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Jane Ihrig, Edward Kim, Ashish Kumbhat, Cindy Vojtech, and Gretchen C. Weinbach

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How have banks been managing the composition of high-quality liquid assets?

Jane Ihrig, Edward Kim, Ashish Kumbhat, Cindy M. Vojtech, and Gretchen C. Weinbach*

August 6, 2017

Abstract

Leading up to 2014, U.S. banks increased their holdings of high-quality liquid assets (HQLA) in part to comply with the liquidity coverage ratio (LCR) requirement. However, once the requirement was met, some banks shifted the compositions of their HQLA portfolios. This raises the question: What is the optimal composition of a given quantity of HQLA? We use standard optimal portfolio theory to benchmark the ideal and find that a range of "optimal" HQLA portfolios is plausible depending on banks' risk tolerance. A highly risk averse (inclined) bank prefers a relatively large share of reserves (mortgage-backed securities). Of course, other factors interact with the LCR and influence banks' management of the composition of HQLA. We highlight several such factors, and show how the pattern of dispersion in the daily variance of banks' HQLA shares may be influenced by them. We also describe an important implication of the LCR for the Federal Reserve's longer-run implementation of monetary policy.

Keywords: bank balance sheets, liquidity management, liquid assets, LCR, HQLA, CAPM, reserve balances
JEL: E51, E58, G21, G28

** Staff of the Divisions of Monetary Affairs and Financial Stability at the Board of Governors of the Federal Reserve System; Kumbhat now at the Bank for International Settlements.* *We thank Roop Ambardekar for his initial help with the data. We also thank seminar participants at the Federal Reserve Board and the Federal Reserve Bank of New York.* *The analysis and conclusions set forth in this paper are those of the authors and do not indicate concurrence by other members of the staff of the Board of Governors of the Federal Reserve System, the Federal Reserve System, or of the Bank for International Settlements.*

1. Introduction

Ensuring the ability to meet cash and collateral obligations has always been a key factor in banks' operations. In the wake of the financial crisis, with new financial regulations in place to improve the resiliency of the banking system—including new liquidity requirements—the need to hold liquid assets has become an even more important factor in banks' determination of the composition of their balance sheets. In particular, beginning in 2015, large banks in the United States have needed to comply with the liquidity coverage ratio (LCR) by holding sufficient "high-quality liquid assets," or HQLA, a requirement that has induced significant changes in banks' balance sheets. In this paper, our focus is on domestic banks' management of the *composition* of their HQLA; that is, given a desired stock of HQLA, how have banks managed the relative shares of the predominant types of liquid assets that comprise that portfolio? We consider seven components of banks' HQLA, focusing mainly on the three largest component shares—namely, excess reserves, Treasury securities, and what we refer to (and define below) as mortgage-backed securities (MBS) of U.S. government-sponsored enterprises, or GSE MBS. We recognize that banks' broader balance sheet management—that is, their management of both assets and liabilities—determines the required stock of HQLA, but in this paper we do not consider such broader interdependencies and focus instead on how banks have chosen to manage a given desired stock of HQLA.

Given that specific regulatory liquidity requirements are relatively new for the banking industry, research regarding how banks are adjusting to these regulations is nascent and growing. Allen (2014) and Diamond and Kashyap (2016) survey the existing literature and generally conclude that more research is needed to understand the effects of liquidity regulation on banks' behavior.[1] Our paper contributes to the discussion by documenting how domestic banks have actually managed the composition of their HQLA pools. In so doing, we distinguish between two periods of differing bank behavior—the period in which banks initially took steps to become LCR compliant and the subsequent period in which some banks adjusted the compositions of their liquid asset holdings, perhaps to achieve a more optimal configuration.

The available empirical research on banks and liquidity regulation has generally focused on the implementation of liquidity rules in other countries. For example, Bonner and Eijffinger (2013) investigate the effects of non-compliance by Dutch banks to an LCR-like requirement regarding these firms' borrowing and lending terms and volumes. Banerjee and Mio (2015) study the impact of an LCR-like requirement in the United Kingdom on bank balance sheets and bank lending in that jurisdiction. Cetina and Gleason (2015) analyze the U.S. LCR rule but focus primarily on the actual formula. They show how compositional caps in the U.S. rule apply to

[1] Allen (2014) states "much more research is required in this area. With capital regulation there is a huge literature but little agreement on the optimal level of requirements. With liquidity regulation, we do not even know what to argue about."

certain asset categories and create nonlinearities in the calculation of the ratio, making the interpretation of changes in the ratio challenging. One example of empirical research on the effects of the LCR in the United States is Rezende, Styczynski, and Vojtech's (2016) examination of the effects of liquidity regulation on banks' use of one of the Federal Reserve's monetary policy implementation tools, the Term Deposit Facility (TDF).[2] These authors find that participation in the TDF by LCR banks increased when term deposits became LCR-eligible. Our paper complements this research by describing how banks are managing their HQLA portfolios, which implicitly includes the decision to participate in a periodic TDF test operation instead of holding some reserve balances.

Other LCR-related research includes theoretical work that explores the interaction between liquidity regulation and monetary policy (Bech and Keister (2015) and Duffie and Krishnamurthy (2016)), dynamic general equilibrium models to explore the interactions between banks' responses to liquidity and capital regulations (Adrian and Boyarchenko (2013) and Covas and Driscoll (2014)), and dynamic models of bank balance-sheet choices (Balasubramanyan and VanHoose (2013)). Our paper adds to the literature on theoretical approaches by using portfolio theory to motivate banks' preferences for the composition of HQLA.

We begin by reviewing in section 2 key aspects of bank liquidity regulation, the data we use to describe banks' actual HQLA, and how LCR-constrained banks have managed their HQLA holdings over the past several years. Next, in section 3, we use optimal portfolio theory to objectively benchmark how a representative bank would optimize its liquid asset portfolio subject to a standard risk-return tradeoff. We find that a range of possible "optimal" portfolios of HQLA are plausible, a range that, in the context of portfolio theory, largely depends on banks' tolerance for risk. In section 4 we compare banks' actual portfolio choices to these benchmarks. We find that banks employ a range of approaches to managing the actual composition of their HQLA, a range that is within the objective benchmark outcomes suggested by portfolio theory. Acknowledging that the LCR is not the only constraint banks face, in section 5, we highlight other possible factors that likely influence banks' preferences for the composition of their HQLA holdings. In section 6 we use confidential microdata to examine the daily volatility of banks' HQLA shares to emphasize the importance of such factors. Section 7 concludes.

[2] Term deposits facilitate the implementation of monetary policy by providing an additional tool by which the Federal Reserve can manage the aggregate quantity of reserve balances held by depository institutions. Funds placed in term deposits are removed from the reserve accounts of participating institutions for the life of the term deposit and thereby drain reserve balances from the banking system. For more information, see the Federal Reserve Board's website: https://www.federalreserve.gov/monetarypolicy/tdf.htm.

2. Background and motivation

Here we review why the LCR was implemented, what the requirement entails, the data we use to approximate banks' HQLA, and how banks have generally managed their HQLA in light of the LCR requirement.

2.1 Post-crisis bank liquidity requirements

During the financial crisis, substantial stress in U.S. funding markets—illiquidity—turned into solvency issues for several large financial institutions. With financial markets quite fragile, shocks easily spread across the financial system. As a result, international financial regulators sought to improve the resiliency of the financial system by incorporating liquidity requirements into the Basel III framework for enhanced regulation of banking institutions. Basel III is a comprehensive set of reform measures, developed by the Basel Committee on Banking Supervision (BCBS), to strengthen the regulation, supervision, and risk management of the banking sector.[3] One key measure, and the focus of our paper, is the LCR. This ratio aims to strengthen the liquidity positions of large financial institutions by creating a standardized minimum daily liquidity requirement for large and internationally active banking organizations.[4] Relative to the pre-crisis period, the LCR requires that bank holding companies (BHCs) maintain ready access to a pre-determined level of highly liquid assets to meet demand over the short term, a one-month period.[5] While the LCR requirement primarily applies to BHCs, this paper will use the terms "BHCs" and "banks" interchangeably.

The BCBS originally issued the full text of the LCR rule on December 16, 2010.[6] National authorities then separately implemented the requirements set out in that standard. The United States released its proposed rule on October 24, 2013, and issued a final rule on September 3,

[3] The BCBS is a committee of banking supervisory authorities that was established by the central bank governors of the G10 countries in 1975. The Office of the Comptroller of the Currency (OCC), Federal Reserve Board, and Federal Deposit Insurance Corporation (FDIC) actively participate in the BCBS and its international efforts. Documents issued by the BCBS are available through the Bank of International Settlements web site at this link: http://www.bis.org/. Information about the Basel III framework may be found here: http://www.bis.org/bcbs/basel3.htm.

[4] The LCR is not the first incidence of liquidity regulation of financial institutions. Reserve requirements of depository institutions, administered by the Federal Reserve, were originally implemented as a prudential requirement to promote banks' liquidity positions. The Federal Reserve Act (FRA) provides the Board with the authority to impose upon "depository institutions" certain specified reserve requirements "solely for the purpose of implementing monetary policy" (FRA section 19(b)(2)(A), 12 U.S.C. § 461(b)(2)(A)). The Board has implemented the FRA's provisions regarding reserve requirements in the Board's Regulation D, "Reserve Requirements of Depository Institutions" (12 CFR Part 204).

