiquid assets for liquid assets. The optimal regulation is that for each of the dollar of deposits, the bank needs to hold a fraction of $\rho = \frac{(t+\Delta)r_1}{R_1}$ in liquid assets. This liquidity buffer deters runs in both states. ρ is also known as the run-off rate of the bank's liabilities.

The presence of the public liquidity backstop complicates the liquidity regulation. Instead of exchanging liquid assets for illiquid assets, the bank can borrow from the public liquidity backstop to purchase liquid assets. Such transaction can relax the liquidity constraint because regulators usually treat public liquidity backstops as a stable funding source and assign lower run-off rates to them.[13] Formally, define ρ_c as the run-off rate of the borrowing from the public liquidity backstop, the liquidity constraint becomes

$$\alpha \geq \rho + \rho_c \beta_0 \tag{7}$$

By drawing one unit of credit to buy liquid assets, the bank can relax the liquidity constraint by $1 - \rho_c$ unit. For simplicity, we assume that the run-off rate of the borrowing from the FHLBs is zero, but the result holds for any $\rho_c < 1$.[14] We can derive the following result:

Proposition 1. *There exists a threshold cost of public liquidity, c^*, which is determined by the following equation:*

$$(p\Delta + t)(R_1 - c^*)r_1 + (-c^{*2} + c^* R_1 - R_1^2 + R_2^2)\rho = 0 \tag{8}$$

such that

- *If the cost of public liquidity is higher than c^*, the bank draws 0 units of public liquidity and holds $1 - \rho$ units of illiquid assets at date 0.*

[13] FHLB advances backed by non-HQLA have substantially lower runoff rate than secured funding with similar collateral or unsecured funding from private-sector counterparties. For instance, the run-off rate of secured funding backed by non-HQLA collateral is 25% if the counterparty is the FHLBs but is 100% for private-sector counterparties. Note that the run-off rate of funding from the central banks is 0% but the associated stigma (high c) makes it unattractive for banks.

[14] In practice, the bank can also raise more retail deposits, However, expanding retail deposits base is usually quite expensive because it requires investment on branch network.

- *If the cost of public liquidity is lower than c^*, the bank draws ρ units of public liquidity and holds* 1 *units of illiquid assets at date 0.*

Note that Prediction 1 links c^* with ρ through a simple quadratic equation. An important question to ask is how the liquidity regulation of banks affects this threshold. We answer this question next:

Proposition 2. *The threshold which makes the bank indifferent between borrowing from the public liquidity backstop and exchanging illiquid assets, c^*, is an increasing function to the liquidity requirement, ρ. Formally, we have*

$$\frac{\partial c^*}{\partial \rho} = \frac{c^{*2} - c^* R_1 + R_1^2 - R_2^2}{-(p\Delta + t)r_1 + (-2c^* + R_1)\rho} > 0 \tag{9}$$

We plot the threshold of c^* as a function of the liquidity requirement ρ in Figure 2. This result shows that a tightening in liquidity regulation increases the bank's demand for public liquidity. To counter the increase in demand, the regulator has to raise the cost of public liquidity backstop. Otherwise, the bank will end up using more public liquidity, defeating the purpose of liquidity regulation.

So far, we have assumed that the lending capacity of the public liquidity backstop is unlimited. In practice, the lending capacity may be binding in some states of the world. For instance, in the recent crisis, the lending capacity of FHLBs significantly shrunk after two other housing GSEs, Fannie and Freddie, ran into trouble, which led investors to question the health of FHLBs (Ashcraft, Bech, and Frame 2010). We incorporate this possibility by assuming that in the bad state of the world, the lending capacity of the public liquidity backstop shrinks to $\phi < \Delta r_1$. In this case, bank runs can still occur even if the bank meets the liquidity regulation. Formally, we can prove the following result:

Proposition 3. *If the credit line is unstable, there exist two thresholds, $c_D^* < c_U^*$, which are determined by the following equations,*

$$\begin{aligned} -(1-p)\rho c_D^{*3} + ((1-p)(\rho R_1 - (t+\Delta)r_1) + \phi)c_D^{*2} \\ -(p(R_2^2 - (1-t-\Delta)r_2^2) - R_2^2\rho)c_D^* + R_2^2((t+\Delta)r_1 - \rho R_1 - \phi) = 0 \end{aligned} \tag{10}$$

$$c_U^* R_1(tr_1 + p\Delta r_1 - \rho R_1) - c_U^{*2}(\phi - \Delta(1-p)r_1) + R_2^2(-\Delta r_1 - tr_1 + \rho R_1 + \phi) \tag{11}$$

such that

- *If the cost of public liquidity is lower than c_D^*, at date 0, the bank draws ρ units of public liquidity and holds* 1 *units of illiquid assets; at date 1, the bank is solvent in the good state and defaults in the bad state.*

- *If the cost of public liquidity is higher than c_D^* and lower than c_U^*, at date 0, the bank draws b_0 units of public liquidity and holds $1 - b_0$ units of illiquid assets, where b_0 is determined by the following equation: $\rho R_1 + \phi - (t + \Delta)r_1 - b_0 c = 0$; at date 1, the bank is solvent in both states.*

- *If the cost of public liquidity is higher than c_U^*, at date 0, the bank draws* 0 *units of public liquidity and holds $1 - \rho$ units of liquid assets; at date 1, the bank is solvent in both states.*

It may be surprising that bank runs may still occur even if the bank meets the liquidity regulation. The intuition is the following. When the cost of public liquidity is very low, the bank borrow extensively from the public liquidity backstop to finance liquid assets. In the bad state, as the lending capacity of the public liquidity backstop shrinks, the bank cannot roll over all of its loans and has to use the liquidity buffer to pay back the public liquidity backstop. This leaves little liquidity to meet the withdrawals of depositors, which ends up triggering a bank run. A general lesson from this result is that funding a liquidity buffer using unstable short-term debt does not effectively deter bank runs. Instead, it creates a phantom liquidity problem: liquidity appears to be abundant in normal times but can quickly disappear in bad times.

We plot the thresholds of c_U^* and c_D^* as functions of the liquidity requirement ρ in Figure 2. We find that to prevent banks from using public liquidity to meet liquidity regulation, regulators need to increase the cost of accessing public liquidity, c, in conjunction with the liquidity requirement ρ. A lack of coordination may result in potential unintended consequences, which we explore in the following empirical tests.

4 Empirical Evidence

In this section, we first describe the data. Then, we evaluate our model predictions empirically.

4.1 Data

We combine several data sources to analyze the linkages between commercial banks, FHLBs, and MMFs. The summary statistics are reported in Table 1. We first use the Call Reports for balance-sheet information of U.S. commercial banks. We consider the sample period from 2011 to 2014, the four-year window surrounding the fourth quarter of 2012 during which the Fed carried out its first ever system-wide stress test of bank liquidity. The HQLA holdings account for 18% of the assets on average. We follow the methodology by Hong, Huang, and Wu (2014) to calculate the liquidity coverage ratio for banks.[15] 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, which accounts for 38% of the wholesale funding of banks.

Second, we use iMoneyNet for information about the U.S. MMFs. This data set provides fund-level information on asset size, yields, and fund families. Following a regulatory reform by SEC in 2010, MMFs in the United States are required to file their detailed portfolio information at individual security level with the SEC through N-MFP forms. We take advantage of this newly available information to trace the shift in the portfolio composition of U.S. MMFs in response to the post-crisis liquidity regulation. Our sample on MMFs is from July 2011 to December 2017 with monthly frequency. We collapse the observations to fund-family level. In our sample the share of the loans made to the FHLBs is around 12% of the total assets of a fund family.

Finally, we manually compile a unique data set on the balance sheets of the FHLBs and the pricing of FHLB advances and debt. We collect the balance sheets and income statements from SEC filings from 2011 to 2017 with quarterly frequency. Advances accounts for 56.9% of the total assets of the FHLBs. The FHLBs are highly levered. The average capital ratio is 5.2%, which is only half of the average capital ratio of banks. We complement the balance sheet data of the FHLBs with the issuance and 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). Lastly, we obtain benchmark yields of money market instruments from the FRED database of the Federal Reserve Bank of St. Louis.

[15] The detailed formula can be found in the Online Appendix.

4.2 Liquid Buffer Held by Banks

We first examine the effect of post-crisis liquidity regulations on the holding of HQLA by commercial banks. Panel A of Figure 3 plots the amount of HQLA as a fraction of the total assets of U.S. commercial banks from 2011 to 2014. The solid line and the dashed line represent the LCR banks and the non-LCR banks respectively.[16] We normalize the starting level of HQLAs to 0. We find that the holdings of HQLA were in a similar trend across the two groups of banks until the late 2012, after which LCR banks substantially increased their HQLA compared to the non-LCR banks. The timing of the divergence lines up with the first ever system-wide liquidity stress test for the big banks which marks the start of post-crisis liquidity regulations.

We confirm the observation from the graph using the difference-in-differences research design. We define *Post* as a dummy variable that equals 1 if the time is after 2012 Q4.[17] Our sample is the four-year window surrounding the treatment event in 2012 Q4. We define *LCR Bank* as a dummy variable that equals one if a bank is subject the full LCR in 2012 Q4. The coefficient of the interaction term between *LCR Bank* and *Post* captures the effect of liquidity regulation. The regression model is the following:

$$HQLA_{i,t} = \beta Post_t * LCR\ Bank_i + \gamma X_{i,t} + \tau_t + \tau_i + \epsilon_{i,t} \tag{12}$$

$X_{i,t}$ is a set of control variables including the lagged log assets, deposit ratio, and capital ratio. The estimation results are presented in Table 2. We include bank fixed effects and time fixed effects consecutively to absorb unobservable differences in bank business models and macro-economic shocks such as quantitative easing. We find that LCR banks increase their holding of HQLA by around 3.6% of the total assets in the post regulation period compared to the control group. The results are robust to the inclusion of bank and time fixed effects.

One may worry that some macro-economic shocks in the post period may affect the two groups of banks differently, which may drive our result. To sharpen our identification, we examine the cross-section relation between pre-regulation liquidity coverage ratio and the subsequent changes in the holding of HQLAs among the 8 LCR banks in Panel A

[16] We exclude Capital One in this graph because its HQLAs appear to vary dramatically from quarter to quarter. However, including this bank would not change the main regression results.

[17] The result is robust to other alternative cutoff dates because the effect of liquidity regulation is quite persistent. The result using alternative cutoffs can be found in the online Appendix.

of Figure 4. We find that banks with lower liquidity coverage ratio before the liquidity regulation to buy more HQLAs subsequently. This result suggests that the increase in the HQLAs is indeed driven by the liquidity regulation.

4.3 Banks' Borrowing from the FHLBs

At a first glance, the increase in banks' holding HQLA seems to suggest that liquidity regulation has achieved its goals. However, a closer look at the balance sheets of commercial banks reveals a worrying trend: commercial banks are increasingly relying the Federal Home Loan Banks as a source of financing.

Panel B of Figure 3 plots the amount of advances over assets of U.S. commercial banks from 2011 to 2014. The solid line and the dashed line represent the LCR banks and the non-LCR banks respectively. We normalize the starting level of advances to 0. We find that LCR banks significantly increase their advances compared to the non-LCR banks at the onset of liquidity regulations. To confirm the graphical observation, we again employ the difference-in-differences strategy by comparing LCR banks to non-LCR banks. The regression model is similar to equation 12:

$$Advances_{i,t} = \beta Post_t * LCR\ Bank_i + \gamma X_{i,t} + \tau_t + \tau_i + \epsilon_{i,t} \tag{13}$$

where *Advances* is the amount of advances normalized by total assets. Other variables are constructed in the same way as in Equation (12). Table 3 presents the results. We find that LCR banks increase their advances by around 1.3% of the total assets during the two-year period after the start of liquidity regulation compared to the control group. Comparing the coefficients with Table 2, the increase in advances accounts for around 30% of the increase in the HQLAs in this period.

Panel B of Figure 4 further relates the pre-regulation liquidity coverage ratio of each of 8 LCR banks to the subsequent changes in advances. We again find a strong negative relationship: banks which have low liquidity coverage ratio (thus further away to meet the liquidity regulations) increase their borrowing by more. This evidence further lends support to the hypothesis that the increase in advances is driven by the liquidity regulation.

What do banks do with the money borrowed from the FHLBs? According to the mission of the FHLBs, advances should be used to promote housing finance and community investment. In this case, we should expect an increase in real estate loans made by banks when they draw advances. In contrast, if advances are used to meet liquidity regulation, we should expect an increase in the HQLAs. To examine the usage of advances, we construct binned scatter plots of the annual changes in advances against the contemporaneous changes in real estate loans or HQLA. The result is shown in the top panel of Figure 5. All the quantities are expressed as a percentage of bank assets. The sample period is from 2012Q3 to 2014Q4. We find a striking difference in the behavior between LCR banks and non-LCR banks. For non-LCR banks, an increase in the advances is associated with a contemporaneous increase in real estate loans. However, for LCR banks, an increase in the advances is associated with a contemporaneous increase in HQLA. This pattern is consistent with some anecdotal evidence that some banks borrow FHLB advances to buy HQLA.[18]

Why do we see an increase in banks' borrowing from the FHLBs expand during the roll-out of liquidity regulations? Proposition 2 of our model shows that an tightening in liquidity regulation increases the demand for funding from public liquidity backstops because public liquidity is qualified as a stable funding source. Whether the borrowing from public liquidity backstops will expand in equilibrium depends on the pricing of public liquidity. Figure 6 plots the spread between 3-month fixed-rate FHLB advances and asset-back commercial papers (ABCPs), which measures the relative cost of borrowing from the FHLBs vs. from a private lender.[19] The solid line is the raw spread and the dashed line adjusts for the dividends that banks receive when they borrow from the FHLBs.[20] We find that the relative borrowing costs remained largely unchanged during the 2012-2014 period despite the fact that LCR had increased banks' demand for FHLB advances. As predicted by the model, the FHLB advances expanded significantly from 2013 to 2014. Another

[18]For instance, FHFA Office of Inspector General reports that a bank admits in an interview with the FHFA officials that "the increase in FHLB advances since our historically low levels of the past two years has been driven specifically by legal entity liquidity coverage ratio (LCR) requirements and our desire to build high quality and long term funding". See Recent Trends in Federal Home Loan Bank Advances to JPMorgan Chase and Other Large Banks Evaluation, FHFA-OIG report, April 16, 2014.

