# On Regulation and Excess Reserves

## The Case of Basel III


Stephen Matteo Miller
and Blake Hoarty


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MERCATUS CENTER
George Mason University
3434 Washington Blvd., 4th Floor, Arlington, Virginia 22201
www.mercatus.org

*Stephen Matteo Miller and Blake Hoarty. "On Regulation and Excess Reserves: The Case of Basel III." Mercatus Working Paper, Mercatus Center at George Mason University, Arlington, VA, July 2020.*

**Abstract**

Recent studies suggest liquidity regulation contributed to the rise in excess reserves, but capital regulations may matter, too. We use a simple model to show that banks may tilt portfolios away from higher risk-weighted assets like loans and toward lower risk-weighted assets like reserves and Treasuries in response to higher risk-based capital requirements, but not in response to higher non-risk-based capital requirements. Empirical results suggest that advanced approaches banks, which were the focus of Basel III capital regulations that preceded Basel III liquidity regulations, held more excess reserves than smaller large banks after the regulatory changes, before later substituting Treasuries for these reserves.

*JEL* codes: E02, F33, G01, G18, G28

Keywords: bank capital regulation, bank liquidity regulation, interest on reserves, unintended consequences

**Author Affiliation and Contact Information**

Stephen Matteo Miller
Senior Research Fellow
Mercatus Center at George Mason University
smiller@mercatus.gmu.edu

Blake Hoarty
MA Fellow
Mercatus Center at George Mason University

**Acknowledgments**

We thank David Beckworth and Darryl Getter, as well as our discussant on an earlier draft presented at the 2019 Western Economic Association International conference, Raymond Kim, and our discussant at the 2019 Southern Economic Association conference, Ricardo Correa.

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This paper can be accessed at https://mercatus.org/publications/financial-markets/regulation-excess-reserves-case-basel-III

**On Regulation and Excess Reserves: The Case of Basel III**

Stephen Matteo Miller and Blake Hoarty

## 1. Introduction

Before Congress authorized the Federal Reserve (Fed) policy in October 2008 to pay interest on bank balances held at Regional Fed banks, or reserves, US banks limited their holdings of excess reserves. However, since payment of interest on reserves began, US banks, especially larger ones, have held substantial excess reserves. US bank holdings of excess reserves increased further as US regulators implemented the Basel III framework, which applies to larger banks. In what follows, we examine the extent to which US Basel III capital regulation, which focuses primarily on the largest, "advanced approaches" banks, may have contributed to their holdings of excess reserves. We also examine how US Basel III could have limited the recovery of lending for these banks, relative to smaller large banks.

To date, few studies discuss and none offer evidence concerning how capital regulation might influence bank holdings of excess reserves, even though risk-based capital regulation favors holding them while non-risk-based capital regulation does not. Consider, for instance, Ennis and Wolman (2015), who among other things tested whether more capital constrained banks had a tendency to hold more reserves during the sample period and found that they did not. While this was certainly an important hypothesis to test, rejecting such a hypothesis does not mean capital regulation does not influence bank holdings of excess reserves. After all, several studies in the banking literature show that banks—especially the larger ones and even during the 2007–2009 crisis—operate with more than the minimum amount of required regulatory capital (see Berger et al. 2008; Flannery 2014; Barth and Miller 2018). Also, several studies document how complex risk-based capital requirements have become over the last 30 years (see Herring 2005, 2007, 2016, 2018; Barth and Miller 2018). Banks can game those complex regulatory capital requirements in ways that alter their balance sheets or business models (see Merton 1995; Jones 2000; Brealey 2006; Acharya, Schnabl, and Suarez 2013; Miller 2018; Efing 2019).

In short, risk weighting penalizes banks for holding higher risk-weight assets, relative to lower risk-weighted assets, by requiring them to have more capital to back those assets. As a result, higher risk-based capital requirements can give banks incentives to substitute away from higher risk-weighted assets, such as loans, and toward lower risk-weighted assets, such as Treasuries and reserves.

At the same time, Covas and Driscoll (2014) and De Nicolò, Gamba, and Lucchetta (2014) show how capital and liquidity regulations could potentially reinforce each other, which poses a challenge for identifying the effects of each type of regulatory change. Moreover, Bech and Keister (2017) and Rezende, Styczynski, and Vojtech (forthcoming) suggest that new Basel III liquidity regulations, which among other things call on banks to invest in a sufficient amount of liquid assets to cover net cash outflows over a 30-day period, explain the rise in excess reserves. Recent releases of the Fed's survey of senior financial officers also point to the role of liquidity regulations as a reason for the rise in excess reserves.[1] We therefore provide an approach to navigate through the regulatory complexity that allows us to highlight the potential effects of capital regulation theoretically and empirically.

We begin by showing how bank capital requirements might, in theory, alter bank allocations. To do so, we extend Dutkowsky and VanHoose's (2017) model by replacing

[1] For a description of the survey, see "Supporting Statement for the Senior Financial Officer Survey," Board of Governors of the Federal Reserve System, last modified October 17, 2019, https://www.federalreserve.gov/data/sfos/sfos.htm. For releases of the survey, see "Senior Financial Officer Survey: Release Dates," Board of Governors of the Federal Reserve System, last modified May 29, 2020, https://www.federalreserve.gov/data/sfos/sfos-release-dates.htm.

interbank lending with Treasuries in addition to loans and reserves, and by adding equity capital in addition to deposits as a source of funding. We numerically solve for the optimal shares of loans, Treasuries, and reserves for a profit-maximizing bank funded with deposits and equity and subject to a binding balance sheet constraint, a non-binding leverage ratio, or a non-binding risk-based capital constraint. We assume banks have non-binding capital constraints because of the empirical studies mentioned above that suggest that banks tend to have more than the minimum amount of required regulatory capital.

The model predicts that the non-binding, risk-based capital constraint distorts a bank's balance sheets considerably more than the non-binding, non-risk-based leverage constraint. This finding occurs because, holding total assets fixed, the risk-based capital ratio can be altered by adjusting not only the measure of capital in the numerator but also the risk-weighted asset measure in the denominator. Specifically, by tilting the bank's portfolio with assets that have lower risk weights, a bank can increase its risk-based capital ratio, even if the bank holds fixed, or even reduces, its capital. On the other hand, holding total assets fixed, the non-risk-based capital ratio can only be adjusted by adjusting the amount of capital.

We then empirically examine whether the implementation of US Basel III capital regulations influenced holdings of excess reserves, Treasuries, and loans, by exploiting the fact that US Basel III capital regulations were proposed and finalized before the US Basel III liquidity regulations were proposed. We also exploit the fact that the capital regulations focus primarily on the largest advanced approaches banks, which tend to have at least \$250 billion in total assets, while the liquidity regulations focus on banks with at least \$50 billion in total assets. We use Mora and Reggio's (2019) fully flexible model to test for common pretreatment and post-treatment trends and to estimate treatment effects. Our estimated treatment effects suggest that Basel III capital regulation initially stimulated holdings of excess reserves for the advanced approaches treatment group, relative to the control group comprised of non-advanced approaches banks with at least $10 billion in total assets. However, the treated banks later substituted from excess reserves to Treasuries, perhaps in response to the rising yields on Treasuries as holdings appear inversely correlated with yields. At the same time, the advanced approaches bank treatment group on average held their share of loans constant, even as the smaller large bank control group on average increased their share of loans. We also estimate the treatment effects of loans by risk weight and find that the highest risk-weighted loan share responded most to the implementation of Basel III capital regulations.

Overall, our findings suggest that advanced approaches banks on average tilted their portfolios toward holding more excess reserves than the control group comprised of smaller large banks in response to Basel III capital regulations. At the same time, the control group tilted their portfolios toward loans, which tend to get assigned higher risk weights, while the advanced approaches banks made no adjustments to loan holdings. We discuss the data and regulatory changes and develop and test our hypotheses before discussing the results and concluding.

## 2. Policy and Data

### *2.1 Key Legislative and Regulatory Changes*

Table 1 summarizes some legislative and regulatory changes that could have contributed to the rise of bank holding company (BHC) holdings of reserves, in particular, the payment of interest on reserves, as well as bank capital regulation and liquidity regulation. Since 1988, US bank regulators have largely adhered to the regulatory capital guidelines issued by the Basel

Committee on Bank Supervision, which called for banks to maintain at least 8 percent total capital relative to risk-weighted assets.[2]

The Basel guidelines introduced the so-called risk weighting of assets for the purpose of calculating the asset measure used in the denominator of the new regulatory capital ratios. The various risk buckets assigned weights that ranged from zero to one for particular classes of assets (e.g., cash, various securities, mortgage loans, and commercial loans), with presumed riskier asset classes assigned higher risk weights (see Avery and Berger 1991; Hogan, Meredith, and Pan 2015; Barth and Miller 2018). By multiplying the sum of all assets within a particular risk bucket by that asset class's risk weight and summing across all risk buckets, bank staff could then compute their total risk-weighted assets. The more high risk-weighted assets that a given bank holds, the higher the risk-weighted assets, and ceteris paribus, the lower its capital ratio. The risk weights referenced above form the basis of the so-called "standardized approach" to calculating risk-weighted assets and applies to all but the smallest banking entities (see table 5 of Barth and Miller 2018). An alternative and more complex model-based risk-weighting methodology applies to the so-called advanced approaches banks, which include the largest internationally active banking entities that will be the focus of the empirical analysis later.

[2] The analysis here focuses on the most recent implementation known as Basel III. Basel I was finalized in July 1988 and phased in over the period 1988–1992, becoming fully effective for all US banks in 1992. Federal Reserve Bank, Banking Organizations, Capital Adequacy; Risk-Based Capital Guidelines, 54 Fed. Reg. 17 (January 27, 1989), 4186. While Basel II had been issued in 2004, US banking regulators published a final Basel II rule in December 2007 with a phase-in, and it did not become effective until April 1, 2008; it applied to only the largest internationally active US banks. Office of the Comptroller of the Currency, Risk-Based Capital Standards: Advanced Capital Adequacy Framework–Basel II, 72 Fed. Reg. 235 (December 7, 2007), 69288.

**Table 1. Legislative and Regulatory Changes Concerning Reserves**

| Event | Date | Summary of change |
|---|---|---|
| Financial Services Regulatory Relief Act of 2006 (Public Law 109-351, 120 Stat. 1967) | enacted Oct. 2006 | Section 201 authorized the Federal Reserve to pay interest equivalent to the market rate on balances held by or on behalf of depository institutions, effective October 1, 2011. |
| Emergency Economic Stabilization Act of 2008 (Public Law 110-343, 122 Stat. 3765) | enacted Oct. 2008 | Section 128 moved the effective date of payment of interest on reserves to October 1, 2008. |
| Basel III regulatory capital rules NPR (77 FR 52792/77 FR 52888/77 FR 52978) | June 7 (Q2), 2012 | Proposed rule makes US capital requirements consistent with Basel III more complex and changes the definition of Tier 1 capital to emphasize the common equity component. For advanced approaches banks, by January 1, 2013, they must have 3.5 percent common equity Tier 1 capital and 4.5 percent minimum Tier 1 capital (common equity Tier 1 + additional Tier 1). For announcement and links to notices of proposed rulemaking, see https://www.federalreserve.gov/newsevents/pressreleases/bcreg2012 0607a.htm. Federal Register notice for new Basel III proposal available from https://www.govinfo.gov/content/pkg/FR-2012-08-30/pdf/2012-16757 .pdf. For Federal Register notice for standardized approach to risk weighting, see https://www.govinfo.gov/content/pkg/FR-2012-08-30 /pdf/2012-16757.pdf. |
| Basel regulatory capital rules III (78 FR 62018) | July 2 (Q3), 2013 | Final rule introduced more complex US capital requirements consistent with Basel III guidelines. For advanced approaches banks, by January 1, 2014, they must have 4 percent common equity Tier 1 capital and 5.5 percent minimum Tier 1 capital (common equity Tier 1 + additional Tier 1). By January 1, 2015, they must have 4.5 percent common equity Tier 1 capital and 6 percent Minimum Tier 1 capital (common equity Tier 1 + additional Tier 1). By January 1, 2016, advanced approaches banks had to implement the capital conservation buffer that was to be phased in by January 1, 2019. For announcement and links to final rulemaking, see https://www.federal reserve.gov/newsevents/pressreleases/bcreg20130702a.htm. Federal Register notice for final rulemaking available from https://www.govinfo.gov /content/pkg/FR-2013-10-11/pdf/2013-21653.pdf. |
| Basel III liquidity coverage ratio NPR (78 FR 71818) | Oct. 30 (Q4), 2013 | Proposed new US liquidity coverage ratio consistent with Basel III guidelines to ensure banks hold a minimum amount of liquid assets relative to available outgoing cashflows. https://www.govinfo.gov/content/pkg /FR-2013-11-29/pdf/2013-27082.pdf. |
| Basel III liquidity coverage ratio regulation finalized (79 FR 61440) | Sept. 3 (Q3), 2014 | Introduced new US liquidity requirements consistent with Basel III guidelines. Banking entities subject to the rule were to meet 80 percent of the liquidity coverage ratio by January 1, 2015, and meet 100 percent of it by January 1, 2017. For announcement see footnote 9, https://www .federalreserve.gov/newsevents/pressreleases/bcreg20140903a.htm. For Federal Register notice see https://www.govinfo.gov/content/pkg /FR-2014-10-10/pdf/2014-22520.pdf. |

The original Basel guidelines also established new definitions of capital, including Tier 1 capital, which had to equal at least 50 percent, while Tier 2 capital could not exceed 50 percent of the 8 percent total ratio of capital to risk-weighted assets.[3] Under Basel I guidelines, Tier 1 capital included common equity capital, noncumulative perpetual preferred stock, and minority interests in equity capital accounts of consolidated subsidiaries. From that amount, banks had to subtract goodwill, other intangible and deferred tax assets disallowed, and any other amounts as determined by the federal supervisor. Tier 2 capital included cumulative perpetual preferred stock; intermediate-term preferred stock; convertible and subordinated debt and allowances for credit losses, such as loan and lease losses; and pretax net unrealized holding gains on available-for-sale equity securities that have determinable fair values.