[5] A separate requirement, the net stable funding ratio (NSFR), establishes liquidity standards for a period of one year. The NSFR has not yet been implemented; the proposed rule, issued in June 2016, may be found here: https://www.gpo.gov/fdsys/pkg/FR-2016-06-01/pdf/2016-11505.pdf.

[6] The BCBS issued a revised LCR rule on January 6, 2013, that expanded the range of HQLA-eligible assets and refined the assumed cash inflow and outflow rates.

2014.[7] The LCR requirement was phased in starting in January 2015, with the regulation taking full effect beginning in January 2017.[8]

As implemented in the United States, BHCs that have $50 billion or more in total consolidated assets must hold sufficient HQLA each day to cover expected net cash outflows over a rolling 30-day period.[9] The LCR formula is shown by equation (1).

$$LCR = \frac{HQLA}{Estimated\ net\ cash\ outflows} \geq 100\% \qquad (1)$$

The numerator of the ratio, HQLA, is made up of "Level 1" and "Level 2" assets. As shown in table 1 below, Level 1 assets, the most liquid form of HQLA with no haircuts or compositional caps, include excess reserves and securities issued or guaranteed by the U.S. government. That last asset category includes U.S. Treasury securities, Ginnie Mae (GNMA) MBS, and obligations issued by U.S. government agencies (or "non-GSE agency debt" in the table below).[10] Level 2A assets, which are subject to a 15 percent haircut, include securities issued or guaranteed by a U.S. GSE, such as GSE debt securities as well as these institutions' residential MBS and commercial MBS (CMBS), as appropriate.[11] Level 2B assets, which include corporate debt securities and tend to comprise a smaller portion of banks' balance sheets, are subject to a substantial haircut and, without loss of generality, we abstract from these assets in our discussion below.[12] Of the various HQLA assets, BHCs in aggregate hold the largest nominal amounts of reserves, Treasury securities, and GSE MBS (the highlighted cells of table 1).

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[7] The text of the final U.S. rule may be found here: https://www.federalreserve.gov/newsevents/pressreleases/bcreg20140903a.htm.

[8] Beginning in January 2015, standard LCR BHCs in the United States were required to maintain an LCR of 80 percent; beginning in January 2016, all U.S. LCR BHCs needed to maintain a ratio of 90 percent; beginning in January 2017, full LCR compliance was required (that is, a ratio of 100 percent or more is now required to be maintained).

[9] For an overview of the LCR rule, see House, Sablik, and Walter (2016).

[10] U.S. government agencies include the Government National Mortgage Association (GNMA, or Ginnie Mae), the Federal Deposit Insurance Corporation, and the Small Business Administration. These institutions are not GSEs.

[11] U.S. GSEs include the Federal National Mortgage Association (FNMA, or Fannie Mae), the Federal Home Loan Mortgage Corporation (FHLMC, or Freddie Mac), the Federal Home Loan Bank (FHLB) System, and the Farm Credit System.

[12] Level 2B assets receive a 50 percent haircut in calculating the LCR and can be no more than 15 percent of total HQLA. In addition, Level 2 assets (level 2A + level 2B) cannot be more than 40 percent of total HQLA. The caps are ignored in creating the descriptive statistics discussed in this section.

Table 1: Selected Components of Banks' HQLA
(largest 3 components highlighted)

Level 1 assets (no haircut)	**Level 2A assets** (15% haircut)
Excess reserves	GSE debt**
Treasury securities	GSE MBS**
GNMA MBS	GSE CMBS**
Non-GSE agency debt*	

*   See footnote 10 for the definition of a non-GSE agency.
** See footnote 11 for the definition of a GSE.

The required stringency of the LCR rule is tied to bank size and to the degree of international exposure. In particular, the largest and most exposed banking organizations—that is, those with $250 billion or more in total consolidated assets or $10 billion or more in on-balance sheet foreign exposure, and these banking organizations' subsidiary depository institutions with assets of $10 billion or more—are subject to the "standard" LCR requirement (hereafter, standard LCR BHCs). Smaller banking organizations—that is, BHCs that do not meet these thresholds but have $50 billion or more in total assets—are subject to a less stringent "modified" LCR requirement (hereafter, modified LCR BHCs).[13] As of year-end 2016, 17 BHCs exceeded the standard LCR thresholds, and 19 BHCs exceeded the modified LCR threshold in the United States. Because 2 BHCs crossed the latter threshold in the past 2 years, these BHCs are excluded from our modified LCR group when analyzing the full sample period we consider.

The LCR is not the only form of liquidity regulation banks face. In 2012, the Federal Reserve Board launched the Comprehensive Liquidity Assessment and Review (CLAR) for BHCs and nonbank financial companies subject to the Large Institution Supervision Coordinating Committee (LISCC) supervisory program. Similar to the well-known Comprehensive Capital Analysis and Review (CCAR), CLAR is an annual process whereby the Federal Reserve conducts a horizontal, forward-looking evaluation of banks' liquidity positions and liquidity risk management practices. In particular, each bank supplies information regarding its own internal liquidity stress test. In so doing, it assesses the liquidity needs associated with its various individual business activities and reviews internal assumptions inherent in its assessment of available liquidity. For example, a bank can evaluate haircuts that are used to account for a potential fall in the value of assets in situations in which liquidity conditions are strained. We

[13] The denominator of the modified LCR is multiplied by 70 percent, making the modified LCR less stringent than the standard LCR.

return to the important role of banks' own internal liquidity requirements in managing HQLA further below. Next, we describe our data sources.

2.2 Data

Starting in April 2017, U.S. banks are expected to begin formal reporting associated with the disclosure requirements that accompany the LCR rule; until then, comprehensive data directly pertaining to banks' LCRs are not publically available.[14] Nonetheless, several large BHCs have disclosed their LCRs for some time, although without releasing the detailed data that underlie the ratio. Indeed, BHCs began discussing their LCRs publically in early 2014, during events such as quarterly earnings conference calls and other investor presentations at the time.[15] Thus, we rely on publicly available information, including banks' own disclosures, in making claims below regarding when individual large banks first became compliant with the LCR requirement.

To approximate the compositions of banks' actual HQLA, in what follows we lean on a range of data sources. Our publicly-available data sources include the *Consolidated Financial Statements for Holding Companies* (FR Y-9C) from which we obtain individual BHCs' securities holdings, including investment securities and securities in banks' trading accounts.[16] We also use the *Consolidated Reports of Condition and Income for a Bank with Domestic Offices* (FFIEC 041) and *Domestic and Foreign Offices* (FFIEC 031) for data on reserve balances.[17]

In addition, we utilize two sources of confidential microdata collected by the Federal Reserve. For historical data on individual bank's reserve balances (figures 1.a and 1.b), we rely on the confidential flows associated with the *Report of Transaction Accounts, Other Deposits and Vault Cash* (FR 2900). We also use confidential supervisory data collected from the *Complex Institution Liquidity Monitoring Report* (FR 2052a) for *daily* data on banks' HQLA components.[18] This form is collected from U.S. BHCs with $50 billion or more in consolidated assets. The very largest BHCs—those with $700 billion or more in consolidated assets or with

[14] LCR-related disclosure requirements for U.S. banks are described here: https://www.federalreserve.gov/newsevents/pressreleases/bcreg20161219a.htm.

[15] Around that time, Citigroup reported an LCR of 110 percent, while Bank of America noted that the LCR of their commercial banks was "well above" the 80 percent level that would be required beginning January 1, 2015, and that it was aiming to achieve a ratio above 100 percent during the first half of 2015, well ahead of the implementation deadline for a 100 percent ratio of January 1, 2017 (Citigroup (2014) and FactSet CallStreet (2014a)). Other BHCs publicly stated that they met the minimum or fully phased-in requirement without disclosing their actual ratios.

[16] We use securities reported on schedule HC-B and HC-D of the FR Y-9C. Given that the LCR requirement is based on market values, we use the fair value measures reported on schedule HC-B for both available-for-sale securities and held-to-maturity securities. The FR Y-9C reporting form and instructions are available on the Board's website: https://www.federalreserve.gov/apps/reportforms/reportdetail.aspx?sOoYJ+5BzDal8cbqnRxZRg==.

[17] These regulatory filings are reported at the commercial bank level; we subsequently match commercial banks to their affiliated BHC. The FFIEC 031 and 041 forms and instructions are available on the FFIEC's website: https://www.ffiec.gov/ffiec_report_forms.htm.

[18] The FR 2900 and FR 2052a reporting forms and instructions are available on the Board's website: https://www.federalreserve.gov/apps/reportforms/reportdetail.aspx?sOoYJ+5BzDblI7g2+r203S0gg6NcUIj6, and https://www.federalreserve.gov/apps/reportforms/reportdetail.aspx?sOoYJ+5BzDbpqbklRe3/1zdGfyNn/SeV, respectively.

$10 trillion or more in assets under custody—submit a report each business day and have been doing so since December 14, 2015; prior to that time, the same BHCs submitted more limited daily data since 2012.[19] (As noted above, other LCR BHCs will begin reporting LCR data in 2017, at a monthly frequency.) The FR 2052a data are comprised of the detailed balance sheet inputs necessary to calculate the LCR, but do not include the actual LCR ratios, or the numerators and denominators of the ratios, themselves. In addition, the data do not include the majority of LCR BHCs.