[19]Because FHLB advances are collateralized loans, we use asset-backed commercial paper (ABCP) as a benchmark. The result is quite similar with other maturities or other money market instruments such as financial commercial paper and repos. It should, however, be noted that the depth of the ABCP market is limited, and the eligible collateral in ABCP markets and repo markets may be more restricted than the ones eligible for FHLB advances. The haircuts may also vary.

[20]Banks need to put down 4% to 5% of principal borrowed as activity-based capital, which will be returned when the associated advances have been repaid. In the meantime, banks receive high dividends from the activity-based capital which substantially lower the effective borrowing costs. The average payout ratio of the FHLBs is 43% from 2010 to 2017.

interesting observation in Figure 6 is that the relative cost of borrowing from FHLBs actually went down in the late 2016 when the Money Market Reform was implemented. We examine this period in the next section.

4.4 Effect of Money Market Reform on the Funding of FHLBs

So far we have shown that the liquidity regulations on banks increase banks' reliance on a public liquidity backstop, the FHLBs. In this section, we show that the other major pillar of the post-crisis liquidity regulations, the Money Market Reform, reinforced this trend by increasing the supply of short-term funding to the FHLBs.

Figure 7 plots the aggregate assets held by MMFs by fund types. The light area is the total assets of government funds, which can only hold treasury or agency debt. The dark area is the prime funds, which can also hold riskier private debt, such as bank commercial paper. The first red vertical line indicates the date when the MMF reform was finalized, July 2014. The second red vertical line indicates the implementation deadline of MMF reform, October 2016. Prime MMFs face more-stringent regulation than government funds because they are exposed to more credit and liquidity risks as witnessed in the crisis. We can see from Figure 7 that the prime funds lost deposits rapidly leading up to the deadline of the reform, while government funds gained deposits at the same time. The total amount of deposits of the MMF industry stayed almost constant.[21]

As more assets shifted from riskier prime funds to safer government funds, it seems that the MMF industry became safer overall. However, an analysis of the security-level data on MMF holdings shows a more nuanced view. We find that the MMF industry has substantially increased their lending to FHLBs. Figure 8 plots holding of FHLB debt by MMFs over time. The sum of the light blue and dark blue areas is the amount of FHLB debt as a fraction of the total MMF assets. The amount of FHLB debt stayed around 5% until 1 year before the MMF reform deadline of 2016 but jumped to a striking 20% afterwards. The total dollar amount skyrocketed to 500 billion at the end of 2017, and accounted for half of the liabilities of the FHLBs. Taken together, the MMF industry has become the single largest creditor of the FHLBs.

[21] 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).

To investigate the reason behind the striking increase in lending to FHLBs by MMFs, we further break down the holding of FHLB debt into two groups of fund families according to their exposure to the MMF reform. As discussed above, prime funds are more affected by the MMF reform. Therefore, fund families that have more assets under prime funds should be more affected by the MMF reform. Following this logic, we separate all the fund families into two groups based on whether more than 50% of their assets were in prime funds as of January 2014. The dark blue area in Figure 8 shows the contribution of FHLB lending from the more exposed fund families, while the light blue area shows the contribution of the less exposed fund families. Figure 8 reveals an interesting pattern. Before the MMF reform, the holding of FHLB debt was almost the same for these two groups of fund families. However, leading to the reform, the fund families that have higher exposure to the reform substantially increased their holding of FHLB debt. In fact, most of the increase in the FHLB debt holdings can be attributed to these more exposed fund families.

This observation is confirmed in a regression analysis. We examine the 6-year window around July 2014, the month when the final MMF rule was released. The unit of an observation is the fund-family-quarter combination. We measure the fraction of FHLB debt held by each fund family and relate it to its exposure to MMF reform as measured by the fraction of assets in prime funds pre-reform. The regression model is the following

$$FHLBDebt_{i,t} = \beta Post_t * Exposure_i + \gamma X_{i,t} + \tau_t + \tau_i + \epsilon_{i,t} \tag{14}$$

Post is a dummy variable that equals one if the month is equal to or after July 2014, the month when the MMF reform was finalized, and zero otherwise.[22] *Exposure* is defined as the fraction of prime fund assets in the fund family. We also include fund family characteristics and time and fund fixed effects to absorb unobservable macro economic shocks and time-invariant fund family characteristics. Table 4 shows that consistent with Figure 8, a higher exposure to the MMF reform leads to more FHLB debt holdings.

[22] We choose this date rather than the implementation deadline in October 2016 to account for the anticipation of MMFs. The result is robust to use the alternative cutoff.

4.5 Summary of Empirical Findings

To summarize, the two major liquidity regulations, LCR and Money Market Reform, affect the U.S. banking system in two phases. In the first phase (2012–2014), LCR increased the *demand* for FHLB advances by big banks. In the second phase (2015–2016), Money Market Reform increased the funding supply of MMFs to the FHLBs, and consequently, the *supply* of FHLB advances to all types of banks. Taken together, these two liquidity regulations have significantly expanded the balance sheet of the FHLBs. As shown in panel A of Figure 9, the total assets of FHLBs increased by 50% during the period from 2012 to 2017 and reached $1.1 trillion by the end of 2017. At the same time, the FHLBs are increasingly funded by short-term debt. As shown in panel B of Figure 9, 70% of the balance sheets are financed by short-term debt by the end of 2017.

4.6 Implications

This section discusses the implications of our findings for the policy outcome of liquidity regulations. We first evaluate whether the post-crisis liquidity regulations have reduced the reliance of private banks on public liquidity backstops. Then we evaluate whether the liquidity buffer mandated by the regulations can effectively deter bank runs. Finally, we examine whether the concentration risk of the FHLB lending has increased following liquidity regulation.

4.6.1 Reliance on Public Liquidity

Stein (2013) argues that one important goal of liquidity regulation is to reduce private banks' reliance on public liquidity stops. However, our results suggest that liquidity regulation seems to paradoxically increase banks' reliance on public liquidity through the FHLB systems, resulting in an expansion of the FHLB balance sheet. One may argue that a large FHLB balance sheet is not necessarily a bad thing because it is the government's intention to promote housing markets by implicitly guaranteeing their debt. Nevertheless, in light of our finding that the FHLB advances are used by banks to meet the LCR requirements, it is unclear how much of the subsidy is passed through to the ultimate borrowers in the housing market. In this section, we estimate the total value of government subsidy to the FHLBs and the fraction got passed through to the ultimate borrowers.

We start by computing the funding advantage of the FHLBs over private banks for different types of debts as shown in Figure 11. From 2011 to 2017, the FHLBs enjoy a funding advantage of around 20-50 basis points compared to private financial institutions. The funding advantage is usually greater in periods of market stress. We then multiply the funding advantage with the corresponding dollar amount of debt outstanding, and sum across different types of debt to calculate the total subsidy. Panel A of Figure 12 plots the total amount of government subsidy over time (the sum of light and dark areas). We find that the FHLBs receive a substantial amount of implicit subsidy: the average subsidy is 3.2 billion per year from 2011 to 2017.

Next, we estimate the fraction of the subsidy passed through to the ultimate borrowers in the housing market using a simple supply and demand framework shown in Figure 13. D is the demand for real estate loans. S_0 is the supply of real estate loans if there are no FHLB advances. The advances increase the loan supply, which shift the supply supply curve to S_1. The borrower surplus gain due to the advances is the shaded regions, which can be calculated using the following equation:

$$\text{Subsidy to Borrowers} = (-\Delta r)q_0 + \frac{1}{2}(-\Delta r)\Delta q \tag{15}$$

where $\Delta r = r_1 - r_0$ and $\Delta q = q_1 - q_0$. The first term is the blue area and the second term is the red area. The intuition of this formula is the following. If the government subsidy is passed through to the ultimate borrowers, we should see that more advances are translated into lower real estate loan rates ($\Delta r < 0$) or greater quantity of real estate loans ($\Delta q > 0$). We can estimate the rate pass-through and the quantity pass-through using the following the regression model with a panel data of bank loan rates and loan quantities:[23]

$$q_{i,t} = \beta_1 a_{i,t} + \tau_t + \tau_i + \epsilon_{i,t} \tag{16}$$

$$r_{i,t} = \beta_2 a_{i,t} + \tau_t + \tau_i + \epsilon_{i,t} \tag{17}$$

where $r_{i,t}$ ($q_{i,t}$) is the real estate loan rate (amount) of bank i in quarter t. $a_{i,t}$ is the amount of FHLB advances. Both the real estate loan amount of FHLB advance amount are normalized by the total assets. We include time fixed effects to absorb the common

[23]Previous studies on the subsidy pass-through of Fannie Mae and Freddie Mac exploit the rate difference between conforming (subsidized) and non-conforming (unsubsidized) mortgages (CBO testimony 2011, Passmore 2005). This methodology does not work for FHLBs because FHLB advances are indirect subsidies that are not linked to specific type of real estate loans.

time trends and bank fixed effects to absorb macro economic shocks and unobservable bank characteristics. The estimated coefficient, β_1, can be interpreted as the increase in the real estate loan amount per unit of advances, and $-\beta_2$ can be interpreted as the reduction in the real estate loan rates per unit of advances. Panel B of Figure 12 plots the coefficient estimates and standard errors for each year. The black dashed line shows the quantity pass-through, β_1. We can see that a one dollar increase in the advances is translated into a 15 cent increase in real estate loans in 2011. However, the quantity pass-through declines substantially to around 5 cents after the LCR started to become binding in 2013. Similar trend is found for the rate pass-through, $-\beta_2$. A 1% increase in advances over assets decreases the real estate loan rates by 1.5 basis points in 2011, but it declines to 1 basis points in 2017. The decline in both the quantity and rate pass-through is consistent with our previous finding that banks start to use advances to purchase liquid assets rather than lend to real estate market following the roll-out of liquidity regulation.

Given the estimates of quantity and rate pass-through, we can calculate the total changes in the real estate loan amount due to advances for bank i at quarter t as $\Delta q = \beta_1 a_{i,t}$, and the total changes in the real estate loan rate due to advances for bank i at quarter t as $\Delta r = \beta_2 a_{i,t}$. Finally, we can plug Δr and Δq into equation 15, to the total subsidy bank i pass through to borrowers at time t. Panel A of Figure 12 plots the total government subsidy and the amount passed through to the borrowers. The most striking finding is that although the balance sheets of the FHLBs have expanded considerably in recent years, which drives up the total subsidy, the amount passed through to ultimate borrowers has stayed almost the same. Most of the increase in the subsidy appears to accrue to commercial banks and FHLBs themselves. This appears to be at odds with the main stated mission of the FHLB system, which is to finance housing and promote community investment.

4.6.2 Phantom Liquidity

Diamond and Kashyap (2016) argue that the other important goal of liquidity regulation is to build a liquidity buffer to deter bank runs. However, our results suggest that a significant fraction of the liquidity buffer is financed by short-term debt intermediated by the FHLBs, which may not be effective in deterring bank runs. Specifically, as shown in Table 2 and Table 3, every dollar increase in the liquidity buffer is associated with around

30 cent increase in the FHLB advances.[24] The advances used by LCR banks to finance the liquidity buffer appear to be exclusively short-term as shown in Table 5. The FHLBs in turn finance the advances using ultra short-term loans from MMFs: as shown in Figure 10, the average maturity of the FHLBs' half-trillion borrowing from MMFs is below 40 days as of 2017.

What could be the problem of using short-term debt to finance liquidity buffers? Our model shows that this may create a phantom liquidity problem: liquidity appears to be abundant in normal times but may quickly disappear in stress time. Consider the following hypothetical scenario: if there is unexpected shock which triggers short-term creditors to withdraw their funding to MMFs, MMFs will be forced to withdraw funding from the FHLBs. The FHLBs in turn will be forced to withdraw funding to banks. Banks will have to draw down their liquid assets to repay the debt with FHLBs, which may leave insufficient liquidity buffers to meet the withdrawals of other creditors.

There are historical episodes which resemble such a scenario described above. Ashcraft, Bech, and Frame (2010) document that in the first half of the 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.

4.6.3 Concentration Risk

As the liquidity regulations increase the demand for advances among the big banks, the lending of FHLBs may have become more concentrated. For instance, at the end of 2017, Wells Fargo's borrowings accounted for nearly 59% of Des Moines Home Loan bank's total advances. Such concentrated lending raises concerns among market participants that the FHLB may be exposed to heightened counterparty risk.[25] Memory of such risk is still fresh: the Seattle FHLB was forced to merge with Des Moines FHLB after the crisis, in part due to the failure of it's largest member, Washington Mutual.

[24]Examining the aggregate quantity leads to similar conclusion: from 2012 to 2017, the liquidity buffer of all U.S. banks increased by around $1,170 billion while banks' borrowing from the FHLBs and the FHLBs' borrowing from MMFs increased by $250 and $330 billion respectively.

[25]See, American Banker, April 28, 2017.

We systematically examine the lending concentration of the FHLB system. Figure 14 plots the average Herfindahl-Hirschman Index (HHI) of the advance lending for the FHLB system over time.[26] We can see that since the roll-out of liquidity regulation in late 2012, the lending concentration has risen rapidly from 12% to 18%. To show that the 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 2012Q4. We find the counterfactual HHI stays almost flat, suggesting the rise in concentration is indeed driven by LCR banks. The increase in concentration is also apparent using an alternative concentration measure, the top 4 bank share of total advances. As shown in Figure 15, 6 out 11 FHLBs have a top 4 bank share over 60% in 2017. Such development is inconsistent with the regulatory effort to reduce the FHLBs' lending concentration.[27]

5 Regulatory fragmentation

The above discussion provides systematic evidence that the post-crisis liquidity regulation have caused a massive expansion of the FHLB system. It is puzzling why such a massive expansion did not receive much scrutiny from the regulators.