Risk-based capital requirements make it possible for a bank to meet higher capital requirements by increasing capital or by reducing the amount of higher risk-weighted assets, or both. Given their highly liquid and high-quality nature, bank reserves have a risk weight of zero, which means that they get excluded from the calculation of risk-weighted assets. While reserves had a risk weight equal to zero, they historically paid no interest, and therefore, banks tended to keep holdings of excess reserves to a minimum beyond required reserves. But with payment of interest on reserves, banks have incentives to increase holdings of reserves. By increasing reserves, a bank can in turn reduce risk-weighted assets, which can help it satisfy regulatory capital ratios, especially when the returns equal or even exceed comparable investments such as US Treasuries.

The path to implementing the payment of interest on reserves began in 2006 when Congress enacted the Financial Services Regulatory Relief Act of 2006 (Public Law 109-351,

[3] For definitions, see 54 Fed. Reg. 17, 4169, 4183–84. See also Barth and Miller (2018), table 4.

120 Stat. 1967). Section 201 of the Financial Services Regulatory Relief Act of 2006 introduced the policy of the Federal Reserve (Fed) paying banks interest on balances due from Regional Fed banks. Section 201 allowed the Fed to pay interest rates on required reserves as well as excess reserves. The rule change was initially supposed to take effect on October 1, 2011. However, as the financial crisis of 2007–2009 began to unfold, Congress fast-tracked the implementation to October 1, 2008, when it enacted the Emergency Economic Stabilization Act of 2008 (Public Law 110-343, 122 Stat. 3765). A key question that arises with the payment of interest on reserves concerns what rate to choose relative to the Fed's discount rate on loans to banks and the federal funds target rate that served as a benchmark for interbank lending.

Since 2008, the Federal Reserve System's management of reserve balances due from Regional Fed banks has operated a "floor" system (see Goodfriend 2002; Keister, Martin, and McAndrews 2008; Ireland 2014; Beckworth 2018; Selgin 2018). In practice, this means that the rate of interest paid on bank balances due from Regional Fed banks exceeds the interbank lending rate, known as the federal funds rate, but lies below the discount rate—the rate of interest charged to banks when they borrow from the Federal Reserve's discount window. Before the adoption of the floor system, the Federal Reserve operated a "corridor" system, in which the federal funds target rate lay between the upper bound discount rate and the lower bound rate of the interest paid on reserves, which was set to zero.

Payment of interest on reserves also resulted in the end of the interbank lending market, as the target federal funds rate remained below the rate paid for interest on reserves (see Cochrane 2014; Ennis and Wolman 2015; Dutkowsky and VanHoose 2017). Moreover, in this new regime, banks instead hold greater excess reserves. In the aftermath of the 2007–2009 financial crisis, officials dramatically revised their approach to bank regulation domestically and internationally.

In particular, the Basel Committee on Bank Supervision (BCBS) sought to extensively revise existing bank regulatory capital guidelines through the Basel III guidelines, which, among other things, introduced new capital and liquidity measures. The Basel Committee first introduced the Basel III guidelines in December 2010, and released a revised version in June 2011.[4] In the United States, the Federal Reserve, the Office of the Comptroller of the Currency, and the Federal Deposit Insurance Corporation issued a joint notice of proposed rulemaking to implement the Basel III guidelines for bank capital in the United States in June 2012. The rule was finalized in July 2013; however, the notice of proposed rulemaking also announced that certain changes would begin being implemented after January 1, 2013. In October 2013, US bank regulators issued a separate notice of proposed rulemaking to implement the Basel III guidelines for liquidity regulation. In September 2014, they finalized the liquidity rules, which were to be phased-in by January 1, 2015. Among the new measures, banks had to hold a minimum amount of high-quality liquid assets relative to net cash outflows over a subsequent 30-day period. Among the highest quality liquid assets, known as level 1 high-quality liquid assets, were central bank reserves, US Treasury securities, and other securities guaranteed by the US government.

While the initial BCBS capital and liquidity guidelines were publicly known after 2011 and subsequently revised, US banks are ultimately subject to the regulation finalized by federal regulators rather than the BCBS guidelines. Federal regulators can and do modify the guidelines, for instance, to make the guidelines consistent with domestic legislation. For example, following the Basel guidelines, many countries still make use of credit ratings to determine the risk weights, but section 939 of the Dodd-Frank Wall Street Reform and Consumer Protection Act (Pub. Law 111-203; 124 Stat. 1376) called for the removal of statutory references to credit

[4] See Bank for International Settlements, “Basel III: International Regulatory Framework for Banks,” *BIS*, accessed April 28, 2020, https://www.bis.org/bcbs/basel3.htm.

ratings. US regulators therefore had to create a new methodology to measure credit risk that did not reference ratings from nationally recognized statistical ratings organizations, which they introduced in the final rulemaking to implement the Basel III capital guidelines. Moreover, regulators can receive input from regulated entities, consumer groups, academics, and other members of the public during the notice and comment period, which may ultimately result in modifications to the proposed rule. Therefore, not only can the proposed rules differ from the Basel guidelines, but the final rules can and do sometimes differ from the proposed rules as well. In our empirical framework, we make use of this institutional feature of the US regulatory process to motivate our empirical analysis in section 4. Before doing so, we will also discuss some of the specifics of the US implementation of the Basel III capital guidelines, beginning with changes proposed in the 2012 notice of proposed rulemaking.

### *2.2 US Basel III*

Table 2 shows some of the key changes to the Basel-style capital requirements that US regulators have implemented. While the 8 percent minimum capital to risk-weighted asset requirement remained in place, the new guidelines called for increasing the Tier 1 component of total capital from 4 percent of risk-weighted assets to 4.5 percent by January 1, 2013, to 5.5 percent by January 1, 2014, and to 6 percent by January 1, 2015. US regulators also adopted changes arising from the Basel Committee's revised definitions of Tier 1 and Tier 2 capital.[5] Under Basel III, Tier 1 capital equals the sum of common stock and retained earnings, accumulated other comprehensive income for non-opt-out and advanced approaches banks, deductions and adjustments, qualifying CET1 minority interest minus the sum of goodwill, other intangibles,

[5] See Office of the Comptroller of the Currency, Regulatory Capital: Implementation of Basel III, Capital Adequacy, Transition Provisions, etc., 78 Fed. Reg. 198 (October 11, 2013), 62172–73. See also Barth and Miller (2018), table 4.

and deferred tax assets. Tier 2 capital includes allowances for loan and lease losses to a limited extent, qualifying preferred stock, subordinated debt, and minority interests. Also, while Basel II guidelines introduced Common Equity Tier 1 (CET1) capital as the key component of Tier 1 capital, in the United States the measure was not included until US Basel III (see Barth and Miller 2018).

**Table 2. Changes in Risk-Based Capital Requirements**

| | 1991–1992 | 1993–2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Min. CET1 ratio | | | | | 3.5 | 4 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 |
| Min. Tier 1 ratio | 3.625 | 4 | 4 | 4 | 4.5 | 5.5 | 6 | 6 | 6 | 6 | 6 |
| Min. total ratio | 7.25 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Capital conservation buffer | | | | | | | | 0.625 | 1.25 | 1.875 | 2.5 |
| GSIB surcharge (lower bound) | | | | | | | | 0.25 | 0.5 | 0.75 | 1 |
| GSIB surcharge (upper bound) | | | | | | | | 4.5 | 4.5 | 4.5 | 4.5 |
| Minimum capital (lower bound) | 7.25 | 8 | 8 | 8 | 8 | 8 | 8 | 8.875 | 9.75 | 10.625 | 11.5 |
| Minimum capital (upper bound) | 7.25 | 8 | 8 | 8 | 8 | 8 | 8 | 13.125 | 13.75 | 14.375 | 15 |

US regulators required banks to fund with at least 3.5 percent CET1 capital relative to risk-weighted assets after January 1, 2013, with at least 4 percent CET1 capital by January 1, 2014, and with at least 4.5 percent CET1 capital by January 1, 2015. In addition, the largest banks also had to meet new capital requirements, including the capital conservation buffer and the global systemically important bank (G-SIB) surcharge, for the largest banks. However, banks had to phase in these measures between January 1, 2016, and January 1, 2019. The end result was to increase the total minimum capital from 8 percent relative to risk-weighted assets under the original 1988 guidelines, to 8.875–13.125 percent by January 1, 2016, and to 11.5–15 percent by January 1, 2019, for the largest banks depending on the activities and size of the bank. While these changes took place after the Basel III liquidity regulations were finalized, the other changes to minimum capital requirements mentioned above took place before then. Lastly, while Basel guidelines included the leverage ratio for the first time in Basel III, US regulators have used a variant of the leverage ratio since the US Basel I regulations were finalized in 1989 (see Barth and Miller 2018).

Lastly, as table 1 shows, the notice of proposed rulemaking for US Basel III liquidity regulations was released in Q4 2013 and finalized in Q3 2014. A more stringent standard applied to the largest advanced approaches banks, and a less stringent standard applied to other BHCs with at least \$50 billion in total assets; but advanced approaches banks and those with at least \$50 billion in total assets all had to maintain the liquidity coverage ratio, while smaller entities did not.[6] The liquidity coverage ratio called for maintaining a certain amount of high-quality liquid assets to cover cash outflows over a 30-day period, which included Treasury securities and reserves.

### *2.3 Changes in Regulatory Capital and Excess Reserves*

Given that Roberts, Sarkar, and Shachar (2018) and Rezende, Styczynski, and Vojtech (forthcoming) discuss the role of Basel III liquidity rules as a driver of liquid asset holdings, this might pose a challenge for those attempting to estimate the potential effects of Basel III regulatory capital rules on excess reserves. However, our attempts to quantify the effects of

[6] "Notice of Proposed Rulemaking—Implementation of Minimum Liquidity Standards," Staff memo to Board of Governors of the Federal Reserve System, October 18, 2013, 4–5.

Basel III regulatory capital rules exploit the fact that the windows between the notice and comment period and the final rule for the Basel III capital regulation came before the liquidity regulations and did not overlap. The timing of the implementation of the capital regulations coincides with much of the rise in excess reserves in 2013.

Figure 1 shows the total volume of quarterly excess reserves—defined as the difference between total reserve balances maintained and reserve balance requirements reported by the Federal Reserve—and highlights some of the Basel III regulatory changes.[7] As banks and bank holding companies do not make their excess reserves publicly accessible, we use the proxy suggested by Rezende, Styczynski, and Vojtech (forthcoming) for bank-level excess reserves, namely balances due from Regional Fed banks. In addition to the excess reserves measure in figure 1, we include three aggregated measures of balances due from Regional Fed banks. The first sums all balances held at Federal Reserve Banks by domestic banks included in the domestic bank-level call report data. The second sums balances held at Federal Reserve Banks aggregated at the holding company level for all large BHCs in our sample that had more than $10 billion in total assets. The last sums balances held at Federal Reserve Banks for advanced approaches banks, which are the focus of Basel III capital regulations.[8]

The so-called advanced approaches BHCs, which had $250 billion in total assets or considerable foreign exposures, or elected to be classified as such, include Bank of New York Mellon, Citigroup, Goldman Sachs, JPMorgan Chase, Morgan Stanley, Northern Trust, State

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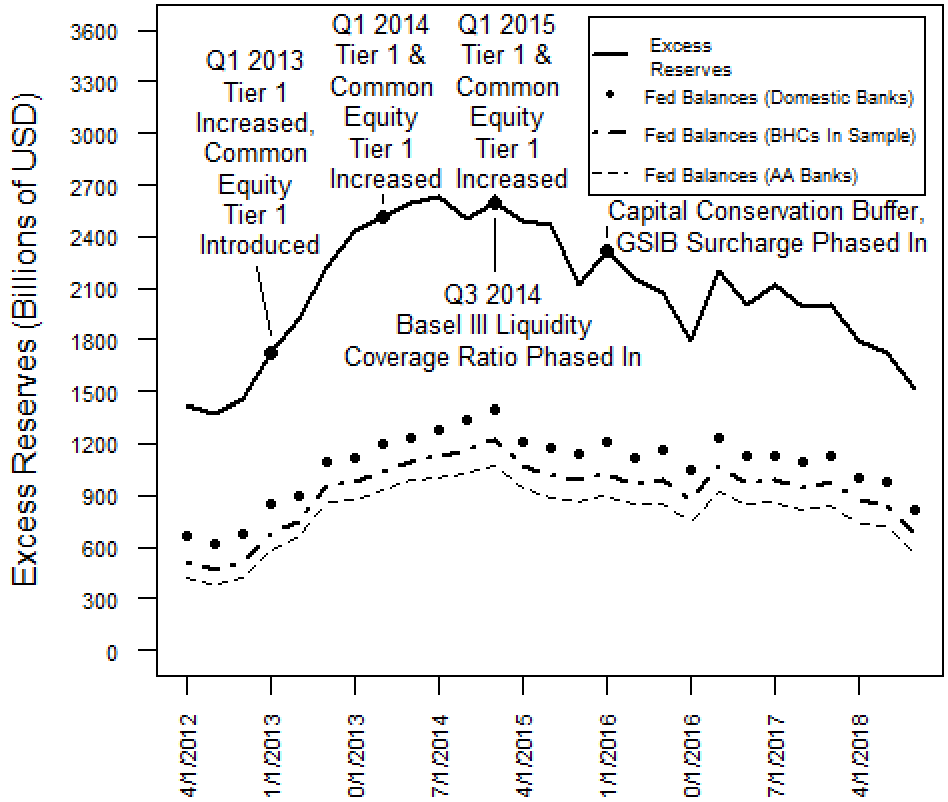
[7] Our graph depicts the data from Q2 2012 to Q4 2018, to focus on the period associated with the implementation of Basel III. Federal Reserve Bank of St. Louis, "Excess Reserves of Depository Institutions (EXCSRESNW)" (FRED data series), accessed April 26, 2020, https://fred.stlouisfed.org/series/EXCSRESNW.