Therefore, for each BHC included in our analysis, we use as a *proxy* for HQLA the sum of the seven asset categories listed in table 1—total reserve balances, Treasury securities, GNMA MBS, non-GSE agency debt, and the debt, MBS, and CMBS of GSEs. In what follows, we clearly distinguish actual HQLA from our proxy which we refer to as "HQLA*." In constructing HQLA*, we rely on the publicly-available data as much as possible without compromising our analysis. For simplicity, we ignore Level 2 asset caps; however, most BHCs are not near those caps. In addition, we ignore LCR-eligible HQLA assets outside of the seven asset categories we consider, including banks' holdings of Level 2B assets such as corporate debt. Banks generally hold relatively small shares of such assets, making our conclusions robust to their exclusion. Moreover, in constructing our proxy we use data on banks' total reserve balances instead of excess reserves, although these measures differ little in aggregate.[20] Finally, due to limitations of the publicly-available data, some non-GSE (Level 1) agency securities are included in our estimates of the GSE (Level 2A) asset categories. However, for very large banks, we think our HQLA* asset category estimates are reasonable and, as noted above, we favor using publicly-available data.[21] See the data appendix for a summary of the publicly-available data that we use to calculate HQLA*.

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[19] The FR 2052a data and their historical counterpart are available at a daily frequency for the top eight U.S. LISCC banks. However, the historical data are quite limited, consisting of reserves, Level 1 HQLA (which includes reserves), and Level 2 HQLA. Since we are interested in tracking banks' behavior over the past several years, we created proxy measures for banks' Treasury and GSE MBS holdings: for the period in which insufficiently detailed data are available, we assumed that *Treasury securities = Level 1 assets – Total reserves* and *GSE MBS = Level 2 assets.* Our assumptions are reasonably robust to a couple of checks. First, we compared each proxy measure to the actual measure using data for 2016 when both measures are available; a ratio of these measures indicates higher accuracy the closer it is to 1, or 100 percent in terms of relative coverage. The performance of our Treasury proxy is somewhat mixed, averaging about 43 percent across banks, while our MBS proxy averages 93 percent. Two banks largely account for the miss in the Treasury proxy, one with large GSE debt holdings and one with a large portion of its Treasury holdings ineligible for the LCR because the assets are not unencumbered. In addition, we consider whether the proxy and actual measures behave similarly over time: We compute the daily standard deviation of our proxies as a share of HQLA, as we approximate it, and compare those results to analogous figures for the actual shares. Our proxy shares exhibit reasonably similar volatility to that of the actual ratios. We conclude that while not perfect, our proxy measures are reasonable for the analysis undertaken here.

[20] According to the Federal Reserve's H.3 statistical release, *Aggregate Reserves of Depository Institutions and the Monetary Base*, required reserves in the banking system totaled about $160 billion on average in February 2017 while total reserves averaged about $2,300 billion.

[21] For example, for the largest eight BHCs, we estimate that use of the publicly-available data results in roughly about 80 percent of banks' Level 1 assets to be sorted accurately, with the remaining 20 percent inaccurately included in our GSE (Level 2A) asset categories.

2.3 How did banks adjust HQLA to become LCR compliant?

Using the data just described, here we review how standard and modified LCR banks adjusted their holdings of the major components of HQLA on their way to becoming LCR compliant, and how they subsequently managed those compositional shares. Of course, to implement the LCR requirement BHCs could also make adjustments to their liabilities in order to reduce the denominator of the ratio, and some banks reportedly did so.[22] In this paper we focus on the numerator of the LCR—banks' adjustments to the composition of their holdings of HQLA.

We begin by examining the behavior of standard LCR banks, taken together. Figure 1.a shows these institutions' holdings over time of four of the categories of Level 1 and Level 2A HQLA assets described above—reserves, Treasury securities, GNMA MBS, and GSE MBS—plotted as a share of these banks' total assets. Key LCR-related dates are denoted by the vertical bars. As shown by the solid black line, in the lead-up to the initial deadline for LCR compliance (January 1, 2015), these institutions substantially increased the share of liquid assets in their portfolios over 2013 and 2014, and did so primarily by taking on substantial reserve balances, shown by the blue-dashed line.

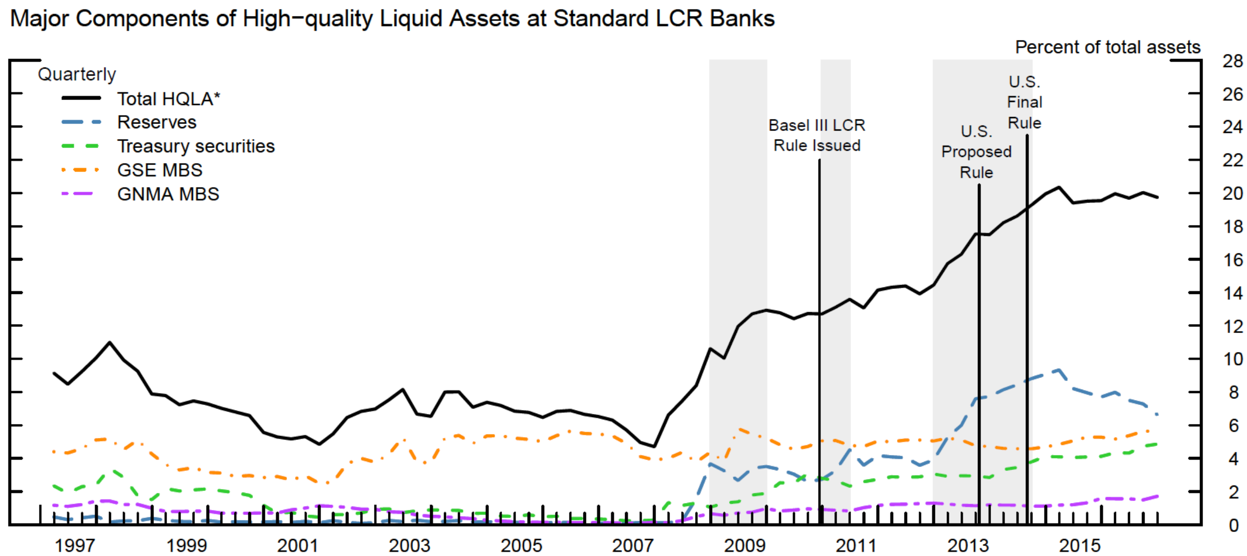
It is important to remember that accumulating reserve balances over this period was easy; in fact, it was not a choice for the banking sector as a whole. Prior to the financial crisis, the amount of reserve balances in the banking system was consistently quite small—that is, the blue-dashed line is close to the zero line prior to 2008. However, as a result of the Federal Reserve's large-scale asset purchase programs (LSAPs), which were conducted between 2009 and 2014 and are denoted in the figure by the gray-shaded regions, reserve balances grew at varying rates over many quarters.[23] As a result of the Federal Reserve's asset purchases, the amount of excess reserves in the banking system increased by over $2 trillion.[24]

[22] For example, a few large banks reportedly reduced their holdings of so-called "nonoperational" deposits, a liability category that requires backing by a relatively high share of liquid assets under the LCR rule. For example, JP Morgan announced a reduction of more than $100 billion in nonoperating deposits during its second quarter of 2015 earnings release (JP Morgan (2015)). In the second quarter of 2016, Bank of New York Mellon announced balance sheet restructuring plans to be implemented in the third quarter to reduce "LCR unfriendly deposits" (Thomson Reuters StreetEvents (2016)).

[23] With the Federal Open Market Committee (FOMC) having already reduced the federal funds rate to its effective lower bound (zero), the Federal Reserve conducted LSAPs in order to support a stronger economic recovery and to help ensure the return of inflation to levels consistent with the Committee's mandate. The FOMC's rationale for conducting LSAPs is provided in the Committee's post-meeting statements; for example, here: https://www.federalreserve.gov/newsevents/pressreleases/monetary20121212a.htm.

[24] For an explanation of the mechanism by which increases in the Federal Reserve's security holdings, such as via LSAPs, result in a commensurate increase in the amount of reserve balances in the banking system, see the appendix to Ihrig, Meade, and Weinbach (2015a or 2015b).

Figure 1.a



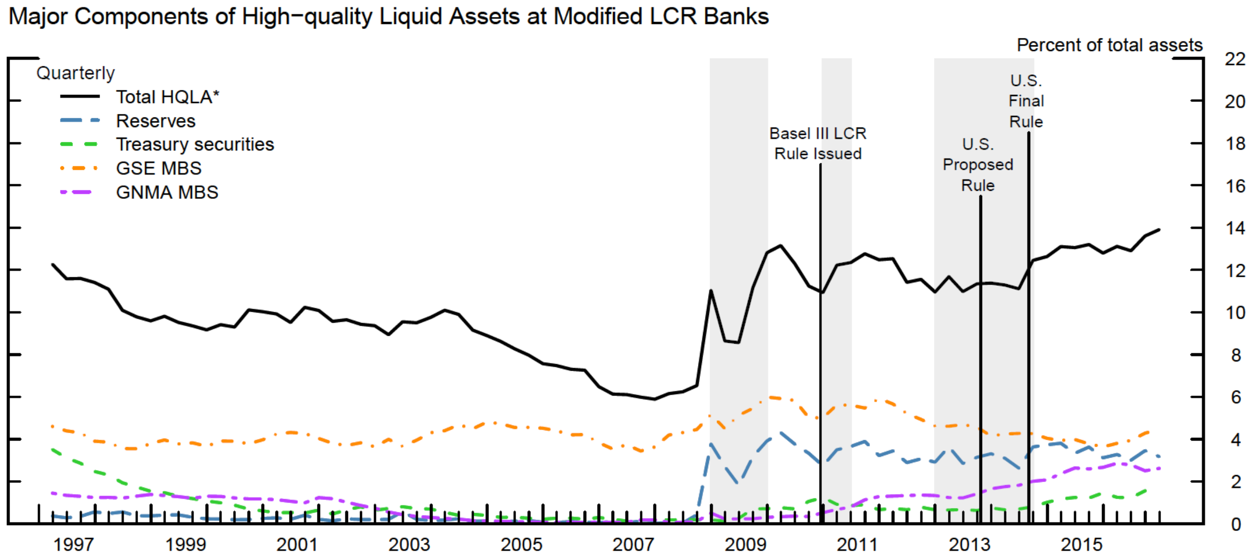
Note: Standard LCR institutions are defined as BHCs with $250 billion or more in total assets or $10 billion or more in on−balance sheet foreign exposures. Shaded bars indicate periods of the Federal Reserve's large−scale asset purchase programs.
Source: Federal Reserve Board, Form FR Y-9C, Consolidated Financial Statements for Holding Companies, Form FR 2900, Report of Transaction Accounts, Other Deposits and Vault Cash (for reserve balances).