We suggest that regulatory fragmentation is likely to explain such regulatory inaction. In the Unites States, different financial institutions are often regulated by different regulatory agencies: Commercial banks are primarily regulated by the Federal Deposit Insurance Corporation (FDIC), the Federal Reserve Board, or the Office of the Comptroller of the Currency (OCC); MMFs are regulated by the SEC; while the FHLBs are regulated by the Federal Housing Finance Agency (FHFA). The regulators have different objectives. For the bank regulators (the Fed, FDIC, OCC), the objective of their liquidity regulation is to reduce liquidity risks and banks' reliance on public liquidity backstop. For the regulator of the MMFs, the SEC, the objective of Money Market Reform is to "make money market funds more resilient." In contrast, the regulator of the FHLBs, the FHFA, has a very different mandate, which is to ensure that the FHLBs to provide liquidity to member institutions to support housing finance and community investment. Because of this mandate, the FHFA seems hesitant about limiting the FHLBs' lending to commercial banks even if

[26] We match regional FHLBs to commercial banks based on the location of the headquarter of the commercial bank.

[27] 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.

it has noticed the rapid expansion of FHLB advances as early as 2014. In its report, the Office of Inspector General of FHFA notes the following:

"The benefits of the surge in advances to the four largest members include an increase in interest income that FHLBs earn from making advances. Further, FHFA defines all advances as 'core housing mission assets." Thus, increased advances could address FHFA's concerns about the relatively high level of System investments in 'non-core housing mission assets', such as mortgage-backed securities issued by Fannie Mae and Freddie Mac.

The risks include the significant losses an FHLB could incur if a large member defaults on its advances, particularly if the advances were improperly collateralized or the value of the collateral had declined significantly. FHFA officials emphasized that FHLB advances for the purpose of meeting recent liquidity requirements are legal and not inconsistent with the Systems mission."[28]

As made clear by this quote, FHFA views the increase in advance borrowing consistent with its mandate because it increases the profits of the FHLBs and shifts the FHLBs' portfolio from "non-core housing mission assets" towards "core housing mission assets". However, from the perspective of the bank regulators or the society as a whole, such a development compromises the effectiveness of the post-crisis liquidity regulations. The growth in advances also create externalities for the FDIC which provides deposit insurance to banks because the FHLBs' "super lien" status gives them priority over depositors.[29]

6 Potential Policy Remedies

In this section, we consider several potential policy responses, to limit the regulatory arbitrage which undermines the liquidity regulation. We emphasize both the theoretical effectiveness as well as the practical feasibility based on the institutional arrangements that banks have with the FHLBs.

[28]See Recent Trends in Federal Home Loan Bank Advances to JPMorgan Chase and Other Large Banks Evaluation, FHFA-OIG report, April 16, 2014.

[29]If a bank is in trouble, the FDIC must repay the FHLBs immediately before paying depositors. This increases the exposure of the FDIC to bank failures.

6.1 Leverage constraint

We first consider a leverage constraint on the FHLB which limits its lending to banks to a fixed multiple of its capital. A particular institutional feature of the FHLBs may, however, render restrictions on leverages ineffective. As discussed more detail in the appendix, banks need to contribute "activity-based capital" when borrowing from the FHLBs. This activity-based capital automatically relaxes the leverage constraint. To see this point, define e as the initial capital of the FHLBs; μ as the amount of activity-based capital that banks need to contribute per dollar of credit they get from the FHLBs; β as the amount of money banks borrow from the FHLBs; κ as the maximum leverage ratio. The leverage constraint can be written as the following

$$\beta \leq \kappa(e + \mu\beta) \tag{18}$$

We can solve the maximium amount of the borrowing from the FHLBs before hitting the leverage constraint as the following[30]

$$\beta \leq \frac{\kappa e}{1 - \kappa\mu} \tag{19}$$

When the the activity-based capital per unit of borrowing, μ, is large enough, the extra equity the FHLB raises through one dollar of lending can mitigate the negative impact on the capital ratio (for instance, μ approaches $\frac{1}{\kappa}$). As a result, the leverage constraint will never be binding. Therefore, we do not expect the leverage constraint to be an effective tool to control the balance sheets of the FHLBs.

6.2 Adjusting the Run-off Rates of Advances

We then consider a policy proposal that adjusts the run-off rates of advances. In the actual LCR regulations, FHLB advances receive favorable run-off rates because they are viewed as a stable source of funding for the banks. This may not be a good assumption given that the FHLBs themselves are increasingly financed by short-term unstable funding. Therefore, a potential remedy is to adjust the run-off rate on the FHLB advances to reflect

[30] Notice that in practice, the initial equity, e, receives a weight of 1.5 while the activity-based capital, βa, receive a weight of 1. Here we use the same weight but the result does not change when we apply different weights.

the lack of stability of the funding source of the FHLBs. Specifically, we can consider the following adjusted liquidity constraint for the bank:

$$\alpha \leq \rho(1+\beta) \tag{20}$$

Where ρ is the optimal liquidity ratio chosen by the banking regulator. The advantage of this policy is that it can be implemented by the bank regulator alone. Therefore, it circumvents the coordination issue among different regulators. The downside of this approach is that banks may incur an exorbitant cost to meet liquidity regulation if liquid assets are scarce. Moreover, a high compliance cost may also incentivize banks to find other ways to evade the regulation.

6.3 Price-based Mechanism

Finally, we consider the a price-based mechanism such as the Committed Liquidity Facility (CLF) used in Australia suggested by Stein (2013) in a speech at the Federal Reserve Bank of Richmond. In this setting, banks can pay a fee to the central bank for a loan commitment. The *unused* capacity of the loan commitment of CLF can be counted as liquidity buffers to meet LCR and banks do not have to draw the loan commitment to purchase liquid assets. The regulator sets the commitment fee of CLF to reflect the expected social cost of supplying public liquidity. Specifically, the optimal fee of accessing the CLF, k, in our model is

$$k = pw \tag{21}$$

where k is the commitment fee; p is probability of the bad state in which case the loan commitment is drawn by banks; and w is the social cost of supplying public liquidity. Note that the commitment fee k is different from c, the cost for the drawn credit, which should be set to risk-free rates in this case. Under the CLF, if the liquidity premium is higher than the commitment fee, banks will use the CLF to meet liquidity regulation. If the liquidity premium is lower than the commitment fee, banks will buy liquid assets instead. In other words, the commitment fee puts a cap on the compliance cost of liquidity regulation (Stein 2013).

There are three important differences between CLF and the FHLBs. First, the cost of borrowing from FHLBs is subsidized which distorts banks' incentive to use public liquidity. In contrast, under CLF, banks bear the social cost of liquidity transformation. Second, under the FHLBs, banks have to draw the advances to buy liquid assets, which may further drive up the liquidity premium. In contrast, under CLF, banks do not have to purchase liquid assets because the unused capacity of the loan commitment of CLF is counted as liquidity buffers in LCR. Finally, the lending capacity of the FHLBs is limited and could be unstable in times of crisis. In contrast, the lending capacity of CLF is unlimited and stable because it is backed by the central bank's ability to create money.

7 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 successfully reduced the liquidity transformation performed by commercial banks and MMFs. Commercial banks hold more liquidity buffers while the risky segment of the MMF industry, the prime MMFs, has shrunk significantly. However, digging deeper, we find that the banking system increasingly relies on a public liquidity backstop, FHLBs, to meet liquidity requirements. Banks ramp up their borrowing from the FHLBs while MMFs shift their short-term lending to FHLBs. We show that much of the implicit subsidy associated with the implicit government guarantee on the FHLBs accrues to banks rather than being passed to the intended recipients, the mortgage borrowers. The increasing role of a government-sponsored enterprise in the aggregate liquidity transformation is at odds with the goal of reducing banks' reliance on a public liquidity backstop.

We develop a simple model building on Diamond and Kashyap (2016) to show that any bank liquidity regulation must also simultaneously address the way in which government-supplied liquidity is priced. If the cost of accessing government-supplied liquidity is underpriced, the liquidity risk will tend to remain in the banking system, thereby compromising the goals of liquidity reforms. We use the model to consider several regulatory remedies for the unintended consequences. We show that tightening leverage requirements may not be effective in constraining the lending of the FHLBs. Instead, adjusting the run-off rate assumption for FHLB advances in the LCR or adjusting the cost of public liquidity may help to align the private and social cost of accessing public liquidity.

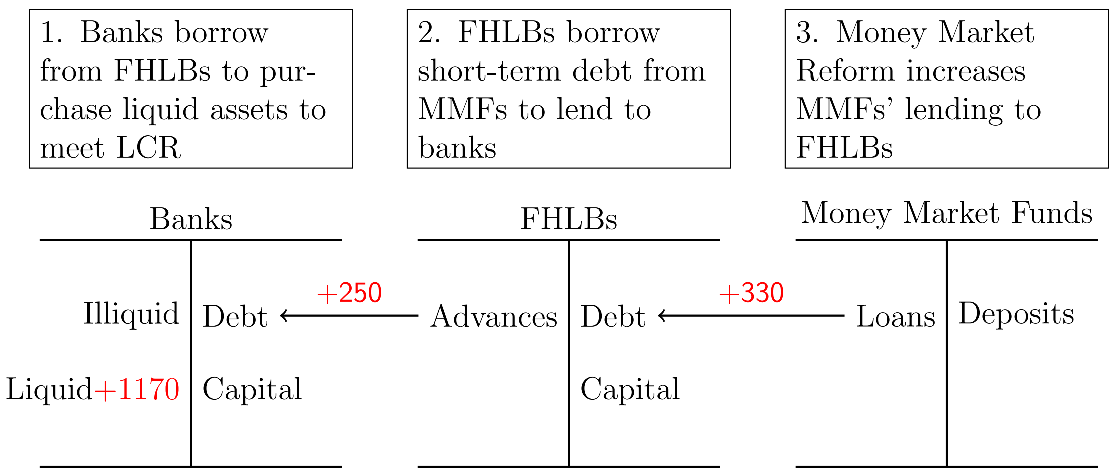


Figure 1: How U.S. Banking System Responds to Liquidity Regulations
This diagram illustrates how banks, FHLBs, and MMFs respond to post-crisis liquidity regulations. From 2012Q3 to 2017Q4, liquidity buffers held by banks increased by $1,170 billion; banks increased their borrowing from the FHLBs by $250 billion, and the FHLBs increased their borrowing from the MMFs by $330 billion.

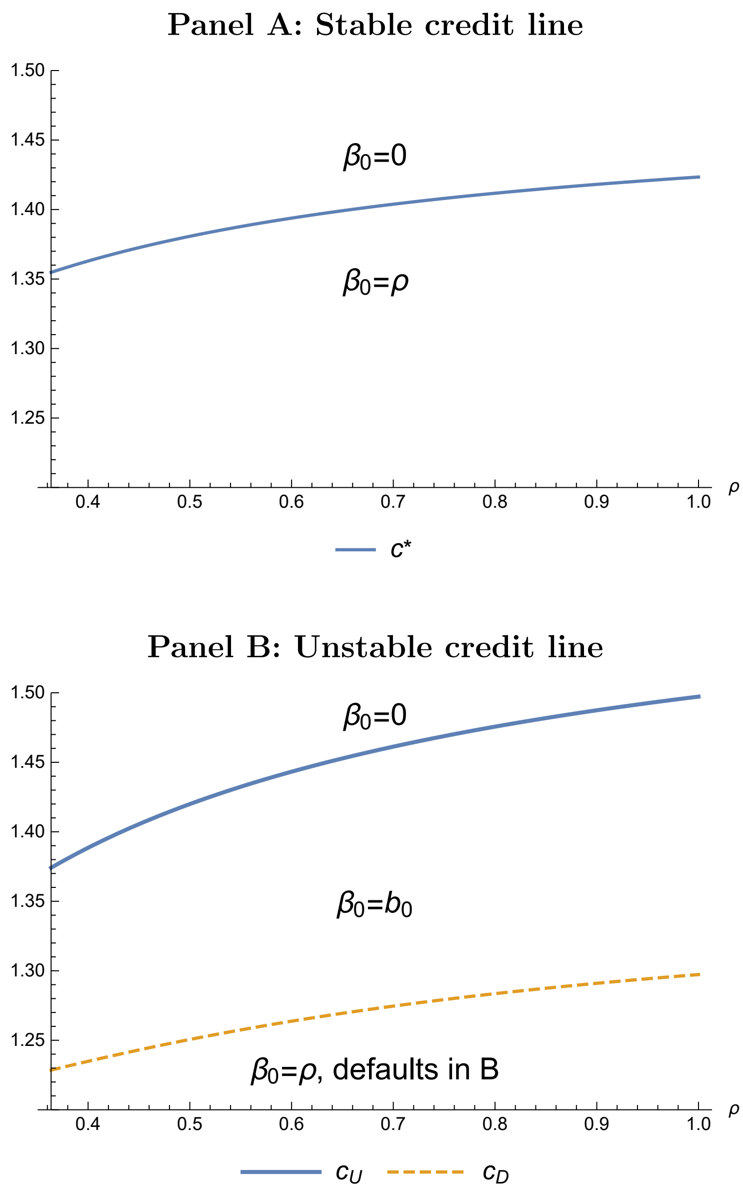
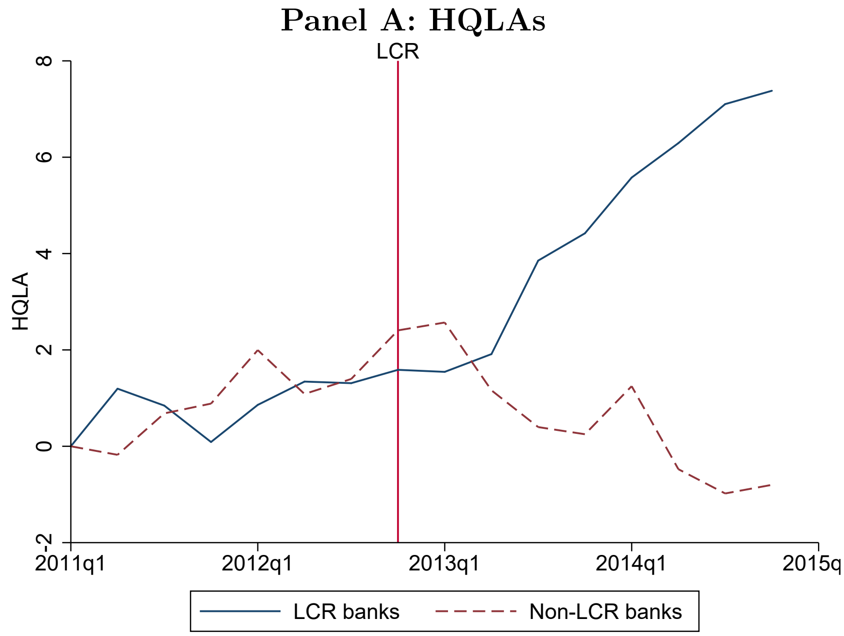


Figure 2: Liquidity Requirement and the Cost of Public Liquidity
This figure plots the cost of public liquidity which makes the bank indifferent between borrowing public liquidity and exchanging illiquid assets as a function of the liquidity requirement ρ. The parameter value are the following: $t = 0.3$, $\Delta = 0.1$, $R_1 = 1.1$, $R_2 = 1.33$, $r_1 = 1$, $r_2 = 1$, $p = 0.05$, $\phi = 0.3$.