[8] We obtain the FDIC's bank call report bulk data from FDIC, Statistics on Depository Institutions (database), Federal Deposit Insurance Corporation, Arlington, VA, available from https://www5.fdic.gov/sdi/download_large_list_outside.asp, accessed April 1, 2020. More than three quarters of all banks submitting call report data operate within a holding company structure; therefore, we aggregate our measure of excess reserves at the holding company level. For banks that do not operate within a holding company, we use bank-level data.

Street, U.S. Bancorp since 2014, and Wells Fargo and Bank of America since 2015.[9] Accordingly, we expect that advanced approaches BHCs may use excess reserves as a way to help meet their targeted capital ratios, consistent with the observations of Berger et al. (2008). The figure reveals that advanced approaches banks held about 62 percent of total domestic excess reserves from Q2 to Q4 2012, and increased holdings to 74 percent from Q1 2013 to Q4 2018. In dollar terms, the advanced approaches banks held about \$400 billion in 2012 and increased that to \$581 billion in Q1 2013 and \$864 billion by Q3 2013. Between Q4 2013 and Q1 2015, the advanced approaches banks collectively increased holdings by roughly \$208 billion to reach a peak of \$1.07 trillion. If we make a strong assumption that Basel III capital regulations only influenced reserves through Q3 2013 and Basel III liquidity regulations only influenced holdings after that, then that suggests \$460 billion (or 69 percent) in additional excess reserves arose from Basel III capital regulations, while \$208 billion (or 31 percent) arose from Basel III liquidity regulations. We next explore a model of a profit-maximizing bank that's subjected to either a risk-weighted capital ratio or a non-risk-based leverage ratio or both, to show how risk weighting may influence bank holdings when capital requirements increase. From there we turn to the empirical research design.

[9] For the original list, see "Agencies Permit Certain Banking Organizations to Begin Using Advanced Approaches Framework to Determine Risk-Based Capital Requirements," joint press release, Board of Governors of the Federal Reserve System and Office of the Comptroller of the Currency, February 21, 2014, https://www.federalreserve.gov/newsevents/pressreleases/bcreg20140221a.htm. For the addition of Wells Fargo see "Agencies Permit Wells Fargo to Begin Using Advanced Approaches Framework to Determine Risk-Based Capital Requirements," joint press release, Board of Governors of the Federal Reserve System and Office of the Comptroller of the Currency, March 31, 2015, https://www.federalreserve.gov/newsevents/pressreleases/bcreg20150331a.htm. For the addition of Bank of America see "Agencies Approve Bank of America to Begin Using Advanced Approaches Framework to Determine Risk-Based Capital Requirements," joint press release, Board of Governors of the Federal Reserve System and Office of the Comptroller of the Currency, September 3, 2015, https://www.federalreserve.gov/newsevents/pressreleases/bcreg20150903a.htm. Banking entities could also opt out, as summarized here: "Advanced Approaches Capital Framework Implementation," Board of Governors of the Federal Reserve System, last modified February 13, 2017, https://www.federalreserve.gov/supervisionreg/basel/advanced-approaches-capital-framework-implementation.htm.

**Figure 1. Excess Reserves, Structural Breaks, and Policy Changes, Q1 2008–Q4 2018**




Source: Excess Reserves means "Excess Reserves of Depository Institutions (EXCSRESNW)" (FRED data series). The Fed Balances series come from the FDIC's Statistics on Depository Institutions (database) for bank call report bulk data.

## 3. A Model of Excess Reserves, Loans, and Capital Requirements

### *3.1 A Simple Framework*

To examine the potential effects of varying risk-based and non-risk-based regulatory capital requirements on bank asset allocations, we extend Dutkowsky and VanHoose's (2017) model, under the regime with no wholesale funding through interbank lending. The bank invests in risky loans and excess reserves, and we add Treasury securities, given the close substitutability with reserves in terms of their identical regulatory capital treatment and comparable rates of returns.

The hypothetical bank funds with deposits and equity. Rather than dollar values, our choice variables consist of asset and funding shares. The bank invests in loans (*L*), Treasury securities (*T*), excess reserves (*X*), and required reserves equal to the product of reserve requirements and deposits (*qD*), with $q$ representing reserve requirements, to maximize profits defined as revenues, minus funding and quadratic administrative costs, subject to a balance sheet constraint, a funding constraint, leverage ratio constraint, and a risk-based capital constraint. This is represented as

$$\max \Pi = w_L r_L + w_T r_T + (w_X + q w_D) r_Q - w_D r_D - w_E r_E$$

$$- \frac{1}{2}(\alpha w_L^2 + \tau w_T^2 + \phi w_X^2 + \delta w_D^2 + \varepsilon w_E^2)$$

$$s.t.\ w_L + w_T + w_X + q w_D \leq 1$$

$$w_D + w_E = 1$$

$$\kappa_{LEV} \leq w_E$$

$$\kappa_{RBC}\left(\omega_L w_L + \omega_T w_T + \omega_Q (q w_D + w_X)\right) \leq w_E,$$

where $w_L = L/A$, $w_T = T/A$, $w_X = X/A$, and $q w_D = qD/A$ denote portfolio shares for loans, Treasury securities, excess reserves, and required reserves relative to the bank's total assets, which sum to one, while $w_D = D/A$ and $w_E = E/A$ denote funding shares from deposits and equity, which sum to one. We also examine the decisions by the bank when it faces only the leverage constraint, only the risk-weighted capital constraint, or both capital constraints. While the model does not include a liquidity constraint, given the assumed parameters, the model predicts banks hold a high fraction of liquid assets, such that the liquidity constraints would not bind.[10]

[10] Van den Heuvel's (2019) model assumes banks face an equity-capital-to-loan ratio of 10 percent and a liquid-bond-to-deposit ratio of 10 percent. When we include an analogous liquidity constraint such that the sum of Treasuries, excess reserves, and required reserves are at least as large as 10 percent of the deposit share ($w_T + w_X + q w_D \geq 0.1 w_D$), the deposit share terms cancel if the reserve requirement, $q$, equals 10 percent. Adding such a constraint has no substantive effects on the optimal asset allocations.

As in Dutkowsky and VanHoose (2017), the cost parameters for assets have the following properties: $\alpha > \tau > \phi$. We also assume that the equity funding cost parameter equals that for deposits, or $\varepsilon = \delta$. Among the other parameters, $q$ denotes the required reserves ratio, $\kappa_{LEV}$ denotes the minimum leverage ratio (defined as equity to total assets), and $\kappa_{RBC}$ denotes the minimum risk-based capital ratio (defined as risk-weighted assets relative to equity), with $\omega_L$, $\omega_T$ and $\omega_Q$ denoting the risk weights for loans, Treasury securities, and excess reserves used to calculate risk-weighted assets.

After forming the Lagrangean and using the second constraint to substitute out the funding share for equity, the Kuhn-Tucker conditions for the model include

1) $r_L - \alpha w_L - \lambda - \mu_{RBC}\kappa_{RBC}\omega_L \leq 0$

2) $r_T - \tau w_T - \lambda - \mu_{RBC}\kappa_{RBC}\omega_T \leq 0$

3) $r_Q - \phi w_X - \lambda - \mu_{RBC}\kappa_{RBC}\omega_Q \leq 0$

4) $r_Q q + r_E - r_D - \delta w_D + \varepsilon(1 - w_D) - \lambda q - \mu_{LEV} - \mu_{RBC}\left(1 + \kappa_{RBC}\omega_Q q\right) \leq 0$

5) $1 - w_L - w_T - w_X - q w_D \geq 0$

6) $1 - w_D - \kappa_{LEV} \geq 0$

7) $1 - w_D - \kappa_{RBC}\left(\omega_L w_L + \omega_T w_T + \omega_Q(q w_D + w_X)\right) \geq 0$

1′) $w_L[r_L - \alpha w_L - \lambda - \mu_{RBC}\kappa_{RBC}\omega_L] = 0$

2′) $w_T[r_T - \tau w_T - \lambda - \mu_{RBC}\kappa_{RBC}\omega_T] = 0$

3′) $w_X\left[r_Q - \phi w_X - \lambda - \mu_{RBC}\kappa_{RBC}\omega_Q\right] = 0$

4′) $w_D\left[r_Q q + r_E - r_D - \delta w_D + \varepsilon(1 - w_D) - \lambda q - \mu_{LEV} - \mu_{RBC}\left(1 + \kappa_{RBC}\omega_Q q\right)\right] = 0$

5′) $\lambda[1 - w_L - w_T - w_X - q w_D] = 0$

6′) $\mu_{LEV}[1 - w_D - \kappa_{LEV}] = 0$

7′) $\mu_{RBC}\left[1 - w_D - \kappa_{RBC}\left(\omega_L w_L + \omega_T w_T + \omega_Q(q w_D + w_X)\right)\right] = 0,$

where λ is the Lagrange multiplier for the budget constraint, $\mu_{LEV}$ is the Lagrange multiplier for the leverage ratio constraint, and $\mu_{RBC}$ is the Lagrange multiplier for the risk-based capital constraint. Given the number of choice variables and multipliers, we get numerical solutions for the case when only the budget constraint binds, as most banking entities tend to operate above the regulatory minimum (see for instance Berger et al. 2008; Flannery 2014; Barth and Miller

2018). We use the augmented Lagrange minimization algorithm discussed in Madsen, Nielsen, and Tingleff (2004).[11]

To solve the optimization problem numerically, we adopt Dutkowsky and VanHoose's (2017) parameterization when possible. They assume the reserve requirement parameter $q = 0.1$, that the cost parameter for loans $\alpha = 0.05$, and that the cost parameter for reserves $\phi = 0.001$. As we add Treasury securities, we assume the cost parameter is low (but higher than reserves) at $\tau = 0.004$. For deposits and equity, we assume equal cost parameters (set to $\delta = \varepsilon = 0.01$) because we find that significantly higher values for deposits, while generating similar optimal shares, tend to generate negative profits when evaluated at the optimal values. For the risk weights, we assume that for loans, $\omega_L = 1$, and that for reserves and Treasuries, $\omega_T = \omega_Q = 0$.

For the return on reserves, we assume $r_q = 0.0025$.[12] Following Dutkowsky and VanHoose (2017), we assume $r_D = 0.0004$. For loan rates, they assume 3 percent, while we assume $r_L = 0.0325$, on the basis of the prime rate during the period from January 2009 through November 2015.[13] For the return on Treasuries, we assume $r_T = 0.0025$ or 0.0033, to illustrate the effects, ceteris paribus, of increasing Treasury rates.[14] For the return on equity, we assume $r_E = 0.06$.

[11] After choosing starting values for the choice variables, the method makes use of a penalty term in the Lagrangean to get close to the optimal choices and then uses the multipliers to converge toward the optimal values. We use the Alabama package for *R* to solve the non-linear optimization problems; see CRAN, "Alabama: Constrained Nonlinear Optimization," *Comprehensive R Archive Network*, March 6, 2015, https://CRAN.R-project.org/package=alabama.

[12] The rate of interest on reserves remained at 0.0025 from July 2013 to November 2015 before rising. See Federal Reserve Bank of St. Louis, "Interest Rate on Required Reserves (IORR)" (FRED data series), accessed April 14, 2020, https://fred.stlouisfed.org/series/IORR.

[13] The prime rate remained at 0.0325 from July 2013 to November 2015. See Federal Reserve Bank of St. Louis, "Bank Prime Loan Rate (MPRIME)" (FRED data series), accessed April 14, 2020, https://fred.stlouisfed.org/series/MPRIME.

[14] The rate of 0.0025 equals the median rate on a 1-year Treasury in Q4 2014, which equaled the interest rate on reserves. We also use as an alternative value, 0.0033, equal to the median rate on a 1-year Treasury in Q3 2015, the last quarter that the rate of interest on reserves remained fixed at 0.0025.

On the basis of these parameters, we examine how the optimal portfolio shares vary as the minimum leverage ratio varies from 3 to 10 percent and as the minimum risk-based capital requirement varies from 4 to 10 percent. Recall that among other changes (see table 2), the US implementation of Basel III called for making Tier 1 capital more like common equity for all banks subjected to the regulation. It also called for phasing in a higher Tier 1 portion of risk-based capital from 4 to 4.5 percent by January 1, 2013, to 5.5 percent by January 1, 2014, and to 6 percent by January 1, 2015, again for all banks except the smallest. For the advanced approaches banks, the US implementation of Basel also added in the capital conservation buffer and the GSIB surcharge, to be phased in between 2016 and 2019, which would further increase the total risk-based capital requirements from roughly 8 to a range of 11.5 to 15 percent.

### *3.2 When the Bank Faces Only a Leverage Ratio Constraint*

We begin by analyzing the effects of varying the leverage ratio from 3 to 10 percent when it serves as the only capital constraint. On the basis of the assumed parameters, if the Treasury rate $r_T = 0.0025$, then the optimal share for excess reserves equals 22.7 to 24.4 percent, which, when combined with required reserves, totals between 32.4 to 33.6 percent; the optimal share for Treasuries equals about 6 to 6.9 percent; and the optimal share for loans ranges from 60.4 to 60.6 percent. To understand the variation, as the leverage ratio increases, the bank funds with fewer deposits, which means that banks hold fewer required reserves, such that the bank allocates more to the other assets, including excess reserves.