Standard LCR BHCs also actively acquired other HQLA-eligible securities in the lead-up to the initial LCR compliance deadline. In particular, these institutions' holdings of Treasury securities, shown by the green-dashed line in the figure, rose over 2014 and continued to grow thereafter. At the end of 2013, the standard LCR BHCs held 1 percent of outstanding Treasury securities; by the end of 2014, this share had risen to 3 percent.[25] In addition, as shown by the orange-dashed line in figure 1.a, these banks' holdings of GSE MBS increased later, in 2015 and 2016. Meanwhile, these banks' holdings of GNMA MBS, the purple-dashed line, stayed relatively low and flat as a share of total assets.

Figure 1.b reports the same data for modified LCR BHCs. Here we see a different pattern. These banks' reserve holdings have been roughly steady from the issuance of the Basel III rule through the end of 2016. In contrast to the standard LCR institutions, these firms mostly increased their holdings of GNMA MBS, a Level 1 asset, over the past several years, and also decreased their holdings of GSE MBS, a Level 2 asset. Of course, another important difference between the two sets of banks is that the modified LCR BHCs needed to undertake a much smaller overall buildup of HQLA, with HQLA now representing about 14 percent of total assets (the black line) compared to about 20 percent for standard BHCs.[26]

[25] Data on Treasury securities outstanding are from the Financial Accounts of the United States in table L.210. These data are published in the Federal Reserve's Z.1 release: https://www.federalreserve.gov/releases/z1/current/default.htm.
[26] This differential in the share of total assets comprised of HQLA at standard versus modified LCR BHCs is approximately accounted for by the differential treatment of the denominator of the modified LCR rule.

Figure 1.b

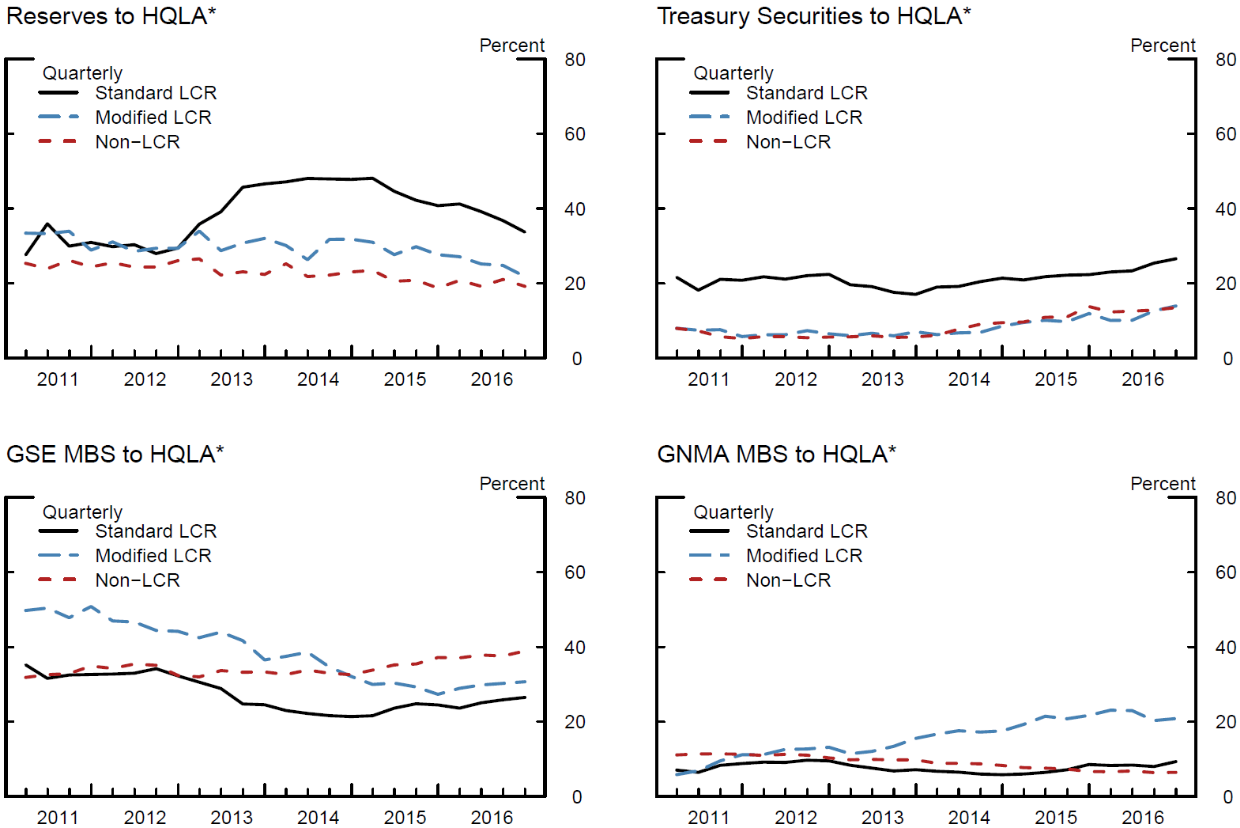


Note: Modified LCR institutions are defined as BHCs with $50 billion or more in total assets. Shaded bars indicate periods of the Federal Reserve's large−scale asset purchase programs.
Source: Federal Reserve Board, Form FR Y-9C, Consolidated Financial Statements for Holding Companies, Form FR 2900, Report of Transaction Accounts, Other Deposits and Vault Cash (for reserve balances).

Next we more directly compare the behavior of the two bank groups, and do so on the basis of compositional HQLA shares. In particular, figure 2 shows the same four HQLA components—reserves, Treasury securities, GSE MBS, and GNMA MBS—but now as a share of banks' holdings of HQLA* (instead of total assets), for both the standard (black lines) and modified (dashed-blue lines) LCR institutions included in figures 1.a and 1.b, respectively. We also plot the same data for non-LCR banks, for comparison (red-dashed lines). The same component contours described above are apparent. Standard LCR BHCs boosted HQLA early in the period by increasing reserves, and then adjusted their compositional shares toward Treasury securities thereafter. Modified LCR institutions mostly boosted HQLA by increasing the share of GNMA MBS while at the same time decreasing their GSE MBS share; they swapped into Level 1 MBS out of Level 2 MBS. Meanwhile, holdings of the non-LCR BHCs across all four HQLA categories shown changed much more modestly.

Overall, we argue that banks were likely facing somewhat different incentives in the run-up to becoming LCR compliant than what they subsequently faced. In the run-up to becoming LCR compliant, some institutions began publicly reporting their early progress; as a result, banks may have felt some pressure at that time to build a sufficient *stock* of HQLA to become compliant. If so, managing the *composition* of HQLA over that period may not have been banks' top priority.

Figure 2: Comparing Shares of Selected HQLA-Eligible Assets by BHC Group (units as a percent of HQLA*)



Note: Reserves defined as balances held at Federal Reserve Banks reported in Call Reports. Only reserve balances held in excess of required amounts are HQLA−eligible. All other data are from the FR Y-9C. Security balances are based on fair values for available−for−sale (AFS) and held−to−maturity (HTM) securities, as well as securities held in trading accounts.
Source: Federal Reserve Board, Form FR Y-9C,Consolidated Financial Statements for Holding Companies, Consolidated Reports of Condition and Income for a Bank with Foreign and Domestic Offices (FFIEC 031), Consolidated Reports of Condition and Income for a Bank with Domestic Offices (FFIEC 041).

Indeed, after late 2014, the time at which banks had to become LCR compliant, our proxies of total HQLA generally level off; banks' subsequent adjustments to HQLA* largely reflect compositional changes. In particular, at the end of 2014, HQLA* comprised about 20 percent of the total assets of standard LCR banks and remained roughly constant thereafter. However, over this same period, reserves started at roughly 45 percent of these institutions' HQLA* and then declined by about 10 percentage points. Meanwhile the MBS and Treasury shares each increased. Similarly, as noted above, modified LCR banks adjusted the composition of HQLA* after becoming LCR compliant, substituting GNMA MBS for GSE MBS as well as more recently increasing the share of Treasury securities.

This reshuffling of banks' HQLA raises the question: What are the optimal shares of HQLA? Below we use standard optimal portfolio theory to shed light on this question, and then examine individual bank's actual portfolio shares while considering other constraints that may interact with the LCR requirement. In the remainder of our analysis we further narrow our focus to the standard LCR banks and to these banks' holdings of the top three HQLA components—reserves, Treasury securities, and GSE MBS.