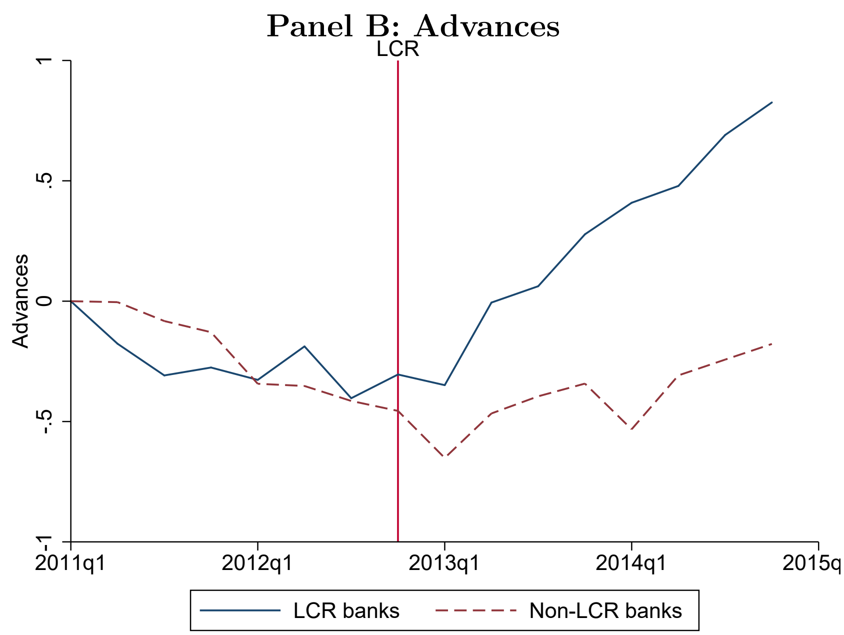


Figure 3: HQLAs and Advances of LCR Banks vs. Non-LCR Banks
This figure plots the high quality liquid assets (HQLAs) and FHLB advances of U.S. commercial banks over assets. The solid line shows LCR banks. The dashed line shows the non-LCR banks. Both lines are normalized to 0% at the beginning of the sample period. The sample period is from 2011 to 2014. Data source: Call Report.

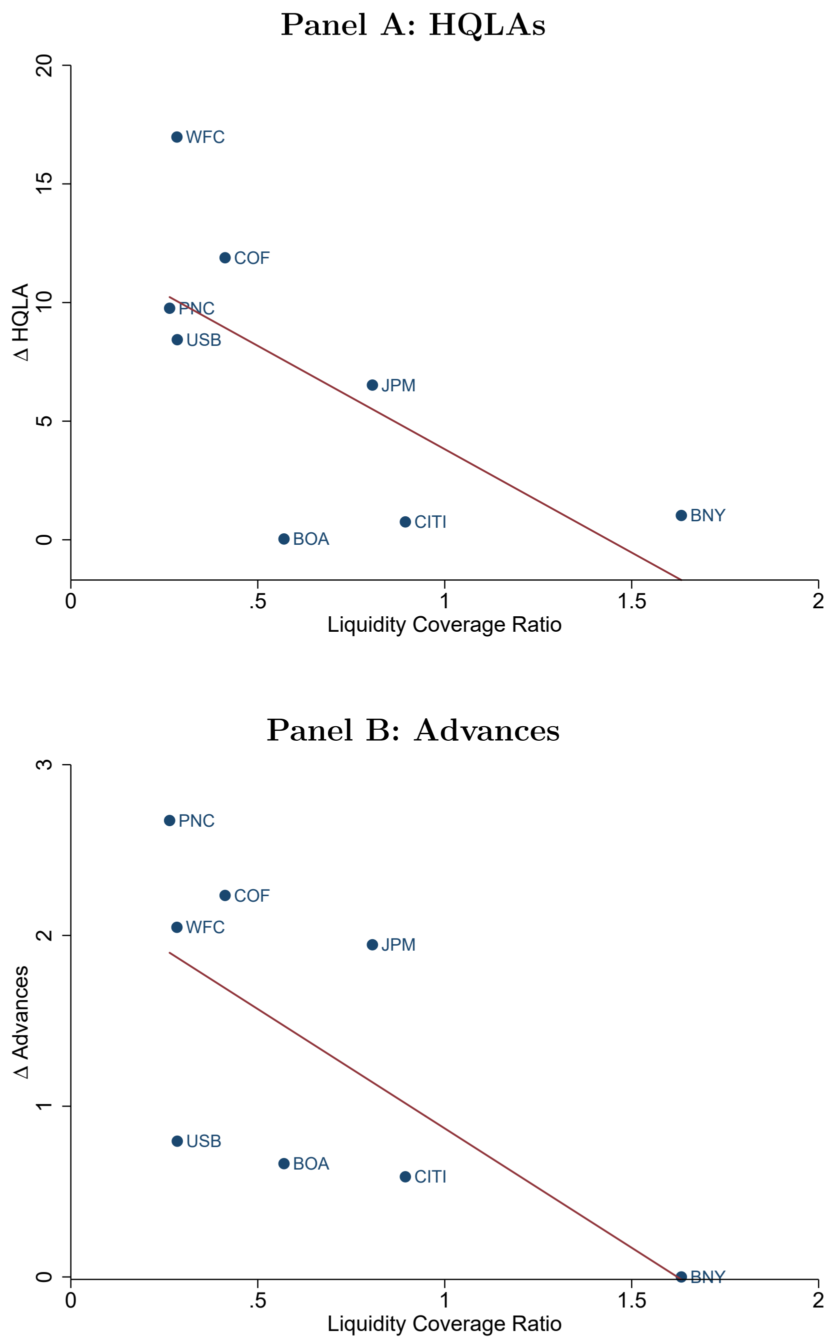


Figure 4: Pre-regulation LCR and Changes in HQLAs and Advances
This figure shows cross-section relation between the liquidity coverage ratio before liquidity regulation (2012Q3) and the subsequent changes in HQLAs and the FHLB advances (2012Q3-2014Q4) for the 8 LCR banks. Each dot represents a bank. Data source: Call Report.

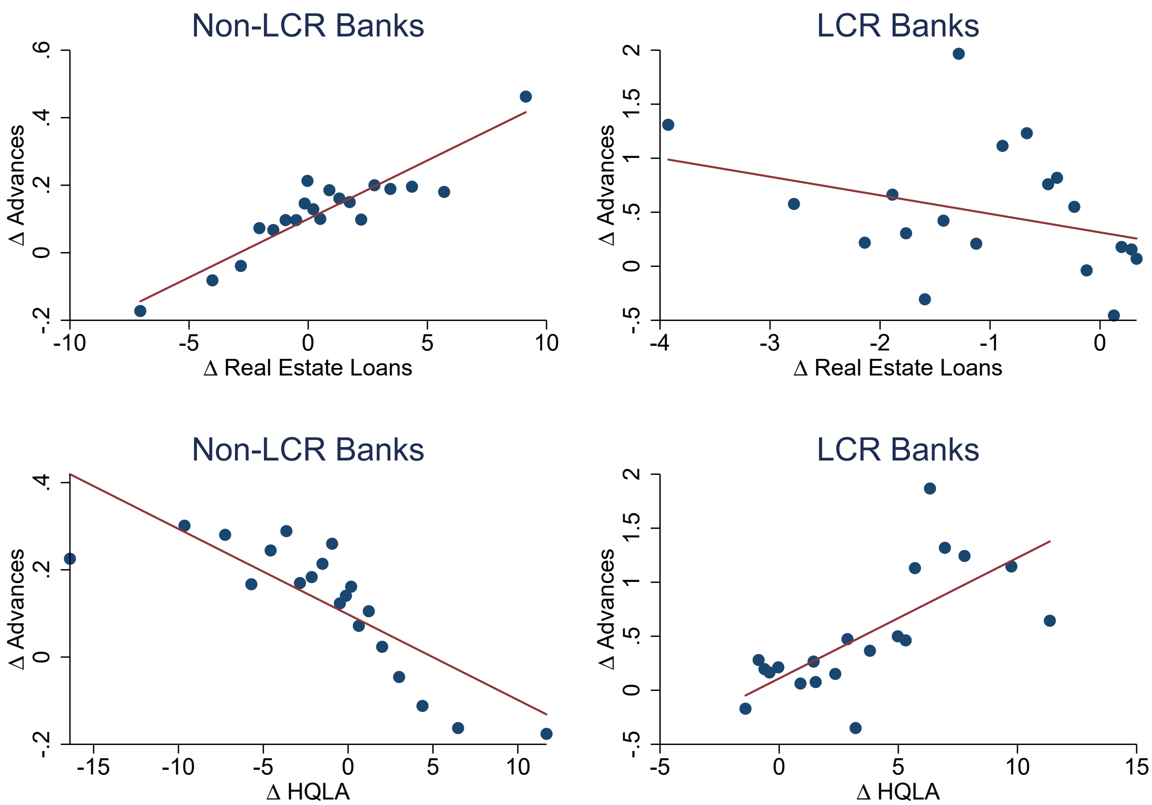


Figure 5: Relation between Advances, HQLAs, and Real Estate Loans
Graph 1 and 2 presents the binned scatter plots of the change in advances against the change in real estate loans for LCR and non-LCR banks. Graph 3 and 4 presents the binned scatter plots of the change in advances against the change in HQLAs for LCR and non-LCR banks. The sample period is from 2012Q3 to 2014Q4. Data source: FRY-9C and Call report.

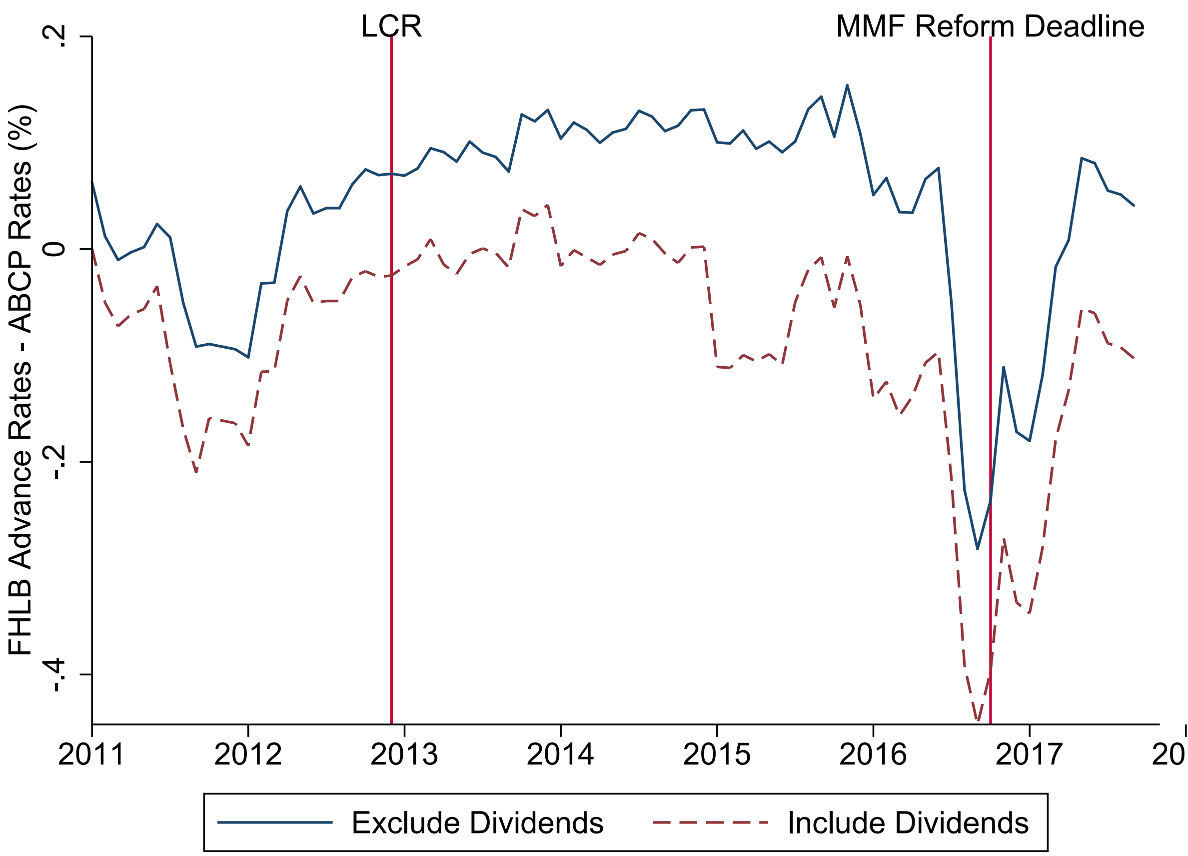


Figure 6: FHLB Advance Rates vs. ABCP Rates

This graph plots the spreads between 3-month FHLB advance rates and ABCP rates from 2011 to 2017. The blue line excludes the dividends associated with activity-based equity while the red dashed line includes the dividends. Data source: FHLB Boston, Dallas, and Des Moines; Federal Reserve Bank of St. Louis.