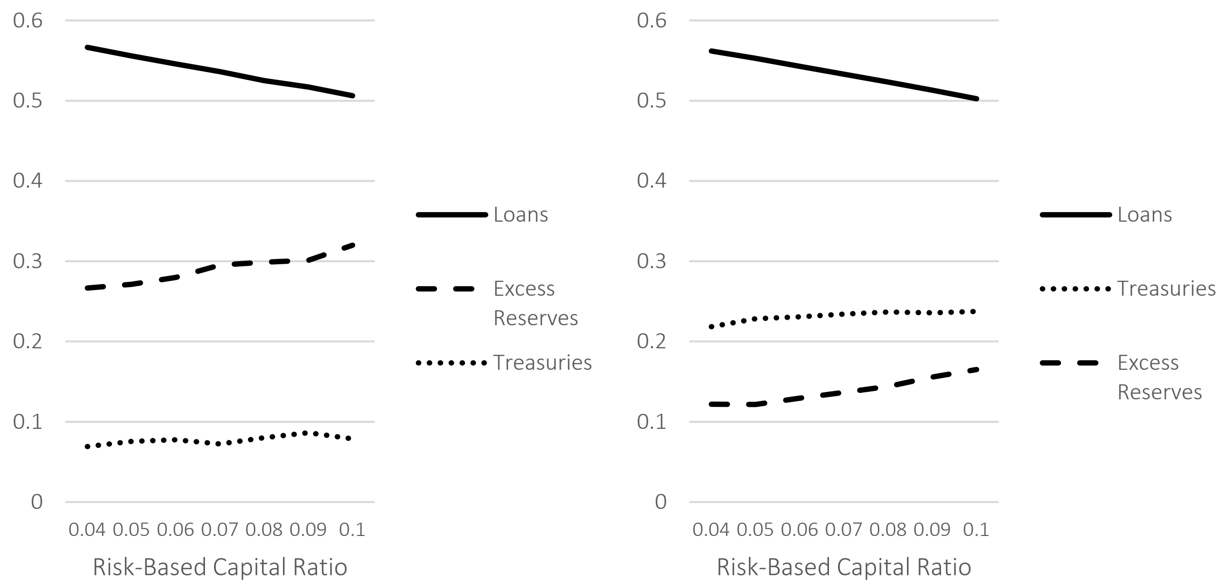
If we increase the Treasury rate to $r_T = 0.0033$, then the optimal share for excess reserves falls to 7.9 to 9 percent, which, when combined with required reserves, falls to 17.5 to 18.1 percent; the optimal share for Treasuries rises to about 21.7 to 22.3 percent; and the optimal share for loans equals 60.2 percent. In this case, the return on Treasuries—the closest substitute for excess reserves in terms of assumed returns and costs—drives the allocation. This finding suggests that the rate of return differential as well as the cost differential between reserves and Treasuries influences the portfolio shares for the two asset classes. Given that we assume Treasuries have higher administrative costs than reserves, the bank would tend to hold more Treasuries when the rate of return on Treasuries exceeds that for reserves.

### *3.3 When the Bank Faces Only a Risk-Weighted Capital Constraint*

If we replace the leverage ratio with a risk-based capital constraint, such as the Tier 1 to risk-weighted asset rate, the optimal shares vary more. On the basis of the assumed parameters, if the Treasury rate $r_T = 0.0025$, the panel on the left in figure 2 shows that as the risk-based capital ratio rises from 4 to 10 percent, then the optimal share of excess (total) reserves exceeds the share of Treasuries and rises from about 26.6 to 32 (36.4 to 41.5) percent. The optimal share for Treasuries rises from about 6.9 to 8.6 percent. The optimal share for loans declines from about 56.6 to 50.6 percent. Unlike with the leverage ratio, when the risk-based capital ratio increases, the risk weights drive much of the reallocation between loans and reserves as the capital ratio rises.

If we increase the Treasury rate to $r_T = 0.0033$, the panel on the right in figure 2 shows that as the risk-based capital ratio rises from 4 to 10 percent, then the optimal share of excess (total) reserves rises from 12.2 to 16.5 (22 to 26) percent. The optimal share for Treasuries now exceeds that for excess reserves, falling in the 21.8 to 23.7 percent range. The optimal share for loans declines from about 56.2 to 50.2 percent. While the optimal share for excess reserves falls when the Treasury rate increases, as the risk-based capital ratio increases, much of the decline in the share of loans goes to reserves, due largely to the risk weighting.

**Figure 2. Share of Assets Held as Loans, Treasuries, and Excess Reserves under Only Risk-Based Capital Constraint (Treasury Rate Equal to 0.0025 to the Left and 0.0033 to the Right)**




Source: Authors' calculations.

### *3.4 When the Bank Faces the Leverage Ratio and the Risk-Weighted Capital Constraint*

If we add both constraints, we get results that reflect each of the cases discussed in sections 3.2 and 3.3. Figure 3 shows how the share of excess reserves varies with the two capital ratios: the excess reserves share ranges from about 22.7 to 31.8 percent as the capital ratios vary, assuming a Treasury rate of 0.0025, and the range falls to 7.9 to 17.2 percent, assuming a Treasury rate of 0.0033. The figure suggests that if the leverage ratio is fixed at low values as the risk-based capital ratio is increased, the share of excess reserves increases. For higher leverage ratio values, however, as the risk-based capital ratio rises, the share of excess reserves changes little. Intuitively, this finding arises because the bank substitutes out of the highest risk-weighted assets and toward reserves, which happen to be the lowest risk-weighted asset with the lowest cost.

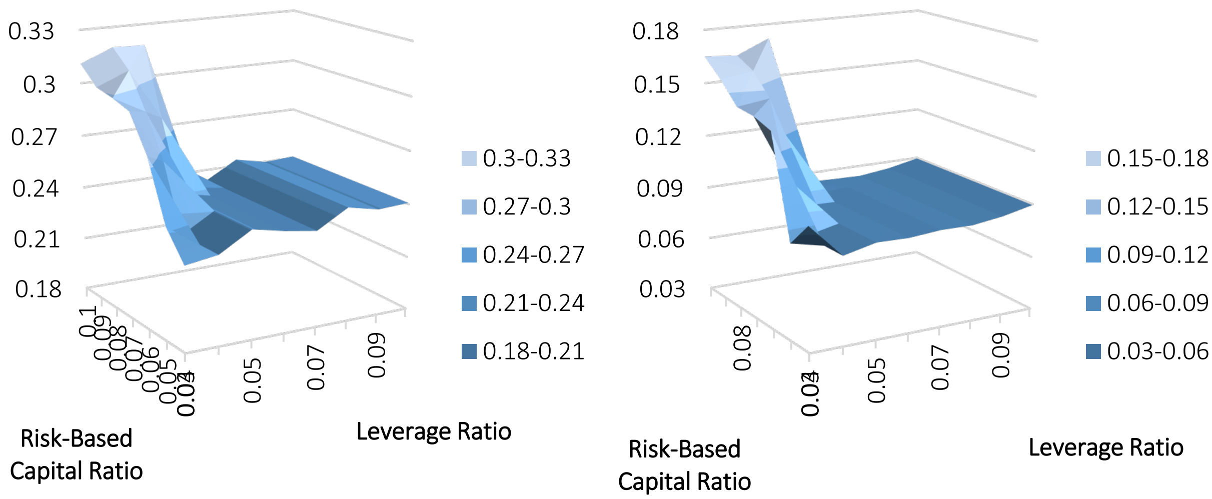
Figure 4 shows the share of Treasury securities varies less as the two capital ratios vary, ranging from only about 6 to 8.7 percent if the Treasury rate equals 0.0025 and 20.6 to 23.9

percent if the Treasury rate equals 0.0033. Although Treasury securities have the same risk weight and a higher return, keep in mind that we assume Treasuries have slightly higher administrative costs than reserves.

Figure 5 shows the relationship between the shares for loans and the two capital ratios, with the loan share ranging from 50.6 to 60.6 percent as the capital ratios vary, assuming a Treasury rate of 0.0025. If we use the higher Treasury rate of 0.0033, the loan share ranges from 50.2 to 60.2 percent as the capital ratios vary. The figure suggests that if the leverage ratio is held fixed at low values as the risk-based capital ratio is increased, the share of loans declines. For higher leverage ratio values, however, as one increases the risk-based capital ratio, the share of loans varies little. These findings suggest that banks may alter their portfolios in response to higher risk-based capital requirements, but not the leverage ratio. That suggests that the risk-based capital ratios may be more binding than the leverage ratio, unless both capital ratios increase together. Intuitively, this arises because a bank faces incentives to substitute out of the highest risk-weighted assets and, as we will show, into the lowest risk-weighted and lowest cost asset, namely reserves.

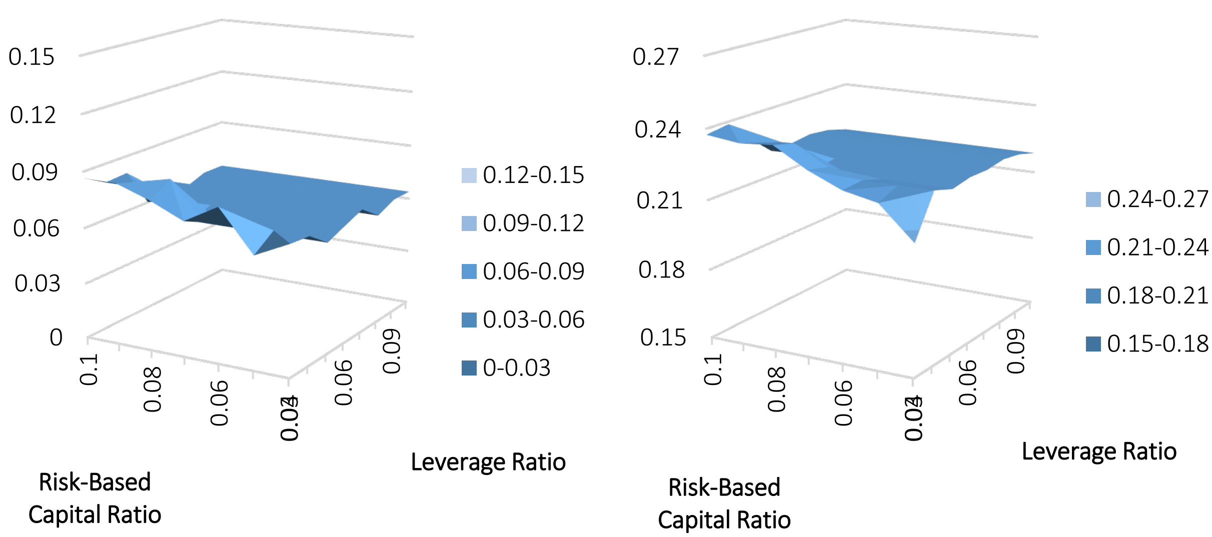
Using the Basel ratios to illustrate—assuming the Treasury rate equals 0.0025, and holding the leverage ratio fixed at 3 percent—an increase in the ratio of Tier 1 capital relative to risk-weighted assets from 4 to 6 percent would result in an increase of 4.8 percentage points in the share of reserves and a decline of 6.1 percentage points in the loan share. If the minimum leverage ratio were at 4 percent, the fraction of loans would begin to decline when the Tier 1 capital relative to risk-weighted asset ratio reached 7 percent. This would result in an increase of 3.6 percentage points for the share of reserves and a decrease of 3.5 percentage points in the loan share. We get slightly smaller magnitudes if we assume the Treasury rate equals 0.0033.

**Figure 3. Share of Assets Held as Excess Reserves under Both Leverage Ratio and Risk-Based Capital Constraints (Treasury Rate Equal to 0.0025 to the Left and 0.0033 to the Right)**



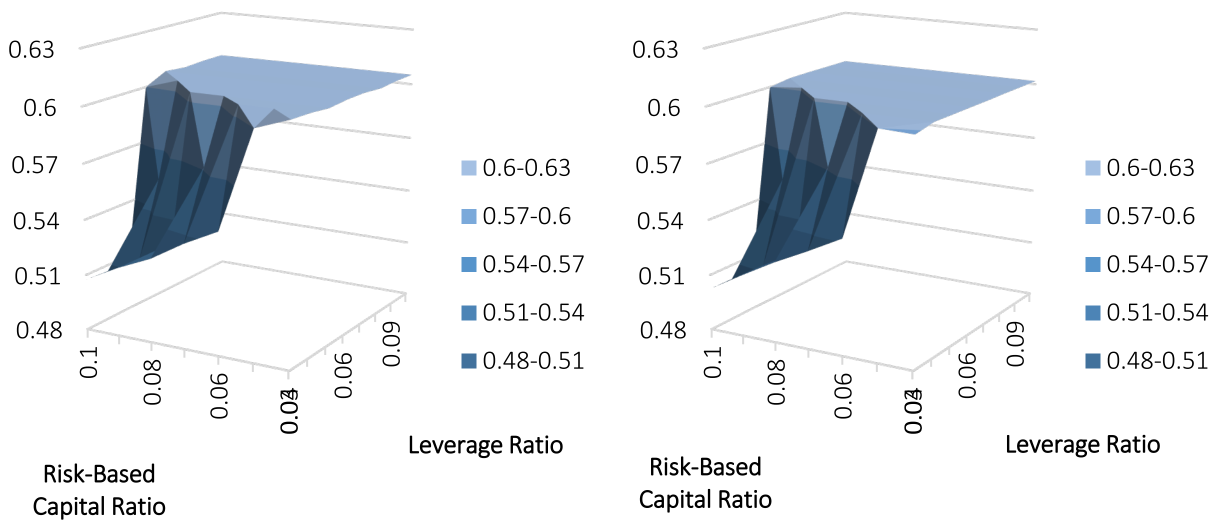

Source: Authors' calculations.

**Figure 4. Hypothetical Share of Assets Held as Treasury Securities (Treasury Rate Equal to 0.0025 to the Left and 0.0033 to the Right)**




Source: Authors' calculations.