3. What does portfolio theory suggest are optimal HQLA shares?

Here we apply standard portfolio theory to solve for the optimal portfolio of HQLA.[27] We use the benchmark capital asset pricing model (CAPM) in which the optimal portfolio of risky assets is constructed by maximizing the risk-return ratio. We assume a BHC allocates HQLA across three assets—reserve balances, Treasury securities, and GSE MBS. In addition, we assume that reserve balances, which have an even lower default risk than Treasury securities, are the risk-free asset.[28] We also assume that each individual bank can choose the level of reserve balances it individually wishes to hold. Of course, the aggregate quantity of reserve balances is determined by the Federal Reserve; unlike other assets, while an individual bank may adjust its individual holdings of reserves, the banking system as a whole cannot do so, and this factor likely constrains our results.

For each bank, we first solve for its optimal "risky" portfolio (denoted with subscript "R")—that is, the shares of Treasury securities and MBS—that maximize the risk-return tradeoff captured by equation (2), where E (r_R) is the expected return of the risky portfolio, σ_R is the standard deviation of the risky portfolio, and A is a parameter that captures the level of the bank's risk tolerance.

$$U(r_R) = E(r_R) - \frac{1}{2} A\, \sigma_R^2 \qquad (2)$$

Then, with this risky portfolio in hand, we find the share of the risk-free asset—reserve balances—to pair with the optimal risky portfolio to generate the bank's full HQLA portfolio. Letting *w* be the share of risky assets in the bank's overall HQLA portfolio (denoted with subscript "P"), the optimal shares solve equation (3).

$$U(r_P) = E(r_P) - \tfrac{1}{2} A\, \sigma_P^2 \qquad (3)$$

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[27] Value at Risk (VaR) is another key metric—a statistical technique—used by banks to assess and monitor the level of financial risk undertaken by the bank or embodied in a specific investment portfolio, but we choose not to utilize such an approach here. VaR estimates potential losses on investments in extreme circumstances (tail risk) and tends to be applied to highly volatile exposures or components of the balance sheet such as swaps and currency exposures and other derivatives positions. In addition, while VaR could be useful in helping to determine the desired buffer of liquid assets to hold above the LCR requirement, it is less useful for assessing the composition of HQLA.

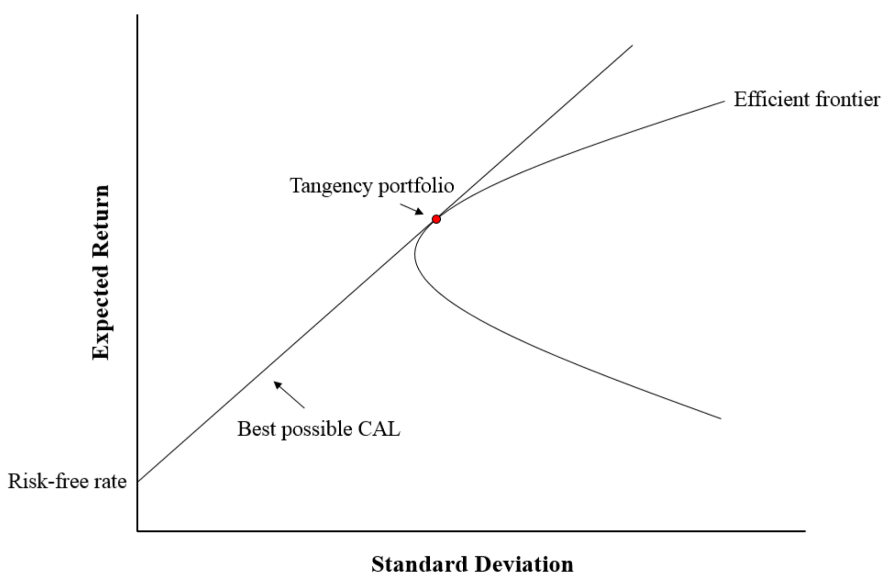
[28] For example, in August 2011, Standard & Poor's downgraded the credit rating of U.S. Treasury debt from AAA to AA+ shortly after Congress voted to raise the debt ceiling of the federal government by means of the Budget Control Act of 2011.

$$where \quad E(r_P) = (1-w) * r_{RB} + w * E(r_R - r_{RB}) \quad and \quad \sigma_P^2 = w^2 * \sigma_R^2$$

Importantly, because the yield on the risk-free asset in our application (the return on reserve balances, r_{RB}) is not a market rate but an administered rate set by the Fed, we interpret differences in "risk"—as measured by the covariance of returns among our three assets—as capturing somewhat broader factors than in a typical application of this approach. In particular, the risk-free asset in our case embodies no market risks, such as, for example, interest rate risk, while the other assets do.

The curve in figure 3 shows the efficient frontier that represents optimal shares of Treasury securities and MBS holdings—the risky portfolio—for given risk-return tradeoffs. When a risk-free asset is introduced, the straight line shown in the figure, known as the capital allocation line ("CAL" in the figure), is the new efficient frontier for the entire portfolio. The line's vertical intercept represents a portfolio that contains only the risk-free asset. The red dot represents a portfolio that consists only of the risky assets. All points on the line between these two corner solutions represent portfolios in which it is optimal to allocate some funds to both the risk-free asset and the risky assets. Where a bank ends up on that line depends on its tolerance for risk—its value of A.

Figure 3: The standard investment "efficient frontier"



To solve for each bank's optimal portfolio shares, we use one representative Treasury security and one representative GSE MBS security in the analysis.[29] Information on the maturity of

[29] For simplicity, our analysis ignores the tradeoffs banks face in choosing among various types of Treasury securities and MBS, as well as among other types of securities that may be held to meet HQLA (albeit under a range

banks' securities holdings is not available through publicly available sources, so we use the confidential FR 2052a data described above to compute the average maturity of securities held by U.S. LISCC banks. The maturity buckets collected are not sufficiently granular to distinguish among specific maturity holdings of Treasury securities or MBS, but we do see that the largest BHCs tend to hold securities of these types that mature in 5 or more years. Therefore, we assume that the market yield on Treasury securities of 5-year constant maturity and 5- and 10-year constant maturity MBS (Fannie Mae) yields are the best available proxies for the returns on the two risky assets in our model portfolio.

Our analysis also relies on an assumed bank-level risk tolerance level. Adjusting the level of the risk tolerance parameter, A, affects the intensity of banks' presumed preference for risky assets relative to the safe asset. Although there is a vast literature on the measurement of risk aversion, there is not a commonly accepted empirical estimate.[30] We report, therefore, results for a generous span of values of the risk tolerance parameter, A—we report results for a value of 1 (high risk tolerance), 10 (low risk tolerance), and 5 (a mid-range value).

Regarding our sample period, to start, we consider a fairly recent period beginning in 2012 in which the Federal Reserve's balance sheet was large and it operated the current monetary policy implementation framework, a floor system. In this case, our model suggests that banks should not want to hold any amount of the risk-free asset—reserve balances—to satisfy HQLA. This holds for all values of the risk tolerance parameter, A. In fact, given the relatively high return on MBS, institutions prefer to hold all assets in MBS. But, as noted above, there is a limit to the amount of GSE (Level 2) MBS that may be used to satisfy HQLA; because no more than 40 percent of a bank's HQLA holdings may consist of such MBS, portfolio theory would indicate that, under such a constraint, the optimal composition of HQLA is 60 percent Treasury securities and 40 percent GSE MBS.[31]

However, one may think that in recent years, the volatility in market rates have been constrained by the zero lower bound, and, given that our model relies on the relationship between asset returns and covariances, this circumstance could bias the results away from holding the risk-free

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of haircuts). Given that rates of return are not perfectly correlated, the choice of assets considered does affect the estimated shares. For example, if in the last row of table 2 a 2-year Treasury security is considered instead of a 5-year security (column 2), the optimal reserves share (column 4) rises to 16 percent (with the share of Treasury securities and MBS falling to 50 and 34 percent, respectively). In addition, as already noted, for simplicity our analysis ignores other HQLA-eligible assets. For example, HQLA may also consist of qualifying corporate debt securities rated AA- or higher (at 15 percent haircut) or rated between A+ and BBB- (at 50 percent haircut).

[30] See Grandelman and Hernández-Murillo (2014) for a review of the risk aversion literature. The most commonly accepted estimates of the coefficient of relative risk aversion probably lie between 1 and 3, but there is a wide range of estimates in the literature—from as low as 0.2 to 10 and higher.

[31] We do not account here for the 15 percent haircut that is applied to banks' holdings of GSE MBS; doing so in this scenario would result in banks holding even more MBS to achieve the 60-40 portfolio. We exclude both haircuts and caps in our portfolio model because it is not straightforward to adjust the yields we consider to reflect such constraints.

asset toward a riskier portfolio. Therefore, we also consider a period from 2001 onward, one that embodies much more variability in asset returns. In this case, because the Federal Reserve began paying interest on reserve balances in late 2008, we assume the risk-free asset is remunerated at the effective federal funds rate prior to the onset of interest on reserves. This assumption can be interpreted as one in which the pre-crisis monetary policy implementation framework was a corridor system that paid interest on excess reserves.[32]

For this longer time period—beginning in 2001—we do find demand for the risk-free asset, reserves. As shown in table 2, the share of reserves in an optimal HQLA portfolio (column 4) ranges widely depending on the assumed degree of banks' tolerance for risk (column 1). For example, when banks' risk tolerance is low (that is, A is set to 10; the first pair of rows in the table), the optimal share of reserve balances ranges from 40 percent to about 80 percent of total HQLA, depending on the securities considered. In contrast, when banks' risk tolerance is assumed to be high (A = 1; the bottom pair of rows in the table), the optimal share of reserves is zero.