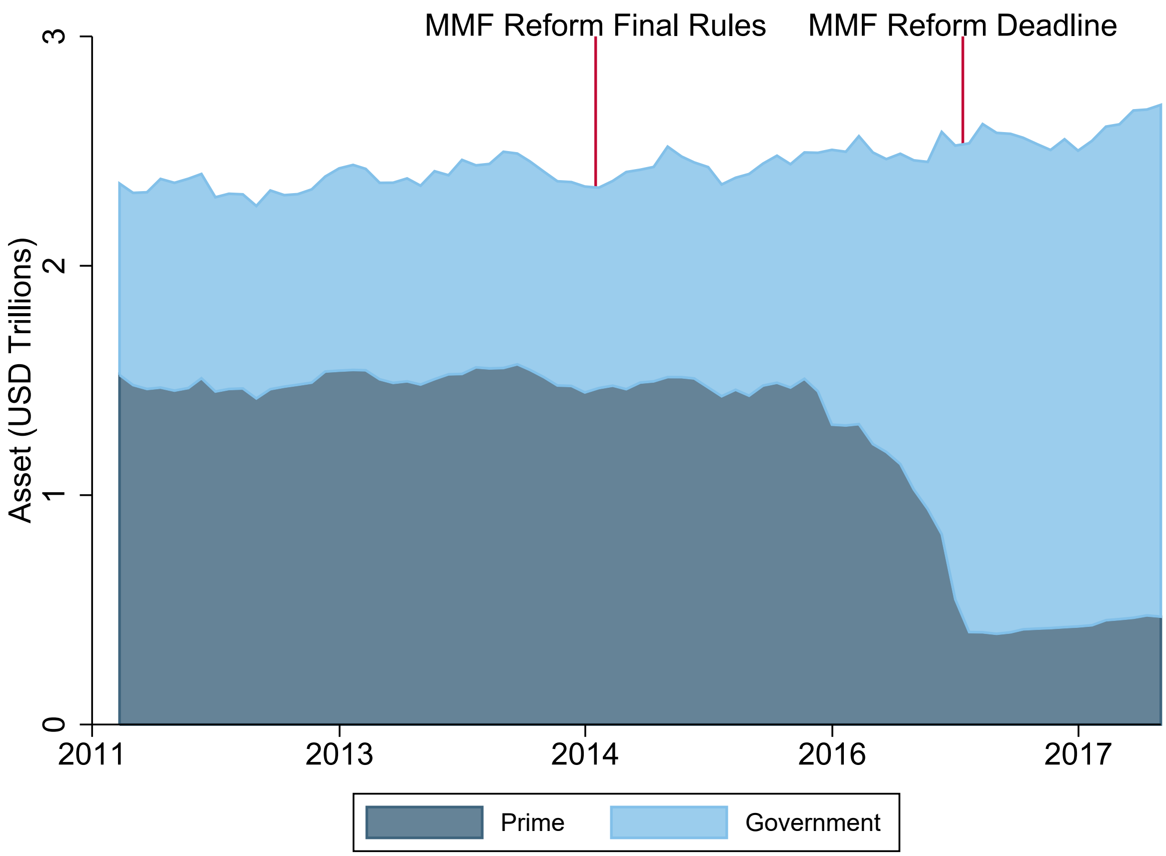


Figure 7: U.S. MMF Assets by Fund Type
This figure plots the amount of assets held by U.S. MMFs for prime and government funds respectively. The sample period is from 2011 to 2017. Data source: iMoneyNet.

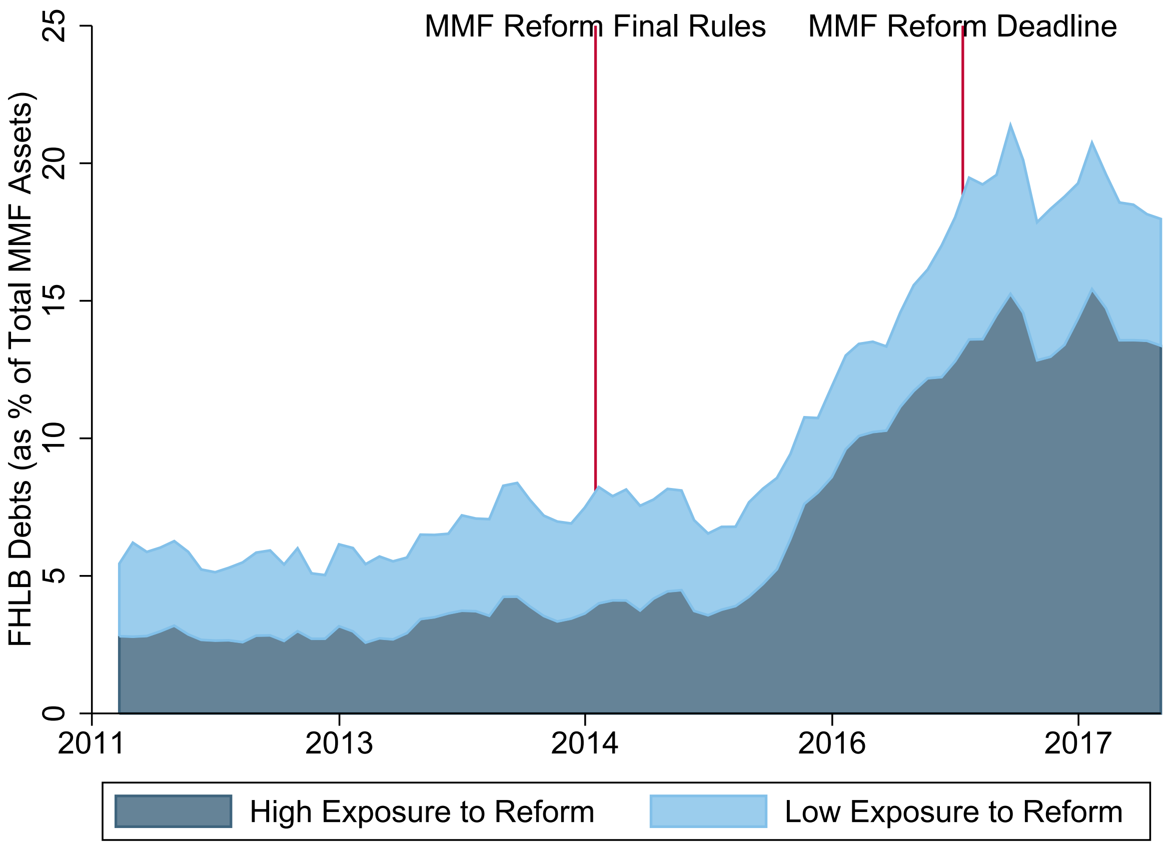


Figure 8: FHLB Debt Held by U.S. MMFs

This graph plots the times series of FHLB debt held by U.S. MMFs as a fraction of the total MMF assets. The red area represents FHLB debt held by fund families that had more than 50% of their assets in prime MMFs in 2014 (high exposure). The blue area represents FHLB debt held by fund families that had less than 50% of their assets in prime MMFs in 2014 (low exposure). Data source: iMoneyNet.

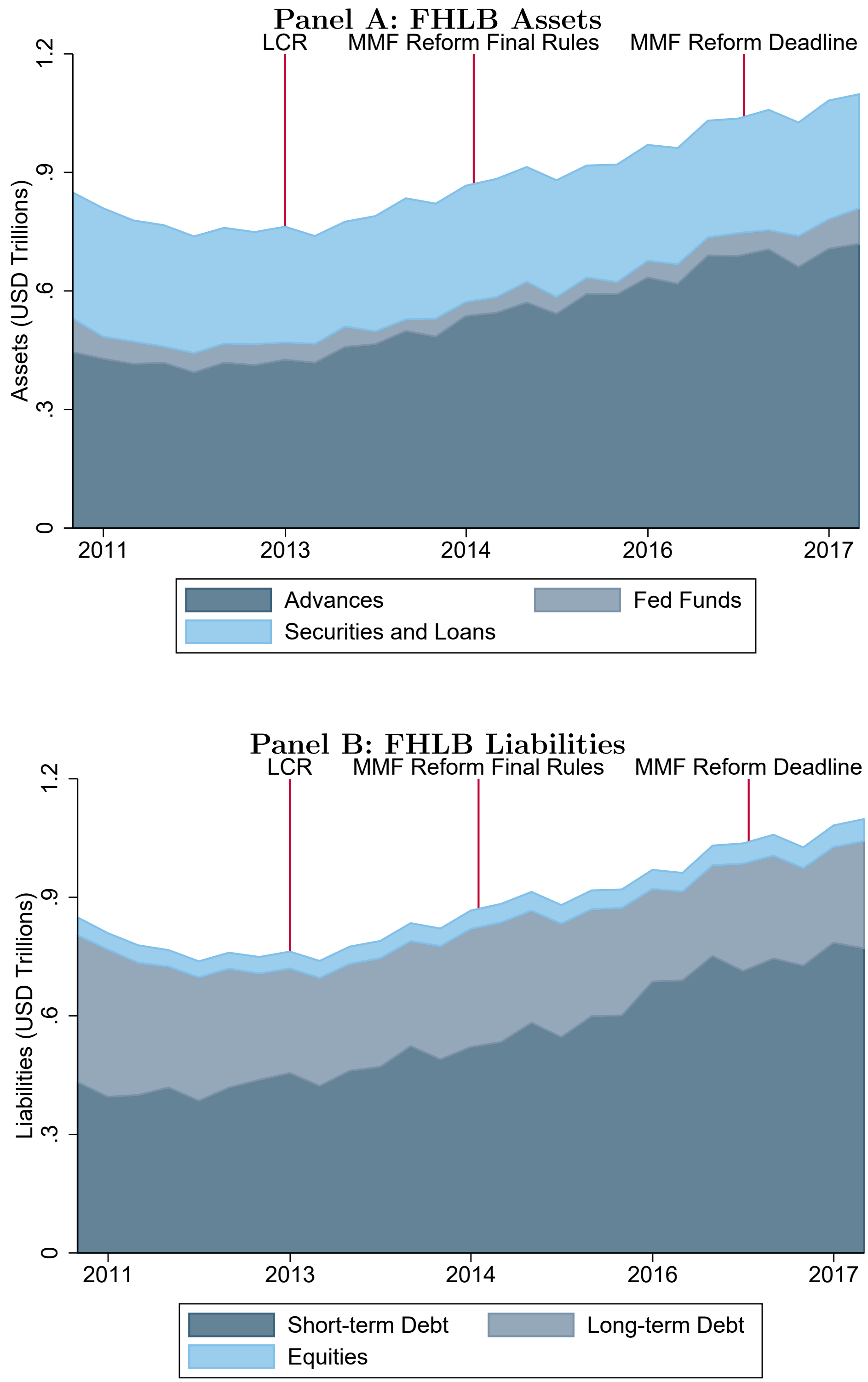


Figure 9: The Balance Sheets of the FHLB System

This figure plots the balance sheet composition of the FHLB system from 2011 to 2017. Panel A is the asset side and Panel B is the liability side. Data source: 10-K filings of FHLBs.

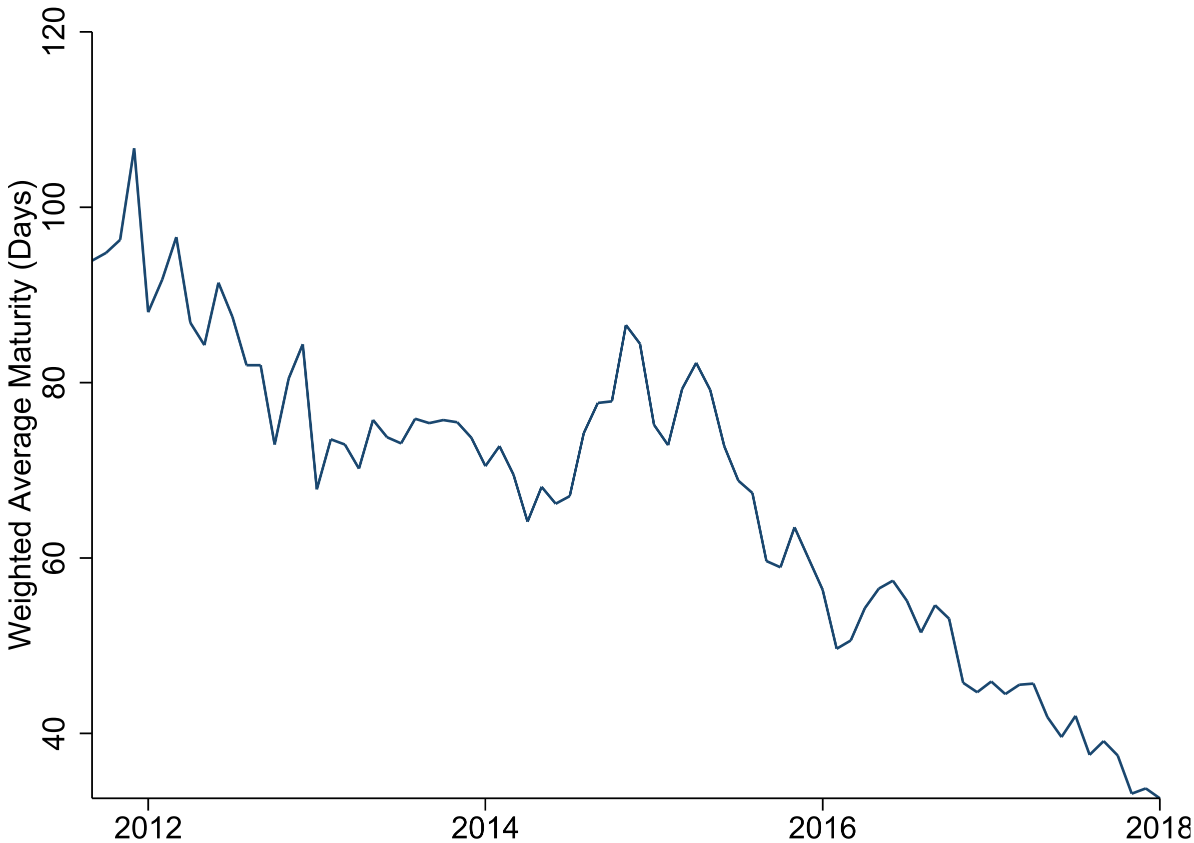


Figure 10: Weighted Average Maturity of MMF Lending to FHLBs
This figure plots weighted average maturity of the MMF lending to the FHLBs. Data source: iMoneyNet.