**Figure 5. Share of Assets Held as Loans under Both Leverage Ratio and Risk-Based Capital Constraints (Treasury Rate Equal to 0.0025 to the Left, and 0.0033 to the Right)**




Source: Authors' calculations.

The model predicts that higher risk-based capital requirements create incentives to shift into more reserves relative to Treasuries and out of the highest risk-weighted loans, if the return on Treasuries is similar to the interest rate on reserves. Given these stylized predictions, in the next section we empirically examine the extent to which the so-called advanced approaches banking entities may have responded to the changes from Basel III capital regulations in a manner consistent with the hypothetical bank examined here.

## 4. Research Design

### *4.1 A Fully Flexible Approach to Estimating Treatment Effects*

Given the model predictions discussed in the previous section, we now examine the extent to which banks may have adjusted their portfolios in response to the introduction of Basel III capital regulations and the Basel III liquidity regulations, which were made public after that. Our research design exploits the timing of the implementation, and uses Mora and Reggio's (2019) fully flexible difference-in-differences (DID) estimator to estimate dynamic treatment effects. The benefits of using this framework arise from the fact that it allows for multiple pre- and post-treatment periods.

Allowing for multiple pretreatment periods opens up the possibility of formally testing whether an implicit assumption of parallel paths in the traditional DID approach holds. To see why, in the traditional two-period DID approach, the implications are that, if untreated, the average treatment effect for the treatment group would equal the average treatment effect of the control group. When more than one pretreatment period exists, then the issue is whether common trends exist for the treatment and control groups. If the trends for the treatment and control groups are the same, the appropriate estimator for the average treatment effect is the DID estimator under the parallel paths (parallel 1) assumption. In this case, the parallel paths assumption yields the same treatment effects as the difference in double-differences estimator, which implies parallel growth (parallel 2). With three pretreatment periods, the parallel paths assumption yields the same treatment effects as the difference in triple-differences estimator, which implies parallel acceleration (parallel 3). If the trends differ, then the parallel paths (parallel 1) assumption will no longer be valid, and with three pretreatment periods, the parallel growth (parallel 2) or parallel acceleration (parallel 3) may be appropriate.

In terms of post-treatment effects, Mora and Reggio's (2019) fully flexible approach makes it possible to estimate period-specific treatment effects, and offers a formal test of equal treatment effects during the post-treatment period. In this sense, the method generalizes the traditional two-period DID approach, which implicitly assumes equal treatment effects over time.

The fully flexible approach calls for estimating ordinary least squares (OLS) regressions:

$$y_{it} = \beta_0 + \sum_{\tau=2}^{T} \delta_\tau d_{\tau,t} + \beta_1 Treatment_{it} + \sum_{\tau=2}^{T} \beta_\tau d_{\tau,t} \times Treatment_{it} + \varepsilon_{it}, \qquad (8)$$

where $y_{it}$ measures excess reserves, Treasuries, or loans relative to total assets at time *t* for BHC *i*; the $\delta_\tau$ serves as the time fixed effect coefficients for a given quarterly time dummy variable $d_{\tau,t}$; and the variable $Treatment_{it}$ equals one if the banking entity falls in the treatment group, and zero otherwise. The time fixed effects in the model can capture omitted time varying factors, such as interest on reserves or uncertainty.

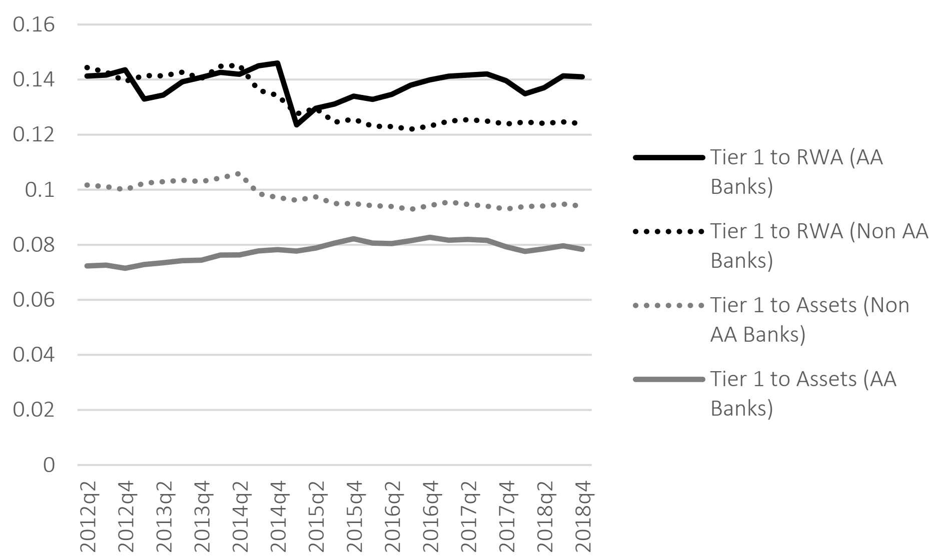
To estimate the potential effects of Basel III capital regulations, we use Q2 2012 to Q4 2012 as the pretreatment period. The notice of proposed rulemaking was released in June 2012, and while the final rule was released in July 2013, the notice of proposed rulemaking announced increases in the common equity component and capital ratio of Tier 1, set to take effect after January 1, 2013. The transition period for other changes to Basel III capital ratios, as well as the introduction of liquidity regulation, happened later. Our use of multiple post-treatment periods allows us to see how the treatment effects evolve over time, possibly in response to these and other changes. As a treatment group to examine the effects of changes in capital regulation, we use the advanced approaches banking entities with at least \$250 billion in total assets or considerable foreign exposure, as they were the primary target of Basel III capital regulations listed in section 2.3. As a control group, we use banks with more than \$10 billion in total assets, given that these banks have been the focus of many post-2009 crisis regulatory changes.[15]

While the initial changes to the definition of capital applied to all banks in our sample, figure 6 below shows that the risk-based capital ratios were similar for both groups of banks on

[15] When we use smaller asset thresholds, such as \$1 billion in total assets, we find different pretreatment trends, suggesting that banks with less than \$10 billion in total assets do not serve as an appropriate control group. This finding would also be consistent with the fact that smaller banks tend to have different business models.

average before Q3 2014 but behave differently starting in Q3 2014. Also, the non-advanced approaches banks have higher non-risk-based Tier 1 capital-to-asset ratios than the advanced approaches banks, although the ratios began to converge starting in Q3 2014 as the ratios increased for advanced approaches banks but decreased for non-advanced approaches banks. The figure suggests that advanced approaches banks on average, while not capital constrained, had less capital than the non-advanced approaches banks. As a result, the increases in the regulatory capital measures would have given advanced approaches banks incentives to use the risk-weighted asset denominator to respond to the higher regulatory capital requirements, given that they tend to face more onerous regulatory burdens.

**Figure 6. Risk-Based and Non-risk-based Capital Ratios for Advanced Approaches and Non-advanced Approaches Bank Holding Companies before and after US Basel III Capital and Liquidity Regulations, Q2 2012–Q4 2018**




Source: Authors' estimates based on Federal Reserve Bank of Chicago bank holding company regulatory capital series.

In section 4.6, as a robustness check, we estimate the potential effects of Basel III liquidity regulations on total holdings of level 1 high-quality liquid assets, and we use Q4 2013 to Q2 2014 as the pretreatment period. The post-treatment period begins in Q3 2014, given that the notice of proposed rulemaking was released in September 2014. As a treatment group we use the systemically important financial institutions (SIFI) with at least $50 billion in total assets, as SIFI banks rather than advanced approaches banks were the primary target of the Basel III liquidity regulations mentioned in section 2. As a control group we again use banks with more than $10 billion in total assets.

### *4.2 Data*

We summarize the construction of the variables used in this study in table A1. As a measure of excess reserves, we use bank-level call report data for balances due from Regional Fed banks, which we aggregate up to the holding company level, as discussed concerning figure 1. The other variables used come from the BHC-level call report data, primarily from schedule HC, which reports aggregate assets and liabilities, and schedule HC-R part II, which reports risk-weighted assets.[16] These variables include the sum of held-to-maturity, available-for-sale and trading asset US Treasuries, net loans and leases, and loans and leases by risk weight. We measure each of the variables relative to total assets.

### *4.3 Results for Basel III Capital Regulation on Excess Reserves*

Figure 7 depicts our measure of average excess reserves relative to total assets for advanced approaches and non-advanced approaches bank holding companies with more than $10 billion in total assets from Q2 2012 through Q4 2018. Before Q1 2013, advanced approaches banks had

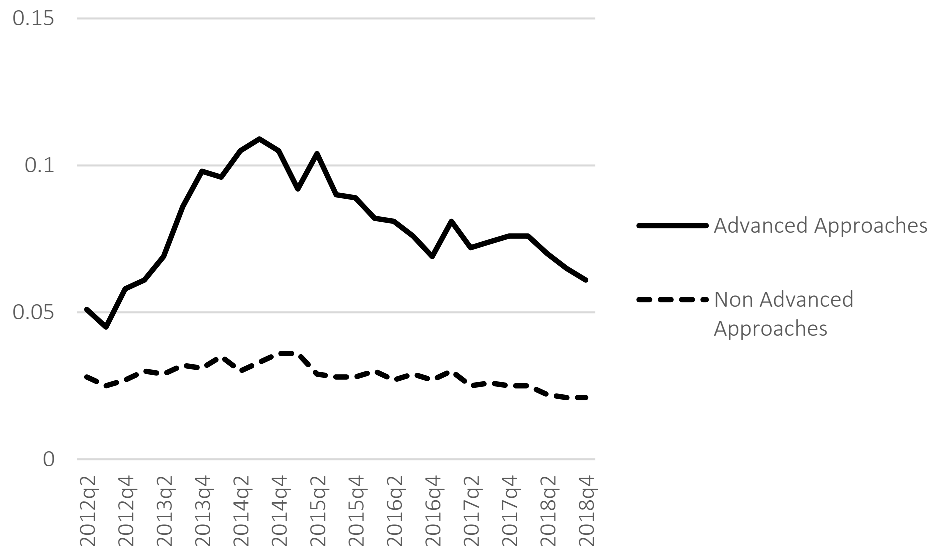
[16] We obtain the bank holding company call report data available from Wharton Research Data Services (database), Wharton School, University of Pennsylvania, accessed April 18, 2020, https://wrds-web.wharton.upenn.edu/wrds/. For our list of holding companies, we use the Federal Reserve Bank of New York's 2014-3 "CRSP-FRB Link," accessed November 15, 2015, https://www.newyorkfed.org/research/banking_research/datasets.html.

about 2 to 3 percent more excess reserves as a fraction of total assets, but beginning in Q1 2013, the advanced approaches banks ramped up their holdings relative to the other banking entities with more than $10 billion in total assets. When we estimate the OLS sensitivity of average advanced approaches bank excess reserves holdings to the rate differential between one-year Treasury rates and the rate of interest on reserves during the Q1 2013–Q4 2018 post-treatment period the coefficient equals −3.13. That means a 1 percentage point increase in the return differential is associated with a 3.13 percent decrease in the average share of excess reserves. When we estimate the OLS sensitivity for non-advanced approaches banks during the same post-treatment period the coefficient equals −1.29. The differences between these sensitivities suggest that advanced approaches bank holdings of excess reserves respond more to changes in the rate differentials than do holdings for smaller large banks; we find similar results if we use rates on shorter-term maturity Treasuries.

In figure 8 we depict the average treatment effects for advanced approaches banks relative to the other large banks on the basis of Mora and Reggio's approach. As summarized in table 3, the sample consists of an unbalanced panel of 2,041 observations for BHCs between Q2 2012 and Q4 2018. The *p* value for the test of common pretreatment dynamics equals 0.25, which indicates that we cannot reject the hypothesis that the parallel paths assumption holds, indicating that the average change for entities in the treatment group, in the absence of treatment, equals the observed average change for entities in the control group. In this case, the *p* values for tests of common post-treatment dynamics equal zero, suggesting that the post-treatment trends also differ after Q4 2012. The post-treatment effect in Q1 2013 equals 1 percent and increases to 2.4 percent by Q3 2013 when the final rule became publicly available. This finding is consistent with the predictions of the model discussed in section 3.

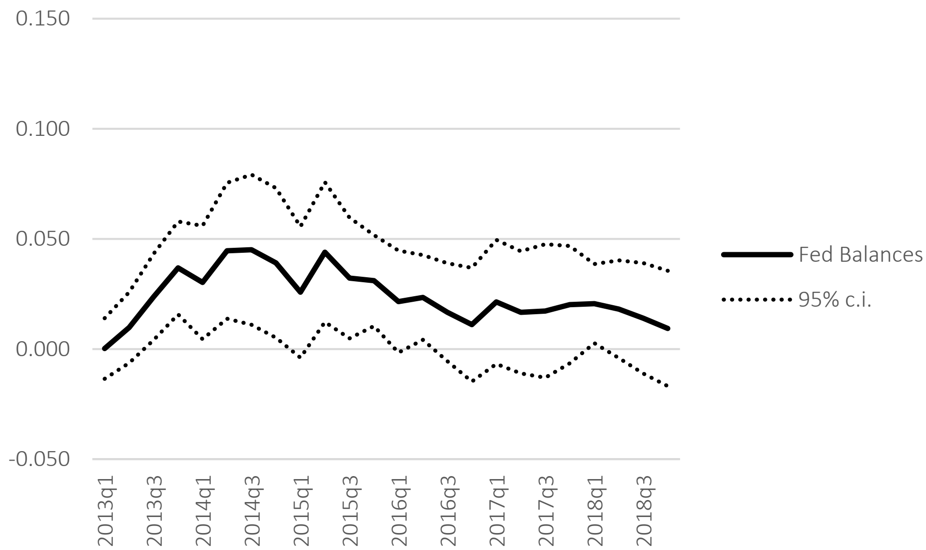
The peak treatment effect for excess reserves occurs in Q3 2014 at roughly 4.5 percent (2.1 percentage points higher than the Q3 2013 treatment) and begins to decline after that. The decline could relate to the increasing rate differential between short-term Treasury rates and the rate of interest on reserves. Also bear in mind that by Q4 2013, US regulators issued an NPR for the Basel III liquidity coverage ratio, which was finalized by Q3 2014. Given that Roberts, Sarkar, and Shachar (2018) and Rezende, Styczynski, and Vojtech (forthcoming) find that holdings of high-quality liquid assets may have been spurred by Basel III liquidity regulations, it stands to reason that this may also explain part of the rise in excess reserves. We can again make the strong assumption that Basel III capital regulations only affected excess reserves through Q3 2013, and Basel III liquidity regulations only affected excess reserves after that. In that case, about 53 percent of the higher premium for advanced approaches banks arises from the capital regulations, and 47 percent arises from the liquidity regulations. We revisit the effects of liquidity regulation in section 4.6.