Table 2: Optimal Portfolio Composition using Data from 2001 to 2016

Banks' risk aversion (A)	Maturity of the two "risky" assets		Portfolio Compositions (optimal portfolio shares, in percent)			
	Treasury securities	GSE MBS	Reserves	Treasury securities	GSE MBS	Total *(by definition)*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Very high A (A = 10; **low risk tolerance**)		5 year	79	0	21	100
		10 year	40	20	40	100
Middle of range (A = 5)	5 year	5 year	59	1	40	100
		10 year	15	45	40	100
Very low A (A = 1; **high risk tolerance**)		5 year	0	60	40	100
		10 year	0	60	40	100

[32] Setting the return on reserves to the effective federal funds rate over the early portion of this sample period may constitute a return that is higher than would have been the case in practice, which would upwardly bias the resultant reserve balance share in our model. More generally, standard models of the federal funds market show that an increase in the rate at which federal funds are remunerated decreases the opportunity cost of holding reserves, suggesting that banks would demand more reserve balances as the remuneration rate rises (see figure 5 of Ihrig et al. (2015a)).

These results have implications for the Federal Reserve's longer-run supply of reserves in the banking system. That is, if banks were to manage their HQLA portfolios solely to maximize their risk-return tradeoff and banks are risk intolerant, then the LCR requirement has effectively caused a structural change that may boost banks' demand for reserves relative to the pre-crisis period. This means that for any given level of the federal funds rate, more reserves may be needed in the banking system than prior to the financial crisis to meet banks' demand. However, the additional amount of reserves that banks may demand is unclear. For example, we have seen that as the level of reserves in the banking system declined through 2016, from $2.5 trillion in March to about $1.9 trillion in December, no pressure was evident on the various interest rates that one might expect if banks in fact desired to hold all of those balances. Moreover, Grandelman and Hernández-Murillo (2014) note that the most commonly accepted measures of the coefficient of relative risk aversion lie between 1 and 3, values for which the reserves share is small relative to that of the risky assets. And, importantly, relative rates matter—if the yield on Treasury securities or MBS is sufficiently higher than the administered rate that the Federal Reserve sets on interest on excess reserves, then any LCR-driven demand for reserves could be relatively dampened.[33]

Next we look at individual bank's HQLA management, which can be influenced by its degree of risk tolerance as well as by several other operating factors that a basic risk-return model ignores.

4. What do individual, bank-level data show?

To get an understanding of how individual BHCs responded to the LCR, we look at eight standard LCR BHCs; the FR 2052a data and their historical counterpart, which we use in section 6, are available at a daily frequency for these representative banks. At the end of 2016, these eight institutions together held more than $1.5 trillion of HQLA* and represented 70 percent of the total assets of all standard LCR BHCs (those shown in figures 1.a and 2). First we look at how banks managed their HQLA* shares over the period in which they were primarily seeking to increase their HQLA holdings to meet the LCR—that is, the period through the end of 2014—and then we look at more recent quarters, a period in which banks subsequently adjusted their HQLA shares.

Figure 4 displays the composition of each of these eight institution's HQLA*, where the institutions are plotted by size of HQLA* holdings, largest to smallest from left to right. The red vertical bars indicate when each institution publically announced that they fully met their LCR. As shown, in the run-up to meeting the LCR, about half of these banks display a heavy reliance on reserve balances, the blue portions of the bars, while others relied on a wider range of assets.

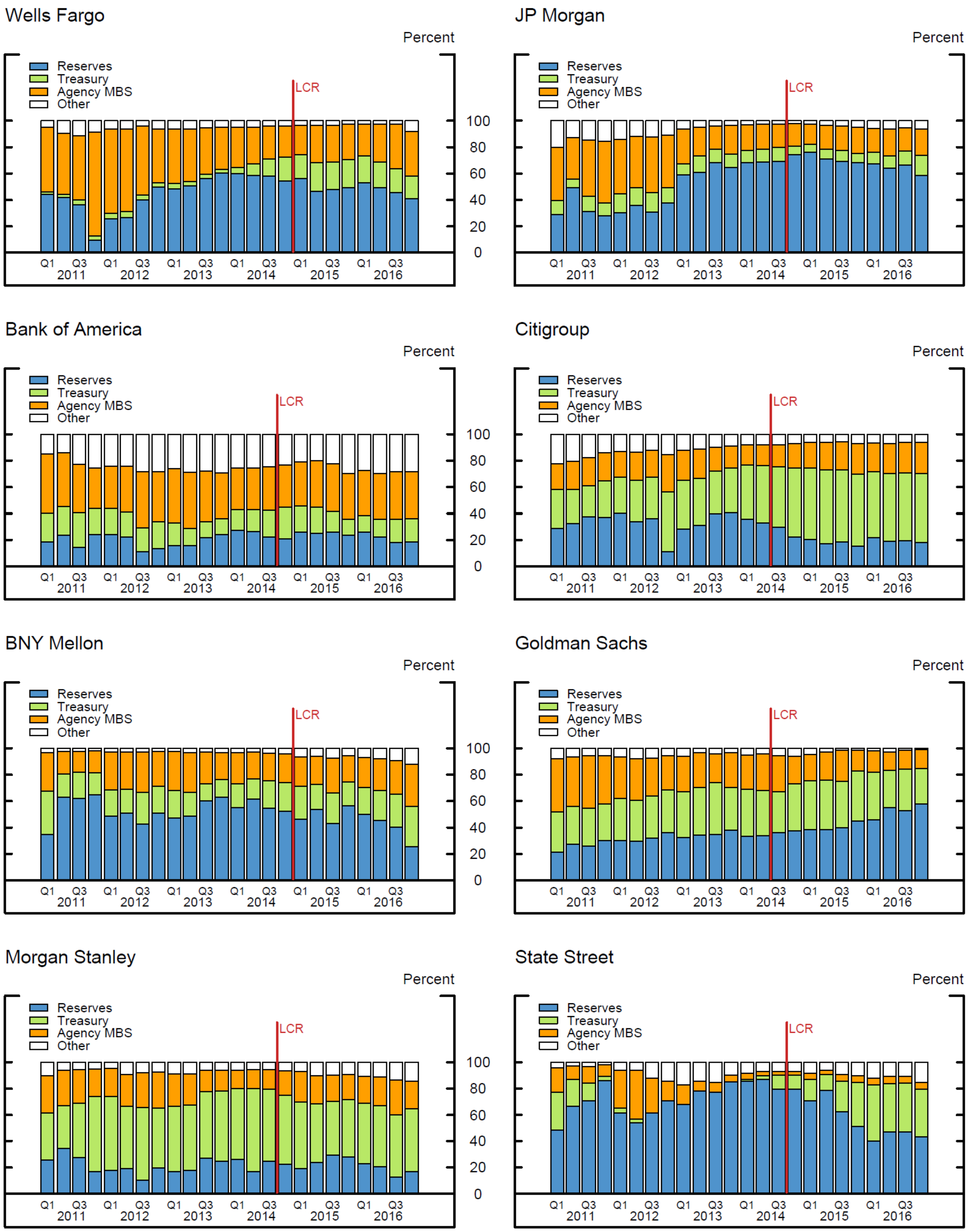
[33] For example, for A equal to 3, if the return on Treasury securities was boosted by 25 basis points relative to its historical average, all else equal the optimal Treasury share would rise by about 10 percentage points, the MBS share would remain at 40 percent, and the reserves share would decline by 10 percentage points.

After this time, those that relied heavily on reserves exhibit a decline in the share of reserve balances in HQLA*, albeit to varying degrees. Such adjustments are consistent with BHCs subsequently aiming to improve the return on their HQLA portfolios and determining that less reserves was needed to meet internal liquidity needs. Considerations about banks' individual internal liquidity needs are discussed in section 5.

Consistent with the portfolio calculations above, currently there is a wide range of shares of HQLA* comprised of the risk-free asset—the share of reserve balances in HQLA* ranges from as little as around 20 percent or less for about half of these institutions up to above 50 percent. Even the four largest holders of HQLA* are noticeably dissimilar in their compositional choices despite the fact that most of these institutions primarily follow a "traditional bank" business model: Wells Fargo relies mainly on a mix of reserve balances and GSE MBS; JP Morgan mainly reserves; Bank of America mainly MBS; and Citigroup mainly Treasury securities. In addition, there are other indications that banks can differ significantly in their individual approaches to managing HQLA. For example, Citigroup and Bank of America have maintained roughly the same composition of HQLA* in 2015 and 2016. Meanwhile, many of the other six BHCs have replaced some reserves with Treasury securities or MBS.

Of course, these differing choices are not just the result of banks' divergent preferences regarding the risk-return tradeoff associated with these assets; many other factors are also in play. In the next section we review a range of other factors that are likely relevant in these institutions' decisions regarding their management of HQLA.