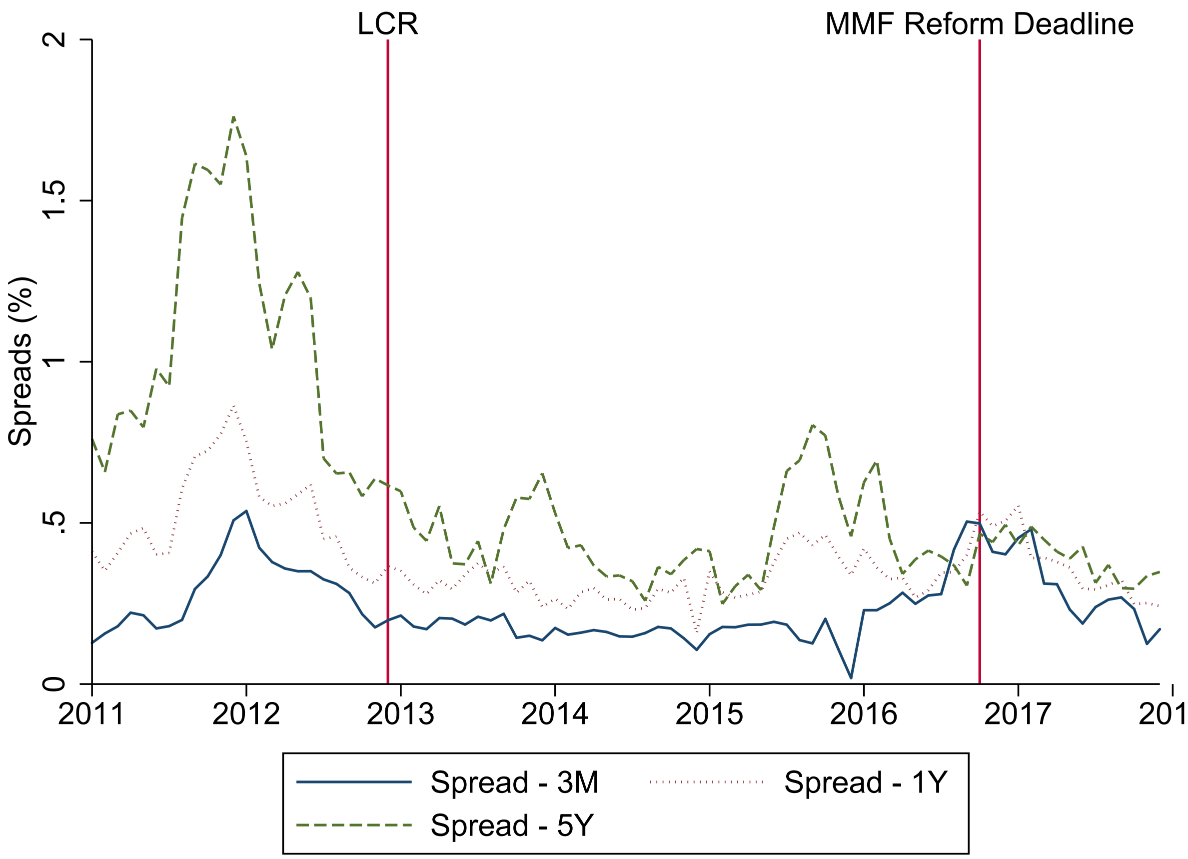
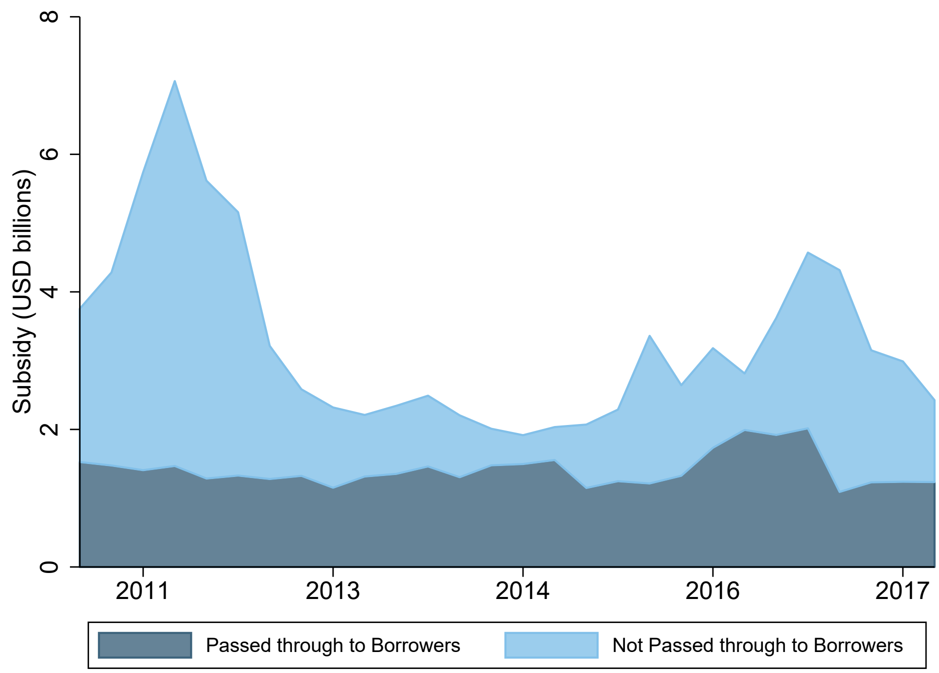


Figure 11: Spreads in Funding Costs: Banks vs. FHLBs
This figure plots the spreads in funding costs between banks and FHLBs from 2011 to 2017. Data source: FHLB Office of Finance and Federal Reserve Bank of St. Louis.

Panel A: Decomposition of Implicit Government Subsidy



Panel B: Quantity and Rate Pass-through

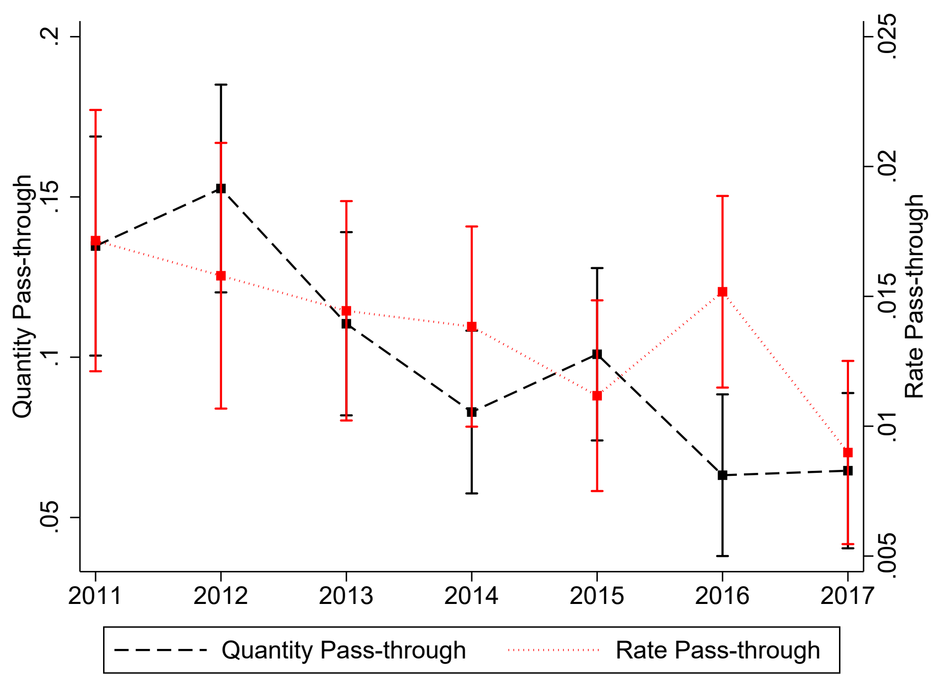


Figure 12: Government Subsidy Pass-through

Panel A plots the estimated total government subsidy to the FHLBs and the amount passed through to the ultimate borrowers in the housing market. Panel B of this figure plots the rate and quantity pass-through as defined in equation 16. Data source: FHLB Office of Finance, 10-K filing of FHLBs, Call Report.

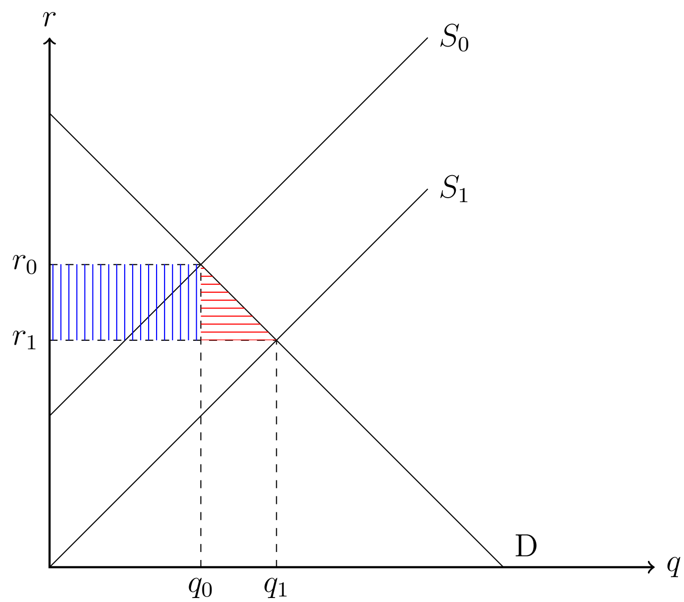


Figure 13: Borrower Surplus due o FHLB Advances

This figure shows borrower surplus in the real estate market. S_0 and S_1 are the supply curves without and with the advances respectively. D is the demand curve. The sum of blue and red region are the increase in borrower surplus due to FHLB advances.

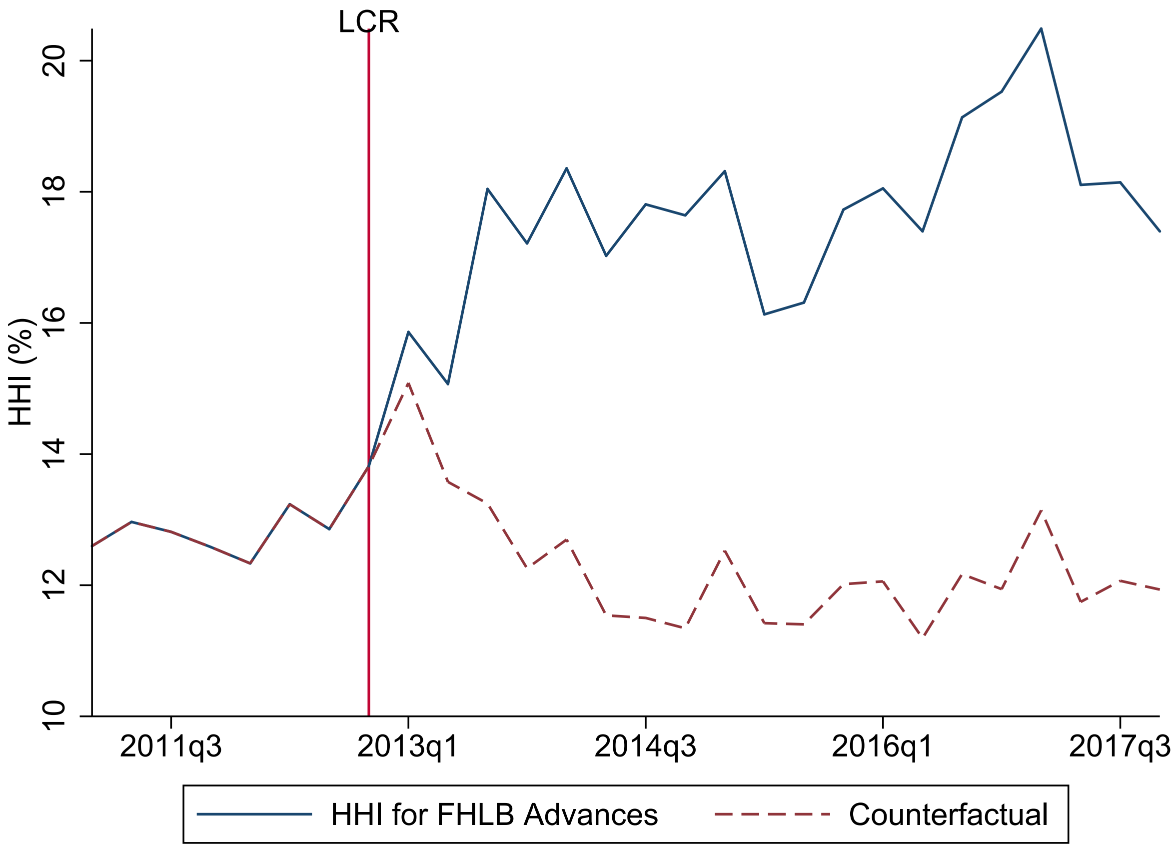


Figure 14: The Herfindahl-Hirschman Index (HHI) of FHLB Lending
This figure plots th HHI of FHLB lending. The counterfactual HHI is computed assuming that the LCR banks' advance-to-asset ratio stays constant after 2012Q4. Data source: Call report.