**Figure 7. Average Excess Reserves as a Fraction of Total Assets for Advanced Approaches and Non-advanced Approaches Bank Holding Companies before and after US Basel III Capital and Liquidity Regulations, Q2 2012–Q4 2018**




Source: Authors' estimates based on the excess reserves series from the FDIC's Statistics on Depository Institutions (database) for bank call report bulk data, as well as the Federal Reserve Bank of Chicago bank holding company total asset series.

**Figure 8. Average Treatment Effects for Advanced Approaches Bank Holding Companies after US Basel III Capital and Liquidity Regulations, Q1 2013–Q4 2018**




Source: Authors' estimates based on the excess reserves series from the FDIC's Statistics on Depository Institutions (database) for bank call report bulk data, as well as the Federal Reserve Bank of Chicago bank holding company total asset series.

**Table 3. Regression Tests of Common Pretreatment and Post-treatment Dynamics: Excess Reserves Relative to Total Assets**

$R^2$: 0.22
N: 2,041

| | Tests for common pretreatment dynamics | | Tests for common post-treatment dynamics | |
|---|---|---|---|---|
| | Test statistic: $q = q - 1$ | *p* value | Test statistic | *p* value |
| $q$ = 1 (parallel paths) | | | 102.18 | 0.00 |
| $q$ = 2 (parallel growths) | 0.01 | 0.21 | 91.63 | 0.00 |
| $q$ = 3 (parallel accelerations) | 0.01 | 0.10 | 80.24 | 0.00 |
| Overall common pretreatment dynamics | 2.81 | 0.25 | | |

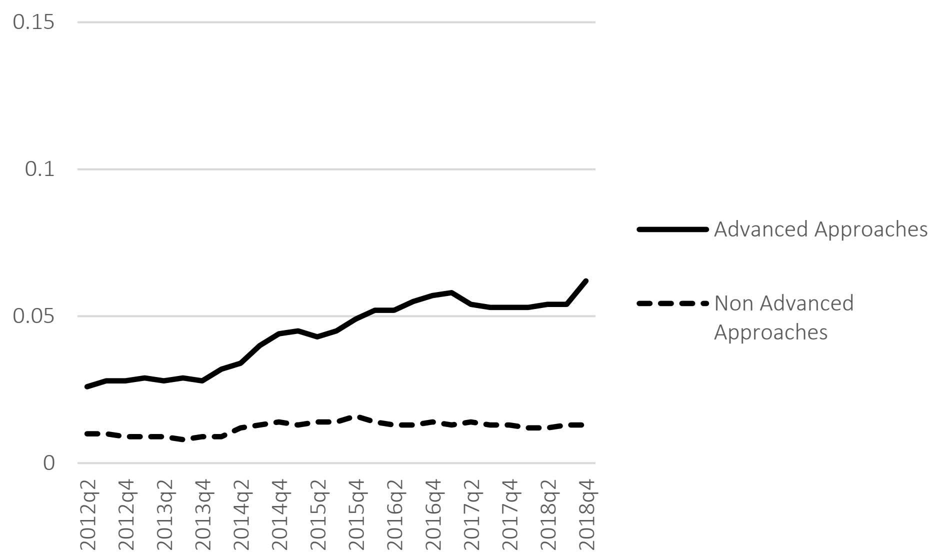
Source: Authors' estimates based on the excess reserves series from the FDIC's Statistics on Depository Institutions (database) for bank call report bulk data, as well as the Federal Reserve Bank of Chicago bank holding company total asset series.

### *4.4 Results for Basel III Capital Regulation on Treasuries*

We examine the bank holding company allocations for Treasuries. Figure 9 shows that the average holdings remain roughly constant through Q4 2013 but begin to rise after Q1 2014. Keep in mind that the rise coincides with a rise in Treasury rates relative to the interest rate on reserves. While non-advanced approaches banks increase holdings by about 0.5 percent, the advanced approaches banks roughly double their holdings from about 3 percent to over 6 percent. The OLS sensitivity of average advanced approaches bank holdings of Treasuries to the rate differential between one-year Treasury rates and the rate of interest on reserves during the Q1 2013–Q4 2018 post-treatment period equals 3.21. This means that a 1 percent increase in the return differential is associated with a 3.21 percent increase in the average share of Treasuries. The OLS sensitivity for non-advanced approaches banks during the same post-treatment period equals 0.37. As with excess reserves, the differences between these sensitivities suggest that advanced approaches bank Treasury holdings respond more to changes in the rate differentials than do Treasury holdings by smaller large banks; we find similar results if we use rates on shorter-term maturity Treasuries.

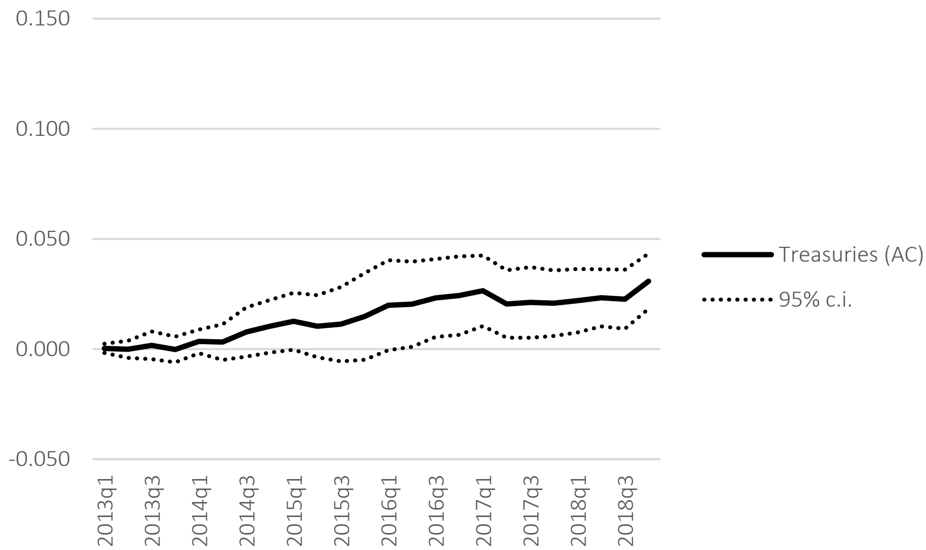
Figure 10 depicts the average treatment effects for advanced approaches banks relative to the other large banks. As summarized in table 4, the sample consists of an unbalanced panel of 2,041 observations for BHCs between Q2 2012 and Q4 2018. The $p$ value for the test of common pretreatment dynamics equals 0.34, indicating that we cannot reject the hypothesis that the parallel paths assumption holds, indicating that the average change for entities in the treatment group, in the absence of treatment, equals the observed average change for entities in the control group. In this case, the $p$ values for tests of common post-treatment dynamics equal zero, suggesting that the post-treatment trends also differ after Q4 2012. The post-treatment effects lie close to zero until Q2 2014, when they begin to rise. Similar to the results for excess reserves, the increase could relate to the increasing rate differential between short-term Treasury rates and the rate of interest on reserves.

**Figure 9. Average Treasuries (Amortized Cost) as a Fraction of Total Assets for Advanced Approaches and Non-advanced Approaches Bank Holding Companies before and after US Basel III Capital and Liquidity Regulations, Q2 2012–Q4 2018**




Source: Authors' estimates based on Federal Reserve Bank of Chicago bank holding company Treasuries and total assets data series.

**Figure 10. Average Treatment Effects for Treasuries (Amortized Cost) for Advanced Approaches Bank Holding Companies after US Basel III Capital and Liquidity Regulations, Q1 2013–Q4 2018**




Source: Authors' estimates based on Federal Reserve Bank of Chicago bank holding company Treasuries and total assets data series.

**Table 4. Regression Tests of Common Pretreatment and Post-treatment Dynamics: US Treasuries (Amortized Costs) Relative to Total Assets**

$R^2$: 0.14

N: 2,041

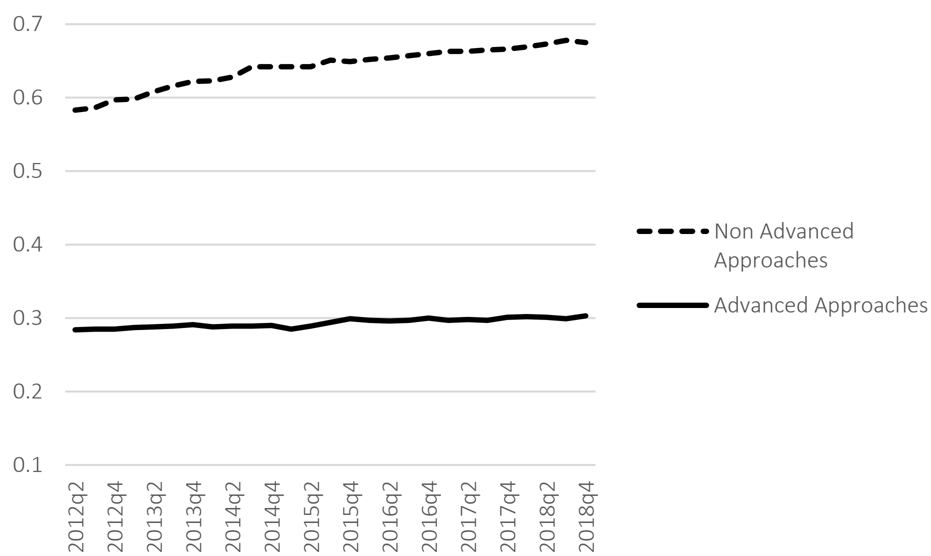
| | Tests for common pretreatment dynamics | | Tests for common post-treatment dynamics | |
|---|---|---|---|---|
| | Test statistic: $q = q - 1$ | $p$ value | Test statistic | $p$ value |
| $q$ = 1 (parallel paths) | | | 824.46 | 0.00 |
| $q$ = 2 (parallel growths) | 0.00 | 0.65 | 309.87 | 0.00 |
| $q$ = 3 (parallel accelerations) | 0.00 | 0.80 | 304.56 | 0.00 |
| Overall common pretreatment dynamics | 2.13 | 0.34 | | |

Source: Authors' estimates based on as the Federal Reserve Bank of Chicago bank holding company Treasuries and total asset series.

### *4.5 Results for Basel III Capital Regulation on Loans and Leases*

The model discussed in section 3 suggests that higher risk-based capital requirements could result in a lower share of assets allocated to loans. Figure 11 shows that non-advanced approaches bank holding companies hold more loans in their portfolios than advanced approaches holding companies. Moreover, these holding companies increase their holdings at a faster rate on average than the advanced approaches holding companies. We should therefore expect to see negative treatment effects.

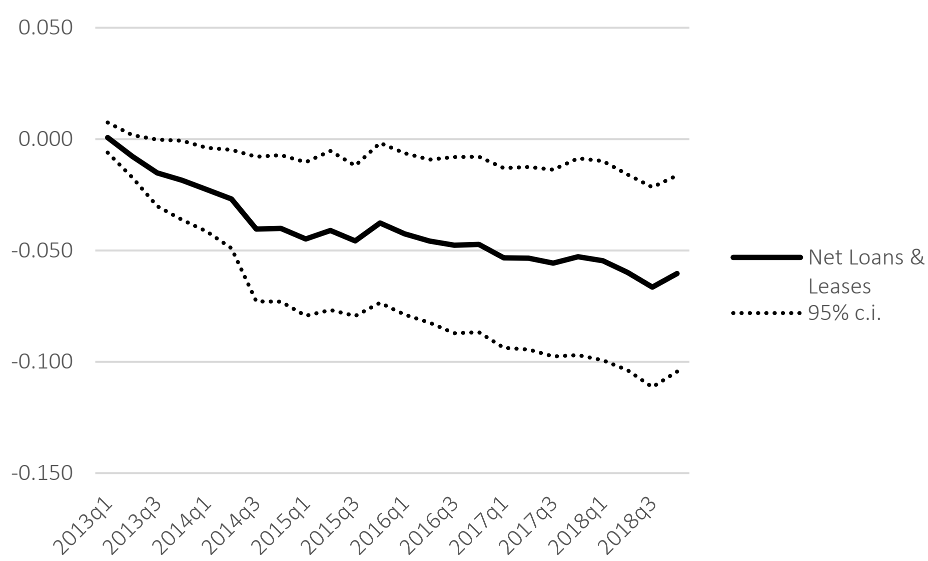
**Figure 11. Average Net Loans and Leases as a Fraction of Total Assets for Advanced Approaches and Non-advanced Approaches Bank Holding Companies before and after US Basel III Capital and Liquidity Regulations, Q2 2012–Q4 2018**




Source: Authors' estimates based on Federal Reserve Bank of Chicago bank holding company net loans and leases and total assets data series.