Figure 4: Individual Bank's HQLA* Shares



Note: Reserves defined as balances held at Federal Reserve Banks reported in Call Reports. All other data are from FR Y-9C. Security balances are based on fair value for available-for-sale (AFS) and held-to-maturity (HTM) securities, as well as securities in trading accounts. Other HQLA includes GNMA MBS, agency CMBS, and agency debt. The red line indicates the quarter in which each entity publicly stated it met the fully phased-in final U.S. LCR rule based on its own calculations.
Source: Federal Reserve Board, Form FR Y-9C, Consolidated Financial Statements for Holding Companies, Call Reports, transcripts from quarterly earnings calls and financial updates.

5. Other factors affecting banks' HQLA management

Since the financial crisis, many banks have devoted significant resources to bolstering their internal liquidity risk management function and various regulators have developed new supervisory initiatives to monitor and assess these changes. These considerations interact with institutions' actions to meet their LCR constraint. Here we discuss how various goals of and constraints on banks' liquidity management result in competing incentives regarding banks' demand for reserves, Treasury securities, and GSE MBS. In particular, table 3 summarizes some key factors that likely interact with banks' HQLA decisions. For each row in the table one can ask, "How should a bank that is concerned with a given factor best increase HQLA or adjust its compositional shares?" That is, if a liquidity management goal or constraint is important to a bank's operations, how should it best add to its stock of HQLA on the margin, or how should it re-optimize a given stock of HQLA, where either one of those actions results in a change in its relative compositional shares of HQLA.

Table 3: Other Factors that Interact with Banks' HQLA Management
(*that is, in light of a given factor, how best to marginally increase HQLA or adjust relative shares?*)

	HQLA Share		
Liquidity management goal / constraint	**Excess reserves**	**Treasury securities**	**GSE MBS**
1. Maximize ability to monetize HQLA	↑	↗	↘
2. Business models/individualized needs	Depends	depends	depends
3. Minimize interest rate risk	↑	↘	↓
4. Leverage ratio is binding	↑	↑	↓
5. Risk-based capital requirement is binding	↑	↑	↓
Portfolio theory: Maximize risk-return tradeoff, assuming bank is risk tolerant	↓	↗	↑
Key: ↑ increase relative share (that is, increase this share relative to other two shares considered); ↗ increase relative share somewhat; → little to no effect on relative share; ↘ decrease relative share somewhat; ↓ decrease relative share			

As noted in the "portfolio theory" row of the table, a bank that seeks to maximize only a risk-return tradeoff in managing its HQLA shares would most likely tend to marginally increase its LCR-compliant liquidity pool by putting an additional dollar into GSE MBS, perhaps some

Treasury securities, and most likely not in reserves (unless risk intolerant). However, as indicated by rows 1 through 5, when we account for banks' other liquidity management goals and constraints, we find that BHCs are more likely to prefer investing that additional dollar in reserves. The implications of considering these other factors in gauging banks' preference for Treasury securities is not as clear cut, but Treasury securities are generally preferable to MBS in this regard. We discuss each of the factors in turn below.

Maximize ability to monetize HQLA. As shown in row 1, a desire to maximize the liquid properties of HQLA—that is, to have sufficient cash as well as sufficient cash-like assets that can be converted easily and quickly into cash with little or no loss of value—would likely lead a bank to prefer different share concentrations than if it were to focus only on the risk-return tradeoff. A bank's assessment of the liquid properties of its HQLA assets are likely based on a number of assumptions that are not only market-based but also bank-specific. For example, a bank may estimate its ability to engage in repurchase agreement transactions (repos), or to conduct outright asset sales of significant size, based on the scope of its own market share associated with these activities. In addition, when assessing the ability to quickly and efficiently monetize Treasury securities or MBS, factors such as the bank's ability to tap lenders for additional credit in certain circumstances (such as when single-counterparty credit limits associated with repo may bind) could be an important consideration. An institution may assess such factors in the form of internal risk limits or haircuts which are applied above and beyond what is prescribed by the LCR.

Business models and individualized needs. A bank's management of liquid assets is driven importantly by its own internal liquidity risk management framework, which in turn reflects its particular business model and individualized liquidity needs. For example, banks that engage in significant payment, settlement, and clearing activities may desire a relatively high share of reserve balances to meet intraday liquidity needs.[34] Investment banks may also face additional intraday liquidity needs from dealer-intermediated activities and businesses such as prime brokerage services and derivatives trading. Banks' commercial lending activities also shape their liquidity needs; banks may provide intraday and overnight lines of credit to nonfinancial firms or to nonbank financial institutions that require relatively quick funding of advances when drawn.[35] And, banks with significant amounts of deposits from institutional clients such as other financial institutions need sufficient cash to meet the possibility of large and variable withdrawals. Meanwhile, banks that engage with retail clients may provide credit cards or home equity lines of credit that can be unpredictably tapped. Finally, the scale of banks' activities affects their liquidity needs. For example, a given liquidity management strategy, such as one

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[34] For example, processing banks such as State Street, Bank of NY Mellon, and JP Morgan, are motivated to maintain access to significant levels of cash to meet payments transactions, with the ultimate amount held determined by assumptions regarding the availability of intraday liquidity.

[35] For example, nonbank financial institutions such as bond funds may have credit lines with banks to manage daily redemptions of their investors, and nonfinancial corporations often have both intraday and overnight lines of credit with various banks to meet their short-term cash needs.

that involves assumptions about a bank's ability to liquidate a set of securities quickly, may not be practical on a substantially larger scale.

In general, banks develop assumptions regarding the amounts and types of liquidity that are necessary to perform various business activities. Most banks intensely manage both their current cash levels and their potential need for cash by modeling numerous scenarios which in turn dictate internal liquidity risk "limits" and other internal liquidity risk management policies. For some banks at least, these internal operational assessments are very important drivers of their overall liquidity management.[36] Because reserve balances play a unique role in meeting intraday (T + 0) and next-day (T + 1) liquidity needs, an optimal portfolio theory model of HQLA may understate banks' demand for liquidity in the form of reserves. Overall, as indicated by row 2 of table 3, these complex and somewhat idiosyncratic decisions are hard to model and assess.[37]

Minimize interest rate risk. As shown in row 3, interest rate risk is another important consideration in a bank's HQLA portfolio choices. The value of a bank's HQLA portfolio is based on current market prices, with movements in interest rates potentially causing a repricing of those assets. Because reserve balances receive a fixed overnight return there is no, or relatively little, interest rate risk associated with these asset holdings.[38] However, the day-to-day returns on longer-term assets vary as their market prices vary with current and expected future financial market conditions. To reduce interest rate risk from Treasury holdings, shorter tenors can be purchased. While shorter tenors of MBS could also be used to manage interest rate risk associated with those securities, the duration of MBS generally lengthens when interest rates rise because in that circumstance, mortgage prepayments tend to decline. As a result, interest rate risk is relatively higher for MBS than Treasury securities, even if the securities pay the same coupon rate. In addition, some BHCs are more broadly affected by marked-to-market changes in their liquidity portfolios.[39]

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[36] Some banks have publically stressed this point. For example, the chief financial officer of JP Morgan said during an earnings conference call that the "LCR is an important measure. It's a regulatory measure. We're measuring it, we're reporting it, but we run the firm based upon our own internal liquidity stress framework" (FactSet CallStreet (2014b)).

[37] Separately, market participants have noted that the extent to which the Fed's CLAR process represents a binding constraint is difficult to assess and is largely dependent on the business model of the bank. See, for example, Elliott (2014).

[38] Reserves have zero interest rate risk in that the principal value cannot change. But fundamentally, just like other assets, the return on reserves varies; reserves have a relatively low (high) return when the Federal Reserve has accommodative (tight) monetary policy.

[39] Under Basel III, some BHCs must include net unrealized gains and losses from available-for-sale (AFS) securities in their calculation of the common equity tier 1 to risk-weighted assets (CET1) ratio. For such institutions, changes in the valuation of AFS securities add volatility to this capital ratio. While both AFS and held-to-maturity (HTM) securities qualify for HQLA, only AFS securities can be immediately sold without accounting rule penalties. There has been a notable increase in the share of HTM securities at large banks since 2011, thus reducing the impact of interest rate risk on the regulatory capital ratios of such banks.

Capital regulations. Some regulations increase the cost of expanding a bank's balance sheet, such as the leverage ratio.[40] The leverage ratio is intended to augment risk-based capital requirements and limit the amount of leverage that a bank may incur using a blunt, non-risk-based measure and one that includes both on- and off-balance sheet exposures. As shown in row 4 of table 3, an institution that is close to or at its leverage ratio would generally prefer Level 1 HQLA to Level 2 HQLA; an additional $1 of either type of these assets would affect the leverage ratio equally, but the latter category is subject to haircuts in calculating HQLA. As shown in table 2, optimal portfolio theory indicates a large weight on reserves and Treasury securities for all but the very high risk-tolerant banks.[41] And, importantly, only a few U.S.-regulated BHCs currently appear to be near a leverage ratio constraint.

In general, risk-based capital requirements are more binding for banks than the leverage ratio.[42] As shown in row 5 of table 3, if a bank's risk-based capital ratios are binding, Level 2 HQLA such as GSE MBS are again less attractive because such assets carry a non-zero risk weight.[43] A bank that was effectively bound by a risk-based capital ratio would likely lean toward onboarding additional excess reserves and Treasury securities to meet its LCR because those assets carry a zero risk weight.

Lastly, the total loss-absorbing capital (TLAC) requirement likely has a similar effect on HQLA composition as risk-based capital ratios because the risk-based metric of the requirement is generally more binding than the leverage-based metric.[44] The TLAC rule seeks to lengthen the duration of banks' funding sources by requiring U.S. GSIBs to hold some long-term debt in addition to their capital buffers.