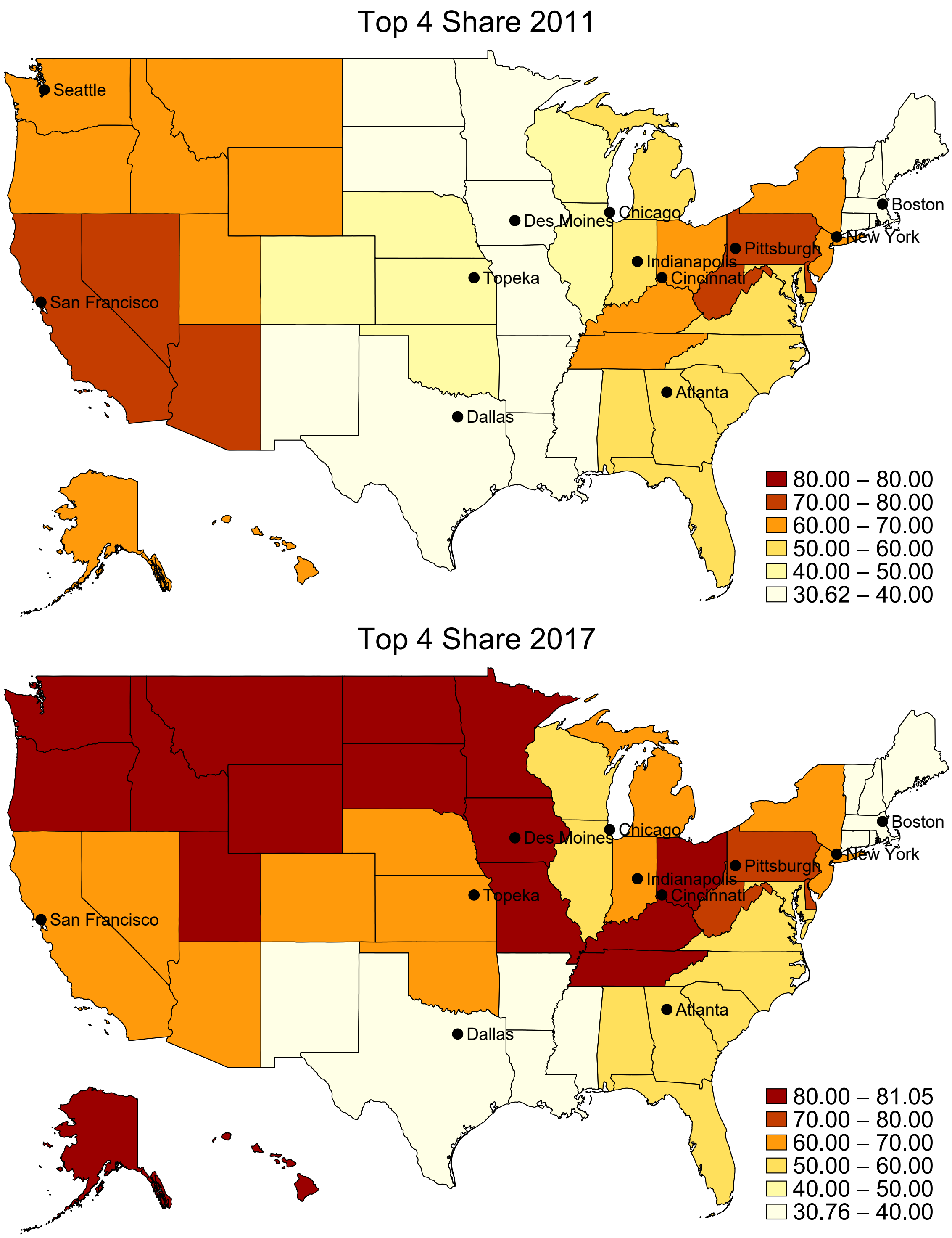


Figure 15: Concentration Risk of FHLB Lending

This figure plots the heat-map of the top 4 bank shares of each regional FHLB in 2011 and 2017. Data source: Call report.

Table 1: Summary Statistics

Panel A: Banks

	N	mean	sd	p5	p25	p50	p75	p95
HQLAs	91841	18.444	10.855	3.936	9.764	16.276	25.117	42.432
LCR	91841	1.082	0.784	0.180	0.477	0.862	1.477	2.994
Advances	91841	2.510	3.435	0.000	0.000	0.586	4.179	11.050
Wholesale Funding	91841	4.264	4.351	0.146	0.621	2.688	6.656	14.788
Advances/Wholesale	91841	37.849	39.288	0.000	0.000	24.415	80.485	95.941
Size	91841	19.116	1.334	17.274	18.258	18.974	19.776	21.427
Deposits	91841	84.612	6.269	73.467	81.885	85.894	88.767	91.447
CapitalRatio	91841	10.906	3.336	7.150	9.077	10.340	12.119	16.533
Real Estate Loan	91841	42.024	15.085	14.110	30.838	42.886	53.532	66.985

Panel B: FHLBs

	N	mean	sd	p5	p25	p50	p75	p95
Log Assets	319	18.040	0.472	17.337	17.633	18.036	18.433	18.773
Advances	319	56.865	13.670	26.240	50.655	56.588	68.289	75.762
Securities	319	24.117	9.884	11.842	16.719	21.406	29.464	45.572
Fed Funds Sold	319	5.903	3.996	1.091	3.215	5.091	7.427	14.958
Mortgage Loans	319	6.725	5.869	0.319	1.502	5.837	11.683	16.998
FHLB Notes	319	34.845	12.894	14.529	25.402	34.732	43.886	56.874
FHLB Bonds	319	57.030	12.102	36.037	47.897	57.965	65.540	76.722
Capital Ratio	319	5.219	0.946	3.751	4.709	5.204	5.713	6.709

Panel C: MMFs

	N	mean	sd	p5	p25	p50	p75	p95
FHLB Share	5412	12.038	13.406	0.000	2.295	7.739	17.064	39.532
Log Assets	5412	15.157	2.285	11.768	13.406	14.651	17.158	19.025
Return	5412	0.309	0.272	0.072	0.140	0.204	0.380	1.042
Expense Ratio	5412	0.194	0.137	0.057	0.111	0.160	0.226	0.501
Fund Flow	5412	0.377	16.144	-9.604	-2.401	-0.298	2.075	10.103

Table 2: Effect of LCR Regulation on HQLA Holdings

	(1) HQLA	(2) HQLA	(3) HQLA
Post*LCR Bank	3.551***	3.686***	3.701***
	[1.176]	[1.193]	[1.211]
Post	-0.212	0.275	
	[0.492]	[0.527]	
LCR Bank	17.401***		
	[0.808]		
Log Assets	-0.993***	-3.580***	-3.432***
	[0.077]	[0.614]	[0.495]
Deposit Ratio	0.412***	0.158***	0.136***
	[0.019]	[0.027]	[0.014]
Capital Ratio	0.412***	-0.138*	-0.259***
	[0.016]	[0.070]	[0.052]
Bank F.E.	No	Yes	Yes
Time F.E.	No	No	Yes
Observations	91,841	91,841	91,841
Adj. R-squared	0.056	0.773	0.781

Note: This table shows the impact of the LCR regulations on the amount of HQLA of U.S. commercial banks. The sample includes all the U.S. banks from 2011Q1 to 2014Q4. The dependent variable, *HQLA*, is the amount of High Quality Liquid Assets normalized by assets. *Post* is a dummy variable that equals one if the time is after 2012Q4, the quarter liquidity stress testing was introduced by the Federal Reserve. *LCR Bank* is a dummy variable that equals 1 if a bank is covered by the full LCR rule in 2012Q4, and 0 otherwise. 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. ***, **, * represents 1%, 5%, and 10% significance levels, respectively.

Table 3: Effect of the LCR Regulation on FHLB Advances Borrowing

	(1) Advances	(2) Advances	(3) Advances
Post*LCR Bank	1.596***	1.294***	1.294***
	[0.167]	[0.160]	[0.160]
Post	0.076	-0.109	
	[0.065]	[0.063]	
LCR Bank	-5.438***		
	[0.171]		
Log Assets	-0.201***	0.894***	0.910***
	[0.021]	[0.137]	[0.106]
Deposit Ratio	-0.630***	-0.381***	-0.380***
	[0.006]	[0.024]	[0.024]
Capital Ratio	-0.719***	-0.363***	-0.355***
	[0.012]	[0.027]	[0.024]
Bank F.E.	No	Yes	Yes
Time F.E.	No	No	Yes
Observations	91,841	91,841	91,841
Adj. R-squared	0.624	0.881	0.883

Note: This table shows the impact of the LCR regulations on the amount of HQLA of U.S. commercial banks. The sample includes all the U.S. banks from 2011Q1 to 2014Q4. The dependent variable, *Advances*, is the amount of FHLB advances normalized by assets. *Post* is a dummy variable that equals one if the time is after 2012Q4, the quarter liquidity stress testing was introduced by the Federal Reserve. *LCR Bank* is a dummy variable that equals 1 if a bank is covered by the full LCR rule in 2012Q4, and 0 otherwise. 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. ***, **, * represents 1%, 5%, and 10% significance levels, respectively.

Table 4: The Impact of MMF Reform on MMF's Lending to the FHLB System

	(1) % FHLB	(2) % FHLB	(3) % FHLB
Post × Exposure	0.096***	0.088***	0.076***
	[0.010]	[0.010]	[0.010]
Log Assets	-0.176***	0.287***	-2.553***
	[0.044]	[0.055]	[0.450]
Return	6.494***	-70.703***	-62.009***
	[0.984]	[5.261]	[7.664]
Expense Ratio	8.681***	16.045***	6.908***
	[2.302]	[1.664]	[1.791]
Fund Flow	-0.011	-0.008	0.001
	[0.010]	[0.009]	[0.009]
Fund F.E.	N	Y	Y
Time F.E.	N	N	Y
Observations	5,412	5,412	5,412
Adj. R-squared	0.150	0.309	0.709

Note: This table shows the impact of the Money Market Reform on MMFs' lending to the FHLB system. The sample includes all money market fund families from January 2011 to December 2017, at that fund family-month level. The dependent variable, % *FHLB Holding*, is the ratio of FHLB assets as a percentage of total assets of the fund family. *Post* is a dummy variable that equals one if month is equal to or after July 2014, which was when the Money Market Reform rules were finalized. *Exposure* is defined as the fraction of prime fund assets in the fund family. *Post* and *Exposure* are included in the regression when there is no corresponding fixed effects. Control variables include *Log Assets*, *Return*, *Expense Ratio*, and *Fund Flow*, all lagged one month. Time and fund family fixed effects are added as shown in the table. Standard errors are shown in parentheses and are clustered at the month level. ***, **, * represent 1%, 5%, and 10% significance levels, respectively.

Table 5: Maturity Composition of FHLB Advances

	$< 1y$	$\geq 1y$	Total
LCR Banks	37.5	1.1	38.6
Non-LCR Banks	26.1	35.3	61.4
Total	63.6	36.4	100

Note: This table shows fractions of FHLB advances by maturity and by bank type. The sample is from 2012Q4 to 2017Q4. LCR banks are defined as banks with assets above $250 billion in 2012Q4. Non-LCR banks are defined as banks with assets below $50 billion. Data source: Call Report.

Appendix: Institutional Background on FHLB System

The Federal Home Loan Bank system was established in 1932 to provide thrift institutions liquidity that commercial banks obtained through the Federal Reserve System (Romer and Weingast 1991). Originally established as 12 (now 11) regional banks, the system has used its status as government-sponsored enterprise to assist its member financial institutions to finance housing and certain types of community development lending. Despite of its importance in the U.S. banking system, the FHLBs remain little known by the public.[31]

The FHLBs first entered policy debate during the saving and loan crisis in the 1980s. In this period, the FHLBs relied on thrifts for lending business but at the same time served as their regulator. Significant conflicts of interests arose in such relationship, which prompted the Congress to abolished the old regulator of the FHLBs and thrifts and installed new ones (McCool 2005; Day 2019). The Congress also opened FHLB membership to commercial banks and credit unions.

Unique Equity Structure

A unique feature of FHLB membership is that the borrowing members are required to post eligible collateral *and* equity capital to borrow money from the FHLB [32]. Members are required to capitalize all advances, typically at 4% to 5% of principal borrowed and FHLB repurchases capital stock once the associated advances have been repaid. This is referred to as the "activity-based equity capital." The "permanent capital" of the FHLB is composed of Class B equity capital that the members must contribute in order to retain membership and must remain committed for at least five years (see the discussion below) before it can be redeemed. The redemptions, when they occur, are at par value.[33] This feature suggests right away two potentially important economic implications; First, the borrowing members may have their skin in the game by virtue of their equity in the

[31] We leave a more detailed description of the institutional background of the FHLBs to the appendix.

[32] The eligible collateral are: U.S. Treasury Securities, Agency Securities, Agency MBS, Private Label RMBS, CMBS, and Municipal. Ineligible collateral types include: Corporates, Private Placements, and Public Equities.

[33] Redeeming permanent equity capital may be costly in the following sense: the FHLB states: "Any member that withdraws its membership from an FHLB may not acquire shares of any FHLB for five years after the date on which its divestiture of capital stock is completed, unless the institution has canceled its notice of withdrawal prior to that date. This restriction does not apply if the member is transferring its membership from one FHLB to another FHLB on an uninterrupted basis."