Figure 12 depicts the average treatment effects for advanced approaches banks relative to the other large banks. As summarized in table 5, the sample consists of an unbalanced panel of 2,041 observations for BHCs between Q2 2012 and Q4 2018. The *p* value for the test of common pretreatment dynamics equals 0.46, which indicates that we cannot reject the hypothesis that the parallel paths assumption holds, indicating that the average change for entities in the treatment group, in the absence of treatment, equals the observed average change for entities in the control group. In this case, the *p* values for tests of common post-treatment dynamics lies close to zero, suggesting that the post-treatment trends also differ after Q4 2012. The post-treatment effect in Q2 2013 equals −0.8 percent and decreases to −1.5 percent by Q3 2013. This finding is likewise consistent with the predictions of the model discussed in section 3. The post-treatment effects continue to rise throughout the sample.

**Figure 12. Average Treatment Effects for Advanced Approaches Bank Holding Companies after US Basel III Capital and Liquidity Regulations, Q1 2013–Q4 2018**




Source: Authors' estimates based on Federal Reserve Bank of Chicago bank holding company net loans and leases and total assets data series.

**Table 5. Regression Tests of Common Pretreatment and Post-treatment Dynamics: Net Loans and Leases Relative to Total Assets**

$R^2$: 0.48
N: 2,041

| | Tests for common pretreatment dynamics | | Tests for common post-treatment dynamics | |
|---|---|---|---|---|
| | Test statistic: $q = q - 1$ | $p$ value | Test statistic | $p$ value |
| $q$ = 1 (parallel paths) | | | 48.54 | 0.00 |
| $q$ = 2 (parallel growths) | −0.01 | 0.25 | 37.41 | 0.03 |
| $q$ = 3 (parallel accelerations) | −0.01 | 0.32 | 35.72 | 0.04 |
| Overall common pretreatment dynamics | 1.57 | 0.46 | | |

Source: Authors' estimates based on the the Federal Reserve Bank of Chicago bank holding company net loans and leases and total asset series.

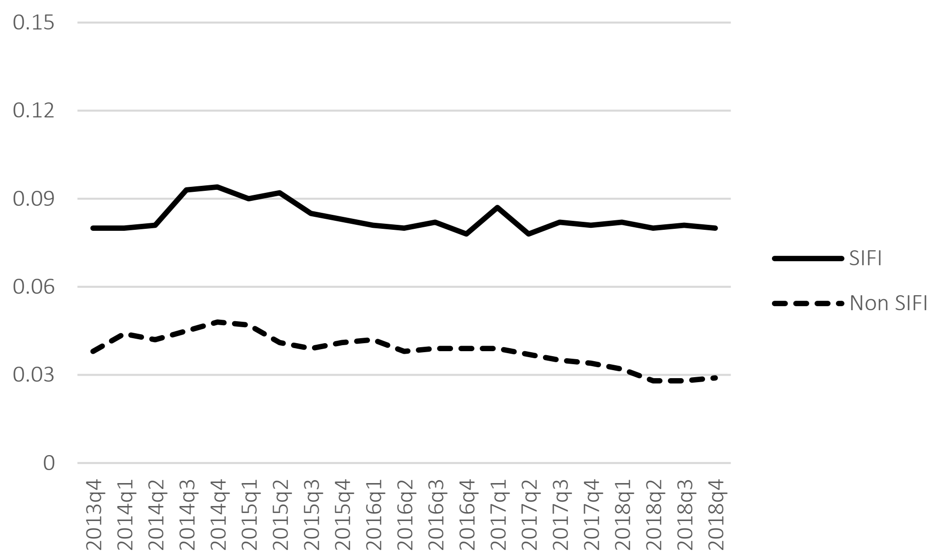
While loans tend to have higher risk weights, some loans do have lower risk weights, so we can examine whether banks may reallocate among loans due to differences in risk weights. In the appendix, figures A1–A4 depict the estimated post-treatment effects for gross loans and leases by risk weight (0 percent, 20 percent, 50 percent, and 100 percent or higher); we do not adjust for loss provisions, as call report data do not break down these data by risk weight. The figures show that the post-treatment effects increase over time but only for the 100 percent risk-weighted loans and, to a lesser extent, for the 50 percent risk-weighted loans. Given that the control group on average expanded holdings of these loans during the sample while the treatment group did not, the treatment effects suggest that risk-weighted capital could have contributed to the limited expansion of loan holdings for the largest banks in response to the regulatory changes. This finding may also relate to findings reported by Chen, Hanson, and Stein (2017), who mention regulatory capital and liquidity changes as potential reasons for the limited post-crisis expansion for the four largest US banks, including their small business lending activities.

### *4.6 Results for Basel III Liquidity Regulation on Level 1 High-Quality Liquid Assets*

Lastly, we can examine the role of the Basel III liquidity coverage ratio as a robustness exercise by examining the evolution of the sum of excess reserves and US Treasury securities relative to total assets. Recall that figure 7 shows that excess reserves began falling in 2014, while figure 9 shows that Treasury holdings began rising in 2014, which suggests some substitution between the two asset classes. Since these two asset classes fall under the level 1 high-quality liquid assets category, for the purpose of examining the effects of liquidity regulation, we examine whether the sum of the two asset classes changes in response to the liquidity regulation. Figure 13 depicts the average sum of excess reserves and US Treasuries relative to total assets for SIFI and non-SIFI bank holding companies with more than \$10 billion in total assets from Q4 2013 through Q4 2018. SIFI banks on average held about 8 percent of their portfolio as level 1 high-quality liquid assets, with a slightly higher amount between Q3 2014 and Q2 2015, while non-SIFI banks held about half that amount or less during the sample.

To estimate the effects of the liquidity regulation on our measure of high-quality liquid assets, in figure 14 we depict the average treatment effects for SIFI banks relative to the other large banks. As summarized in table 6, the sample consists of an unbalanced panel of 1,651 observations for BHCs between Q4 2013 and Q4 2018. The $p$ value for the test of common pretreatment dynamics equals 0.42, which indicates that we cannot reject the hypothesis that the parallel paths assumption holds, indicating that the average change for entities in the treatment group, in the absence of treatment, equals the observed average change for entities in the control group. In this case, the $p$ values for tests of common post-treatment dynamics do not differ from zero, suggesting that the post-treatment trends also differ after Q3 2014. The post-treatment effect in Q3 2014 equals just under 1 percent but remains small throughout the sample. These findings suggest that the Basel III liquidity regulations may have had a small effect on the combined sum of excess reserves and US Treasury securities relative to total assets, and the effects were smaller than those observed during the implementation of Basel III capital regulations.[17]

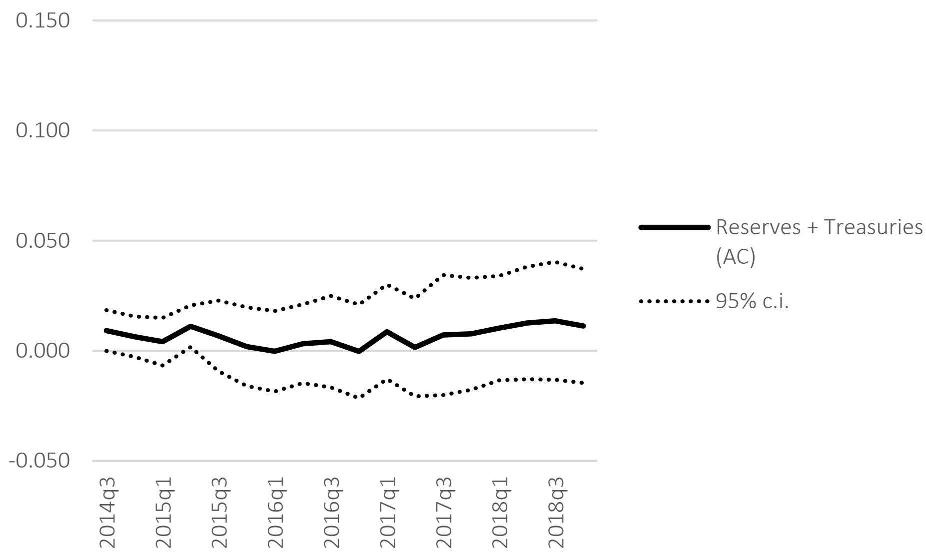
**Figure 13. Average Level 1 High-Quality Liquid Assets as a Fraction of Total Assets for before and after US Basel III Liquidity Regulations, Q4 2013–Q4 2018**




Source: Authors' estimates based on the excess reserves series from the FDIC's Statistics on Depository Institutions (database) for bank call report bulk data, as well as the Federal Reserve Bank of Chicago bank holding company Treasuries and total asset series.

[17] We focus on the results for the combined share of excess reserves and Treasuries, given the substitutability between the two asset categories, but in unreported results, we also estimate the dynamic treatment effects for excess reserves and Treasuries, separately. For excess reserves, the dynamic treatment effects are negative rather than positive. In addition, the tests of the null hypothesis of common pretreatment dynamics for excess reserves indicate that the parallel paths assumption yields different treatment effects than the difference in double- or triple-differences estimators, the latter indicating that economically significant deceleration exists. For Treasuries, we find positive and economically significant portfolio shifts only after Q1 2016; tests suggest we do not reject the null hypothesis of common pretreatment dynamics.

**Figure 14. Average Treatment Effects for SIFI Bank Holding Companies after US Basel III Liquidity Regulations, Q3 2014–Q4 2018**




Source: Authors' estimates based on the excess reserves series from the FDIC's Statistics on Depository Institutions (database) for bank call report bulk data, as well as the Federal Reserve Bank of Chicago bank holding company Treasuries and total asset series.

**Table 6. Regression Tests of Common Pretreatment and Post-treatment Dynamics: Sum of Excess Reserves and US Treasuries (Amortized Costs) Relative to Total Assets**

$R^2$: 0.14
N: 1,651

| | Tests for common pretreatment dynamics | | Tests for common post-treatment dynamics | |
|---|---|---|---|---|
| | Test statistic: $q = q - 1$ | $p$ value | Test statistic | $p$ value |
| $q$ = 1 (parallel paths) | | | 20.08 | 0.27 |
| $q$ = 2 (parallel growths) | 0.00 | 0.44 | 19.48 | 0.30 |
| $q$ = 3 (parallel accelerations) | 0.01 | 0.19 | 22.55 | 0.16 |
| Overall common pretreatment dynamics | 1.76 | 0.42 | | |

Source: Authors' estimates based on the excess reserves series from the FDIC's Statistics on Depository Institutions (database) for bank call report bulk data, as well as the Federal Reserve Bank of Chicago bank holding company Treasuries and total asset series.

## 5. Conclusions

The results of the model and evidence presented here show how the implementation of Basel III capital regulations may have contributed to greater holdings of excess reserves. In short, without interest on reserves, since excess reserves and US Treasury securities get assigned the same risk weights of zero, excess reserve holdings get penalized relative to Treasuries, but payment of interest on reserves makes them much closer substitutes.

Fast-forward to the post-crisis implementation of Basel III capital regulations, excess reserves earned interest that often exceeded interest earned on short-term US Treasury securities. As a result, the advanced approaches banks held more excess reserves than Treasuries. Advanced approaches banks also showed little recovery in the fraction of loans held compared to non-advanced approaches banks, as risk-based capital requirements began to increase. However, once the yields began to rise on Treasuries relative to excess reserves, advanced approaches banks substituted Treasuries for excess reserves. At the same time, we find that bank capital regulation may explain more of the rise in excess reserves than liquidity regulation.

These outcomes seem to be the result of policies designed to control bank liquidity and solvency risk, which were implemented in a new regime where significant central bank reserves replace interbank lending of nonborrowed reserves. The combined effects may also have limited the extent to which the largest advanced approaches banks contributed to the post-crisis recovery via bank lending. Future research and policy should consider the combined intended and unintended consequences of bank capital regulation and the payment of interest on reserves, and whether replacing risk-based capital requirements with a simple leverage ratio, combined with using market rates as policy variables, may eliminate those unintended effects.

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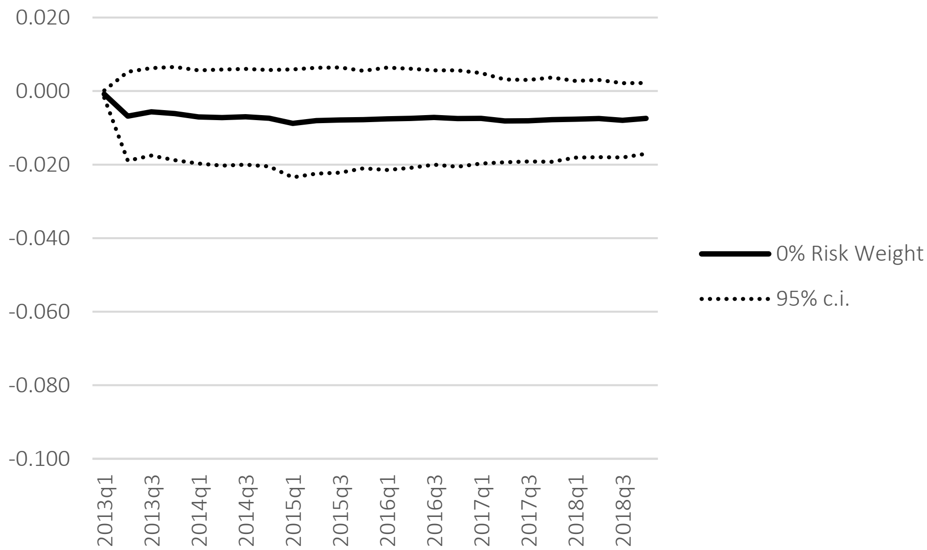
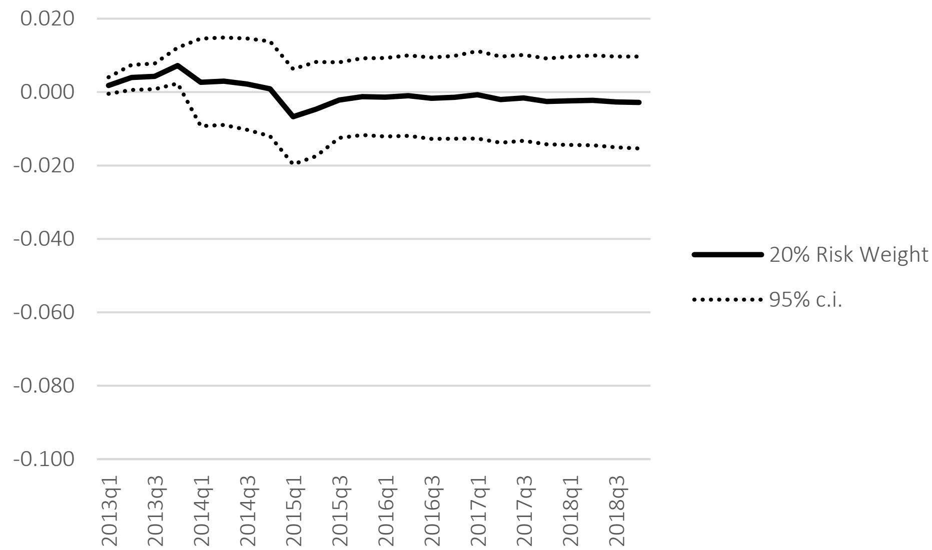
## Appendix