6. Recent behavior of HQLA shares—daily variability

Thus far we have considered the behavior of banks shares of HQLA based on publically-available, quarter-end data. Here we examine the *daily* movement in banks' individual HQLA

[40] Here we generally refer to "the leverage ratio" but it takes different forms. Leverage ratios include the supplementary leverage ratio that is applicable to Advanced Approaches BHCs (including international holding companies, or IHCs) and the enhanced supplementary leverage ratio (eSLR) that is applicable to BHCs with $700 billion or more in consolidated assets. The definition of the eSLR may be found on the Board's website: https://www.federalreserve.gov/newsevents/pressreleases/bcreg20140408a.htm.

[41] For example, a risk-inclined bank may want to hold 40 percent of HQLA in MBS, but if it happen to also be effectively bound by their leverage ratio, it would be incented instead to hold more Treasury securities.

[42] The CET1 ratio is generally the most binding for traditional banks (those whose assets consist of a large portion of loans), for two reasons. First, CET1 equity is the most costly form of funding. In addition, loans are subject to large assumed loss rates for stress testing purposes and have higher risk weights than securities.

[43] An example of a risk-based capital ratio is the CET1 to risk-weighted assets ratio.

[44] For more information on the TLAC rule, see the press release regarding the final rule which includes a link to the Federal Register Notice: https://www.federalreserve.gov/newsevents/pressreleases/bcreg20161215a.htm. BHCs affected by the rule must comply by January 1, 2019. The leveraged-based TLAC requirement is generally less binding because the capital buffer is effectively redundant with the eSLR requirement. The leverage-based requirement can be met by complying with the 5 percent eSLR requirement and maintaining 4.5 percent TLAC-eligible debt. (Footnote 40 defines the eSLR.)

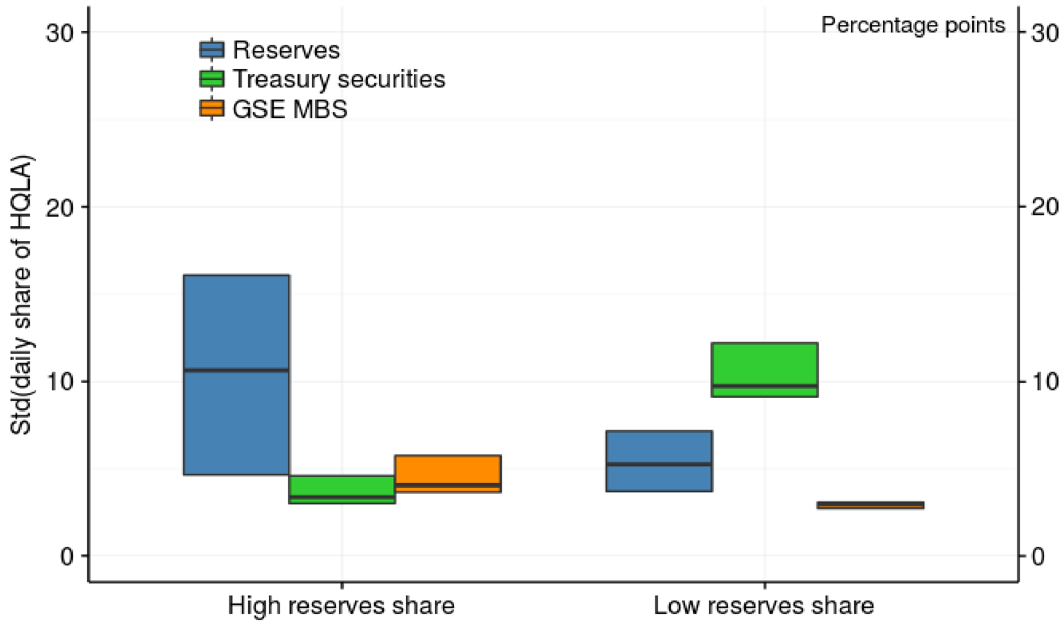
shares based on the confidential FR 2052a microdata described above. Overall, we find that the pattern of dispersion in the variance of these shares supports the view that banks' individual business models and other idiosyncratic factors are important drivers in the management of HQLA.

In particular, focusing on the period after 2014 in which banks had become compliant with the LCR and adjustments to component shares were more common, we compute the average daily standard deviation of the reserves, Treasury securities, and GSE MBS shares of HQLA for each of the eight banking firms shown in figure 4. As shown in figure 5, we divide the sample into two bank groups: banks with relatively high reliance on reserve balances—the left-hand set of bars—and banks with a low reliance on reserve balances, the right-hand set of bars. As shown by the left-most blue bar, the median share of reserves that comprises reserve-reliant institutions' HQLA varies day-to-day by about 10 percentage points, and the interquartile dispersion runs from 5 to 15 percentage points on any given day. Meanwhile, the shares of these banks' Treasury securities (in green) and MBS (in orange) are significantly more stable. In contrast, as shown by the right-hand set of bars, banks with relatively low reliance on reserve balances in this context tend to exhibit higher average daily variation in the Treasury share of HQLA, with relatively low volatility in these banks' reserves and MBS shares.

We do not find it surprising that the MBS shares exhibit relatively little daily volatility across the two bank groups. While MBS are a desirable type of HQLA in terms of the risk-return tradeoff, as we noted above, such holdings are restricted by the 40 percent cap on Level 2 assets. Thus, BHCs may largely position their MBS holdings at a desirable level and not seek to adjust that component of HQLA on the margin. As evidence of this, across all eight banks, about 30 percent of MBS holdings are booked as hold to maturity (HTM).[45] In contrast, closer to 20 percent of Treasury securities are classified as HTM. In addition, as discussed above, banks' business models and individual activities, including deposit taking, lending activities, payments settlement or broker-dealer activities, importantly drive banks' differing needs for liquidity as well as the behavior of banks' balance sheet components. As such, we would generally expect reserves and Treasury securities—the most liquid forms of HQLA—to be the shares that exhibit the highest daily swings.

[45] See footnote 39 for the significance of banks' HTM versus AFS holdings.

Figure 5: Daily Variance of Bank's HQLA Shares Post-LCR



Note: The post-LCR time period begins in 2015. Here we build on figure 4: "High reserves share" banks are comprised of the four banks with highest average shares of reserves to HQLA, and "Low reserves share" banks are comprised of the remaining four banks. The horizontal line through each bar is the median bank's standard deviation; the high and low ends of each bar signify the 75th and 25th percentiles, respectively. (With four observations in each bank group, medians and percentiles are the midpoint (mean) of the appropriate neighboring observations.)
Source: Federal Reserve Board, Form FR 2052a, Complex Institution Liquidity Monitoring Report.

7. Conclusion

The LCR is a post-crisis liquidity requirement that has importantly affected the management of banks' balance sheets, research about which is only emerging. Our paper contributes to the discussion by not only documenting how domestic banks have managed the compositions of their HQLA pools over recent years, but by providing a theoretical framework to examine how the LCR affects banks' preferences for the composition of a given stock of HQLA.

Using a range of data, including some unique confidential data, we showed that large bank holding companies initially took on excess reserves as they moved to become compliant with the LCR, and that subsequently some banks adjusted the compositions of their HQLA, reducing shares of reserves and increasing shares of Treasury securities and GSE MBS. We demonstrated that optimal portfolio theory is consistent with banks reducing their reserve balance shares once they became LCR compliant and began optimizing their HQLA compositions. We also described an important implication of the LCR for the Federal Reserve's longer-run implementation of monetary policy. That is, the LCR affects banks' liquidity management and thus banks' demand for reserves, and therefore could influence the longer-run size of the Federal Reserve's balance sheet. However, the extent of banks' LCR-induced demand for reserve balances is unclear. Our model analysis showed that banks' demand for reserves is sensitive to their risk preferences as well as to the opportunity cost of holding such balances. In the context of our model, if banks are relatively risk tolerant, their demand for reserves to meet their LCRs may not be very large. We also discussed several other constraints faced by banks—including the desire to minimize interest rate risk, to manage capital considerations, and to enable individualized business models and other banking activities to function well—and how these constraints interact with banks' choice of HQLA shares. We looked at both the current compositions of banks' HQLA shares and the pattern of daily volatility of those shares and found support that such constraints interact with banks' HQLA decisions and thus their liquidity management.

Data Appendix

Publicly Available Data Sources Used to Construct HQLA*

HQLA* Item	**Calculation**
Reserves	FFIEC 031/041 RC-A item 4
Treasury securities	FR Y-9C HC-B item 1 (column B) + item 1 (D) + HC-D item 1 (A)
GNMA MBS	FR Y-9C HC-B item 4.a.(1) (B) + item 4.a.(1) (D)
Non-GSE agency debt	FR Y-9C HC-B item 2.a (B) + item 2.a (D)
GSE debt	FR Y-9C HC-B item 2.b (B) + item 2.b (D) + HC-D item 2 (A)†
GSE MBS	FR Y-9C HC-B item 4.a.(2) (B) + item 4.a.(2) (D) + item 4.b.(1) (B)† + item 4.b.(1) (D)† + HC-D item 4.a (A)† + item 4.b (A)†
Agency CMBS	FR Y-9C HC-B item 4.c.(1)(a) (B)† + item 4.c.(1)(a) (D)† + item 4.c.(2)(a) (B)† + item 4.c.(2)(a) (D)† + HC-D item 4.d (A)†

† Includes obligations of both U.S. government agencies and U.S. government-sponsored enterprises.

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