FHLB: their equity will potentially be wiped out if the FHLB takes excessive risks and fails. As an example, the FHLB Seattle bank's capital was locked down by the FHFA, (the regulator of the FHLB system) in 2009, which prohibited the Seattle FHLB from paying dividends or redeeming its equity as a way to conserve the FHLB's capital.[34] This incentive may be undercut by the possibility that the FHLB system is backed by explicit and implicit government guarantees, and members who post equity may expect to get bailed out. Second, the FHLB has the ability to expand or contract its balance sheet in relation to the demand for loans from its members. We will expand on both these themes below.

Three features of FHLB equity are worth emphasizing; First, the ownership is restricted as FHLB stock can only be sold to/from FHLBs or a member institution. Second, the stock can only be redeemed at par value. Finally, the equity lacks a market because there is no real "market" for the stock other than the FHLBs or member institutions. Given the fact that the membership is small, equity holders are fairly concentrated and are largely big insured depository institutions.[35] While at a first glance, co-operative structure of the FHLB may be seen as being less risky than firms with outside equity holders, keen observers have noted that the FHLB system is difficult to fully comprehend and analyze. See, Greenspan (2004), for example.

Each regional FHLB is permitted to issue one or two classes of capital stock, each with sub-classes, to its members. Members can redeem Class A stock by giving six-months' written notice, and members can redeem Class B stock by giving five-years' written notice, subject to certain restrictions. Most regional FHLBs only issue Class B stock, with some offering sub-classes of Class B stock, which represent either membership or activity-based stock requirements based upon the terms of the respective regional FHLB's capital plan. Each regional FHLB has the ability to hold capital up to five years. Therefore, the FHLB is able to scale up or scale down capital, depending on the size of its balance sheet. This is referred to as a controlled scalability. The two sub-class Class B stockholders may or

[34]See Merger of the Federal Home Loan Banks of Des Moines and Seattle: FHFA's Role and Approach for Overseeing the Continuing FHLB, white paper, FHFA, March 16, 2016.

[35]Flannery and Frame (2006) make the point that "The Banks' equity holders are the member financial institutions, while their bondholders are widely dispersed throughout the capital markets. These two groups remain distinct in the FHLB structure, rendering the "bundling of claims" argument inapplicable. Hence, the cooperative structure of the FHLB System does not necessarily insulate the Banks from excessive risk taking."

may not have the same voting rights and dividend rates, which are based on the terms of the respective FHLB's capital plan.[36]

Stock ownership entitles the borrowing members to dividend payments on both classes of equity capital that the member contributes. For example, FHLB-Boston reported that the dividend payout for its equity holders was $LIBOR + 300$ basis points.[37] Appendix A shows the dividend history of FHLB-Pittsburgh for the period $4Q2013 - 2Q2018$ for both classes of equity holders, as well as the weighted-average dividend payouts for each year. Two patterns emerge; First, the activity-based equity generates higher dividend payouts, relative to the permanent (membership) equity. Second, the weighted-average dividend payouts exceed $LIBOR$ by 200 to nearly 400 basis points over this period. This type of payout is handsome, considering the low interest rates that prevailed during this period. It shows that while the equity holders redeem equity at par, there is nevertheless some upside potential through dividend payments. This feature is pertinent when calculating the net costs of obtaining cash advances from FHLB by the member banks. It is also relevant to thinking about how any government subsidy that may be backing the FHLB system is divided between FHLB regional banks, and the member banks who borrow from FHLB.

The FHLB's Funding Advantages

The FHLB regional banks enjoy both explicit and implicit funding advantages. Gaberlavage (2017) notes that the FHLB Act confers on the FHLBs a number of special privileges and exemptions that result in lower costs, which include the following. First, the Treasury may purchase up to $4 billion of FHLB securities (line of credit for system as a whole); One might argue that this is small relative to the size of the balance sheet of the FHLB system, but the symbolic significance is important. Second, FHLB debt is eligible for Federal Reserve open market purchases, including unlimited investment by insured commercial banks and thrifts, and collateralizing public deposits. Third, FHLBs enjoy exemption from the bankruptcy code because they are considered "federal instrumentalities". FHLBs have a priority on collateral claims on member institutions, over any and all other creditors (the "super lien"). Fourth, FHLB's earnings are exempt from federal, state, and local income

[36]Source: Discussion of the FHLBs' Capital Structure and Regulatory Capital Requirements, Federal Home Loan Bank System, Office of Finance, August 23, 2018.

[37]Federal Home Loan Bank Funding Strategies for Insurance Companies, FHLB Boston, 2Q2016.

tax. Fifth, Interest paid to investors is exempt from state income tax. These features make the debt issued by FHLBs very attractive to institutional investors. We will later present evidence that the funding costs of FHLB are significantly lower than other institutions on a duration-adjusted basis.

One of the key funding channels for the regional FHLBs is the Office of Finance. All senior, unsecured debt securities issued through the Office of Finance are *the joint and several obligations of the entire FHLB system.* This arrangement also implies that any major exposure faced by a single regional FHLB may spill over into the entire system. This observation is important as regional FHLBs have had big exposures to just a few big banks, causing some debate in policy circles, and reviews by the FHFA's Office of Inspector General.[38]

FHFA Capital Requirements and Regulation

The FHFA imposes certain capital requirements on the regional FHLBs. FHLBs must maintain a minimum of 4% total capital ratio. This capital is defined as the sum of permanent capital (5-year Class B stock plus retained earnings) and amounts paid for Class A stock (6-month redeemable), plus any general loss allowance and other sources approved by the regulator. In addition, the FHFA requires a minimum leverage capital ratio of 5%. The capital applicable here is the sum of permanent capital weighted by a 1.5 multiplier, plus all other capital. Finally, there are also risk-based capital requirements, which can vary across regions. To preserve capital, FHLBs may voluntarily suspend or eliminate dividends and/or early excess stock repurchases, and may increase the membership and/or activity-based stock requirements. The FHFA can place limits on dividends and stock redemptions. It retains the ultimate authority to place any FHLB into conservatorship or to merge FHLBs (as discussed earlier with regarding the Seattle FHLB case).

[38]The Seattle FHLB merged with Des Moines FHLB after the crisis, in part due to the failure of it's largest member, Washington Mutual. See, American Banker, April 28, 2017. Also, Gaberlavage (2017) notes that among the two largest FHLBs, Atlanta and New York, the banks' ten largest borrowers held 75% and 73% respectively of total advances.

Dividend History

Period Ending	Payment Period	Activity-based capital stock - annualized rate	Membership capital stock - annualized rate	Weighted average dividend rate - includes both subclasses of stock	Quarterly Average 3-Month LIBOR
2Q 2018	3Q 2018	6.75%	3.50%	6.42%	2.34%
1Q 2018	2Q 2018	6.75%	3.50%	6.42%	1.93%
4Q 2017	1Q 2018	6.75%	3.50%	6.42%	1.50%
3Q 2017	4Q 2017	5.00%	2.00%	4.70%	1.31%
2Q 2017	3Q 2017	5.00%	2.00%	4.87%	1.21%
1Q 2017	2Q 2017	5.00%	2.00%	4.72%	1.07%
4Q 2016	1Q 2017	5.00%	2.00%	4.71%	0.92%
3Q 2016	4Q 2016	5.00%	2.00%	4.68%	0.79%
2Q 2016	3Q 2016	5.00%	2.00%	4.69%	0.64%
1Q 2016	2Q 2016	5.00%	2.00%	4.71%	0.63%
4Q 2015	1Q 2016	5.00%	3.00%	4.80%	0.41%
3Q 2015	4Q 2015	5.00%	3.00%	4.80%	0.31%
2Q 2015	3Q 2015	5.00%	3.00%	4.79%	0.28%
1Q 2015	2Q 2015	5.00%	3.00%	4.79%	0.26%
2014 Special	1Q 2015	2.50%	2.50%	2.50%	NM
4Q 2014	1Q 2015	4.00%	4.00%	4.00%	0.24%
3Q 2014	4Q 2014	4.00%	4.00%	4.00%	0.23%
2Q 2014	3Q 2014	4.00%	4.00%	4.00%	0.23%
1Q 2014	2Q 2014	4.00%	4.00%	4.00%	0.24%
4Q 2013	1Q 2014	2.50%	2.50%	2.50%	0.24%

FHLBank PITTSBURGH

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Appendix Table: Dividend history reported by FHLB-Pittsburgh

Note: This table shows the dividend history of FHLB-Pittsburgh relative to the relevant historical LIBOR levels. Data source: FHLB-Pittsburgh.

Appendix: Proofs

Public Liquidity Backstop with Unlimited Lending Capacity

We compare two choices of the bank:

Choice 1: $\beta_0 = \rho$, $\alpha = \rho$

$$\beta_1(G) = tr_1 + \rho c - \rho R_1 > 0 \tag{22}$$

$$\beta_1(B) = (t + \Delta)r_1 + \rho c - \rho R_1 > 0 \tag{23}$$

Note that $\beta_1 \geq 0$ implies that the bank needs to draw the credit line at a cost of c from date 1 to date 2. This implies the following profits in the two states.

$$\pi(G) = R_2^2 - (1-t)r_2^2 - (\rho(c - R_1) + tr_1)\, c \tag{24}$$

$$\pi(B) = R_2^2 - (1-t-\Delta)r_2^2 - (\rho(c - R_1) + (t+\Delta)r_1)\, c \tag{25}$$

Choice 2: $\beta_0 = 0$, $\alpha = \rho$

$$\beta_1(G) = tr_1 - \rho R_1 < 0 \tag{26}$$

$$\beta_1(B) = (t + \Delta)r_1 - \rho R_1 < 0 \tag{27}$$

Note that $\beta_1 \leq 0$ implies that the bank has extra liquid assets to earn R_1 from date 1 to date 2. This implies the following profits in the two states.

$$\pi(G) = (1-\rho)R_2^2 - (1-t)r_2^2 - (tr_1 - \rho R_1)\, R_1 \tag{28}$$

$$\pi(B) = (1-\rho)R_2^2 - (1-t-\Delta)r_2^2 - ((t+\Delta)r_1 - \rho R_1)\, R_1 \tag{29}$$

The indifference condition between the two choices gives the threshold, c^*.

$$(p\Delta + t)(R_1 - c^*)r_1 + (-c^{*2} + c^* R_1 - R_1^2 + R_2^2)\rho = 0 \tag{30}$$

Take derivative of equation 30 with respect to the ρ, we have

$$\frac{\partial c^*}{\partial \rho} = \frac{c^{*2} - c^* R_1 + R_1^2 - R_2^2}{-(p\Delta + t)r_1 + (-2c^* + R_1)\rho} > 0 \tag{31}$$

The denominator is clearly smaller than zero. The numerator is also smaller than zero because $c > R_1$. Therefore, tightening in the liquidity regulation increases the cost threshold which prevents the bank to use the credit line to full-fill liquidity regulation.

Public Liquidity Backstop with Unstable Lending Capacity

We compare three choices of the bank:

Choice 1: $\beta_0 = \rho$, $\alpha = \rho$

$$\beta_1(G) = tr_1 + \rho c - \rho R_1 < \phi \tag{32}$$

$$\beta_1(B) = (t + \Delta)r_1 + \rho c - \rho R_1 > \phi \tag{33}$$

Note that $0 \leq \beta_1 < \phi$ implies that the bank draw the credit line at a cost of c from date 1 to date 2 in the good state, $\beta_1(B) > \phi$ implies that the bank cannot access enough liquidity to meet the withdrawals in the bad state. This implies the following profits in the two states.

$$\pi(G) = R_2^2 - (1-t)r_2^2 - (\rho(c - R_1) + tr_1)\, c \tag{34}$$

$$\pi(B) = 0 \tag{35}$$

Choice 2: $\beta_0 = b_0 = \frac{\rho R_1 + \phi - (t+\Delta)r_1}{c}$, $\alpha = \rho$

Note that the maximum amount that the bank can draw at date 0 which avoids default in date 1 in the bad state is determined by the following equation:

$$\rho R_1 + \phi - (t + \Delta)r_1 - b_0 c = 0 \tag{36}$$

$$\beta_1(G) = \phi - \Delta r_1 < \phi \tag{37}$$

$$\beta_2(B) = \phi \tag{38}$$

Note that $\beta_1 \geq 0$ implies that the bank needs to draw the credit line at a cost of c from date 1 to date 2. This implies the following profits in the two states.

$$\pi(G) = (1-\rho+\beta_0)R_2^2 - (1-t)r_2^2 - (\phi - \Delta r_1)\, c \tag{39}$$

$$\pi(B) = (1-\rho+\beta_0)R_2^2 - (1-t-\Delta)r_2^2 - \phi c \tag{40}$$

The following indifference condition pins down the threshold, c_D^*.

$$\begin{aligned} -(1-p)\rho c_D^{*3} + ((1-p)(\rho R_1 - (t+\Delta)r_1) + \phi)c_D^{*2} \\ -(p(R_2^2 - (1-t-\Delta)r_2^2) - R_2^2\rho)c_D^* + R_2^2((t+\Delta)r_1 - \rho R_1 - \phi) = 0 \end{aligned} \tag{41}$$

Choice 3: $\beta_0 = 0$, $\alpha = \rho$

$$\beta_1(G) = tr_1 - \rho R_1 < 0 \tag{42}$$

$$\beta_1(B) = (t+\Delta)r_1 - \rho R_1 < 0 \tag{43}$$

Note that $\beta_1 < 0$ implies that the bank has extra liquid assets to earn R_1 from date 1 to date 2. This implies the following profits in the two states.

$$\pi(G) = R_2^2 - (1-t)r_2^2 + (\rho R_1 - tr_1)\, R_1 \tag{44}$$

$$\pi(B) = R_2^2 - (1-t-\Delta)r_2^2 + (\rho R_1 - (t+\delta)r_1)\, R_1 \tag{45}$$

The indifference condition between the choice 2 and choice 3 gives the threshold, c_U^*.

$$c_U^* R_1(tr_1 + p\Delta r_1 - \rho R_1) - c_U^{*2}(\phi - \Delta(1-p)r_1) + R_2^2(-\Delta r_1 - tr_1 + \rho R_1 + \phi) = 0 \tag{46}$$

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