### Figure A1. Zero Percent Risk Weight Total Loans Average Treatment Effects for Advanced Approaches Bank Holding Companies Banks after US Basel III Capital and Liquidity Regulations, Q1 2013–Q4 2018



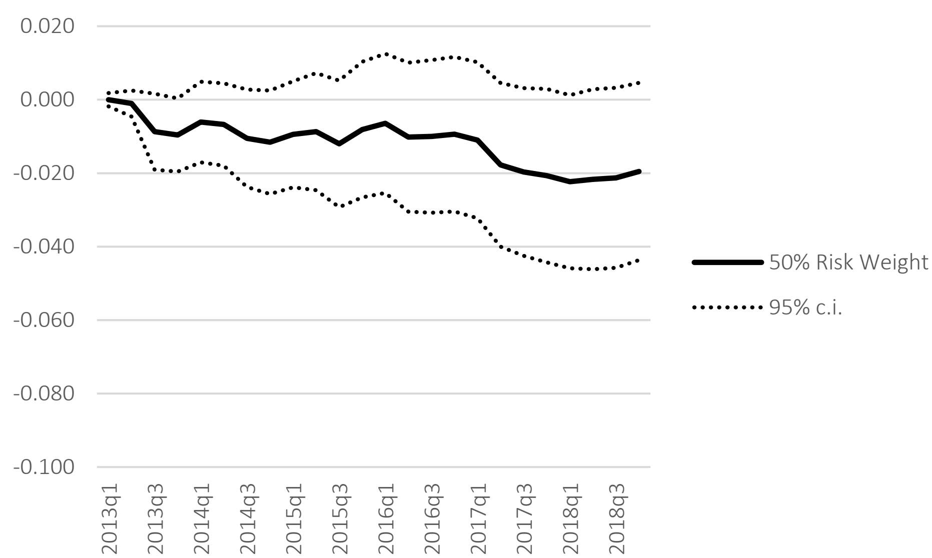

Source: Authors' estimates based on the the Federal Reserve Bank of Chicago bank holding company 0% risk-weighted loans and total assets data series.

**Figure A2. Twenty Percent Risk Weight Total Loans Average Treatment Effects for Advanced Approaches Bank Holding Companies Banks after US Basel III Capital and Liquidity Regulations, Q1 2013–Q4 2018**



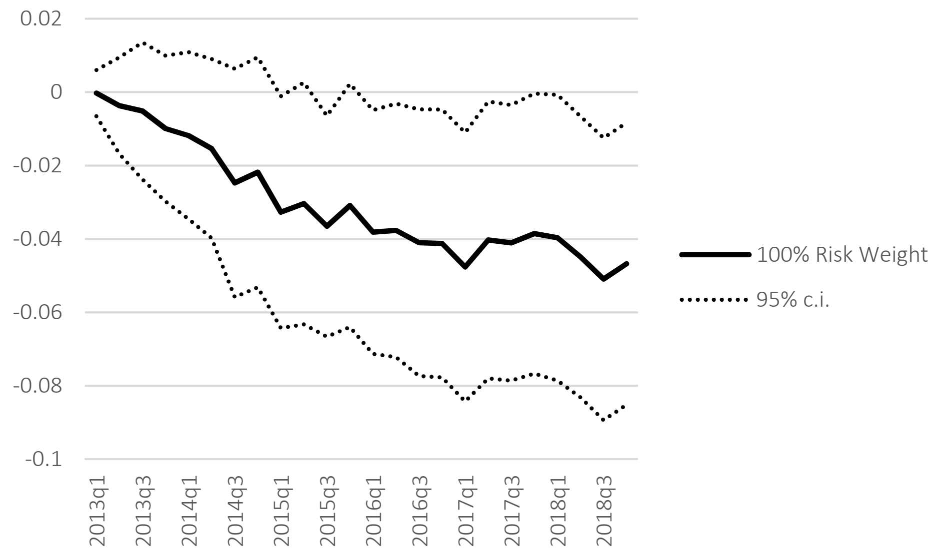

Source: Authors' estimates based on the the Federal Reserve Bank of Chicago bank holding company 20% risk-weighted loans and total assets data series.

**Figure A3. Fifty Percent Risk Weight Total Loans Average Treatment Effects for Advanced Approaches Bank Holding Companies Banks after US Basel III Capital and Liquidity Regulations, Q1 2013–Q4 2018**




Source: Authors' estimates based on the the Federal Reserve Bank of Chicago bank holding company 50% risk-weighted loans and total assets data series.

**Figure A4. One Hundred Percent Risk Weight Total Loans Average Treatment Effects for Advanced Approaches Bank Holding Companies after US Basel III Capital and Liquidity Regulations, Q1 2013–Q4 2018**




Source: Authors' estimates based on the the Federal Reserve Bank of Chicago bank holding company 100% risk-weighted loans and total assets data series.

**Table A1. Variable Construction**

| Variable name | Transformation applied to raw series |
|---|---|
| Excess reserves, proxied by balances due from FRB, relative to total assets | From the bulk bank call report data, available from https://www5.fdic.gov/sdi /download_large_list_outside.asp (see footnote 8), aggregate the bank level values by holding company and merge it into the bank holding company call report data before dividing by total assets reported from schedule HC, bhck2170. |
| Treasuries measured at amortized costs relative to total assets | The sum of held-to-maturity Treasuries, bhck0211, available-for-sale Treasuries, bhck1286, measured at amortized cost from schedule HC-B, as well as consolidated Treasuries for trading, from schedule HC-D, bhcm3531, divided by total assets reported from schedule HC, bhck2170. |
| Treasuries measured at fair value relative to total assets | The sum of held-to-maturity Treasuries, bhck0213, available-for-sale Treasuries, bhck1287, measured at fair value from schedule HC-B, as well as consolidated Treasuries for trading, from schedule HC-D, bhcm3531, divided by total assets reported from schedule HC, bhck2170. |
| Net loans and leases | The difference between "loans and leases, net of unearned income," bhckb528, and "allowance for loan and lease losses," bhck3123, from schedule HC, divided by total assets reported from schedule HC, bhck2170. |

*continued on following page*

| Variable name | Transformation applied to raw series |
|---|---|
| 0 percent risk weight loans and leases, net of unearned income | Before Q1 2015, divide “0 percent risk weight Loans and Leases, net of unearned income,” bhc0b528, from schedule HC-R, by total assets reported from schedule HC, bhck2170. Starting in Q1 2015, 0 percent risk weight “Loans and Leases, net of unearned income” equal the sum of “0 percent risk weight Residential mortgage exposures,” bhckh178, “0 percent risk weight High volatility commercial real estate exposures,” bhckh179, “0 percent risk weight Exposures past due 90 days or more on nonaccrual,” bhcks451, and “0 percent risk weight All other exposures,” bhcks459, from schedule HC-R, divided by total assets reported from schedule HC, bhck2170. |
| 20 percent risk weight loans and leases, net of unearned income | Before Q1 2015, divide “20 percent risk weight Loans and Leases, net of unearned income,” bhc2b528, from schedule HC-R, by total assets reported from schedule HC, bhck2170. Starting in Q1 2015, 20 percent risk weight “Loans and Leases, net of unearned income” equal the sum of “20 percent risk weight Residential mortgage exposures,” bhcks441, “20 percent risk weight High volatility commercial real estate exposures,” bhckh180, “20 percent risk weight Exposures past due 90 days or more on nonaccrual,” bhcks452, and “20 percent risk weight All other exposures,” bhcks460, from schedule HC-R, divided by total assets reported from schedule HC, bhck2170. |
| 50 percent risk weight loans and leases, net of unearned income | Before Q1 2015, divide “50 percent risk weight Loans and Leases, net of unearned income,” bhc5b528, from schedule HC-R, by total assets reported from schedule HC, bhck2170. Starting in Q1 2015, 50 percent risk weight “Loans and Leases, net of unearned income” equal the sum of “50 percent risk weight Residential mortgage exposures,” bhcks442, “50 percent risk weight High volatility commercial real estate exposures,” bhckh181, “50 percent risk weight Exposures past due 90 days or more on nonaccrual,” bhcks453, and “50 percent risk weight All other exposures,” bhcks461, from schedule HC-R, divided by total assets reported from schedule HC, bhck2170. |
| 100 percent risk weight loans and leases, net of unearned income | Before Q1 2015, “100 percent risk weight Loans and Leases, net of unearned income,” bhc9b528, from schedule HC-R, divided by total assets reported from schedule HC, bhck2170. Starting in Q1 2015, 100 percent risk weight “Loans and Leases, net of unearned income” equal the sum of “100 percent risk weight “Residential mortgage exposures,” bhcks443, “100 percent risk weight High volatility commercial real estate exposures,” bhckh182, “100 percent risk weight Exposures past due 90 days or more on nonaccrual,” bhcks454, and “100 percent risk weight All other exposures,” bhcks462, “150 percent risk weight High volatility commercial real estate exposures,” bhcks447, “150 percent risk weight Exposures past due 90 days or more on nonaccrual,” bhcks455, and “150 percent risk weight All other exposures,” bhcks463, from schedule HC-R, divided by total assets reported from schedule HC, bhck2170. |

### Table A2. Regression Tests of Common Pretreatment and Post-treatment Dynamics: 0 Percent Risk Weight Loans and Leases

$R^2$: 0.00

N: 2,034

| | Tests for common pretreatment dynamics | | Tests for common post-treatment dynamics | |
|---|---|---|---|---|
| | Test statistic: $q = q - 1$ | $p$ value | Test statistic | $p$ value |
| $q$ = 1 (parallel paths) | | | 35.20 | 0.05 |
| $q$ = 2 (parallel growths) | 0.00 | 0.23 | 34.25 | 0.06 |
| $q$ = 3 (parallel accelerations) | 0.00 | 0.12 | 38.71 | 0.02 |
| Overall common pretreatment dynamics | 2.89 | 0.24 | | |

Source: Authors' estimates based on the the Federal Reserve Bank of Chicago bank holding company 0% risk-weighted loans and total assets data series.

### Table A3. Regression Tests of Common Pretreatment and Post-treatment Dynamics: 20 Percent Risk Weight Loans and Leases

$R^2$: 0.07

N: 2,041

| | Tests for common pretreatment dynamics | | Tests for common post-treatment dynamics | |
|---|---|---|---|---|
| | Test statistic: $q = q - 1$ | $p$ value | Test statistic | $p$ value |
| $q$ = 1 (parallel paths) | | | 98.83 | 0.00 |
| $q$ = 2 (parallel growths) | 0.00 | 0.78 | 98.83 | 0.00 |
| $q$ = 3 (parallel accelerations) | 0.00 | 0.51 | 126.30 | 0.00 |
| Overall common pretreatment dynamics | 3.18 | 0.20 | | |

Source: Authors' estimates based on the the Federal Reserve Bank of Chicago bank holding company 20% risk-weighted loans and total assets data series.

**Table A4. Regression Tests of Common Pretreatment and Post-treatment Dynamics: 50 Percent Risk Weight Loans and Leases**

$R^2$: 0.10
N: 2,041

| | Tests for common pretreatment dynamics | | Tests for common post-treatment dynamics | |
|---|---|---|---|---|
| | Test statistic: $q = q - 1$ | $p$ value | Test statistic | $p$ value |
| $q$ = 1 (parallel paths) | | | 28.55 | 0.20 |
| $q$ = 2 (parallel growths) | 0.00 | 0.43 | 31.07 | 0.12 |
| $q$ = 3 (parallel accelerations) | 0.00 | 0.32 | 31.31 | 0.12 |
| Overall common pretreatment dynamics | 1.31 | 0.52 | | |

Source: Authors' estimates based on the the Federal Reserve Bank of Chicago bank holding company 50% risk-weighted loans and total assets data series.

**Table A5. Regression Tests of Common Pretreatment and Post-treatment Dynamics: 100 Percent Risk Weight Loans and Leases**

$R^2$: 0.37
N: 2,041

| | Tests for common pretreatment dynamics | | Tests for common post-treatment dynamics | |
|---|---|---|---|---|
| | Test statistic: $q = q - 1$ | $p$ value | Test statistic | $p$ value |
| $q$ = 1 (parallel paths) | | | 58.22 | 0.00 |
| $q$ = 2 (parallel growths) | −0.02 | 0.07 | 63.58 | 0.00 |
| $q$ = 3 (parallel accelerations) | −0.01 | 0.12 | 54.50 | 0.00 |
| Overall common pretreatment dynamics | 4.48 | 0.11 | | |

Source: Authors' estimates based on the the Federal Reserve Bank of Chicago bank holding company 100% risk-weighted loans and total assets data series.