Bank Leverage Limits and Regulatory Arbitrage: New Evidence on a Recurring Question

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November 15, 2018

Abstract

Banks are regulated more than most firms, making them good subjects to study regulatory arbitrage (avoidance). Their latest arbitrage opportunity may be the supplementary leverage rule (SLR) recently imposed on the largest U.S. banks; because the rule requires equal capital against assets with unequal risk, banks can sidestep it by shedding safer assets and/or adding riskier ones. Our difference-in-difference analysis suggests they are; riskier (risk-weighted) asset shares and security yields at banks subject to the SLR rose relative to control banks after the SLR was finalized in 2014. The differences tend to be larger at more constrained banks, and some are substantial; mean yields at SLR banks rose (relatively) about 30 basis points. Security level analysis suggests banks *actively* added riskier securities, rather than passively shedding safer ones. Overall bank risk did not increase, however; evidently because the most constrained SLR banks also significantly de-levered.

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> Because our existing capital standards treat all bank assets alike, they have had the effect of encouraging some institutions to scale back their holdings of relatively liquid, low-risk assets (Paul Volcker, 1987)

> …a leverage requirement that is too high favors high-risk activities and disincentivizes low-risk activities (Randal K. Quarles, 2018)

I. Introduction

The *déjà vu* aspect of our question is reflected in the quotes above. The first is former Federal Reserve Chairman Volcker explaining why bank regulators were moving from the leverage rule imposed in 1981 to more risk-based capital rules. The second is the current Vice Chairman for Supervision explaining why the new leverage rule that took effect this year was being recalibrated to curb risk-shifting incentives. Bankers, for their part, have warned that the new leverage rule would tempt them:

> … the proposal would have discouraged banks from holding low-yielding, high-quality assets…in preference for riskier assets which would produce a higher relative return of capital. (J.P. Morgan (2014))

Despite these long-standing concerns, evidence of banks arbitraging leverage rules is scarce. Koehn and Santomero (1980) and Kim and Santomero (1988) predicted asset substitution and potentially higher overall risk after the leverage rule was imposed in the early 1980s but Furlong (1988), the only test, found no evidence of either effect. That earlier rule was not well suited for testing, however, as all U.S. banks were covered and the limit was rarely binding. The SLR, to our advantage, covers only the very largest U.S. banks and strictly binds for some.

We re-visit the arbitrage conjecture using difference-in-difference analysis applied to the latest leverage rule experiment. Our treated group comprises the 15 bank holding companies ("banks") covered by the SLR, the designated "advanced approach" firms that use internally generated risk estimates for setting risk-based (weighted) capital requirements. It was regulators' doubt about those estimates that motivated the leverage rule as a "simple, back stop" (BCBS 2009) immune to "model risk" at advanced approach firms.[2] Advance approach firms are very large; at least $250 billion in total assets or $10 billion in foreign exposures. Our control group comprises the set of the next largest banks: the 18 other "systemically important" (Dodd Frank 2010) banks with assets under $250 billion but over $50 billion. The two sets of banks faced similar post-crisis reforms apart from the leverage rule, including stress testing, so any differential risk change can, arguably, be attributed to the SLR.

Of course, the post-crisis reforms included many elements so parsing the effect of any particular reform is a challenge. For example, regulators imposed a liquidity requirement on large banks at the same time as the leverage rule. The liquidity rule requires sufficient "high quality liquid assets" to cover potential outflows, and since high quality assets are likely safer, the liquidity rule could limit leverage rule arbitrage. All banks with over $50 billion in assets are subject to the liquidity rule, but banks subject to the leverage rule also face a stricter liquidity rule. We include a proxy for liquidity constraints, but if it performs worse for SLR banks, as we suspect, the SLR effect we estimate will be understated.[3]

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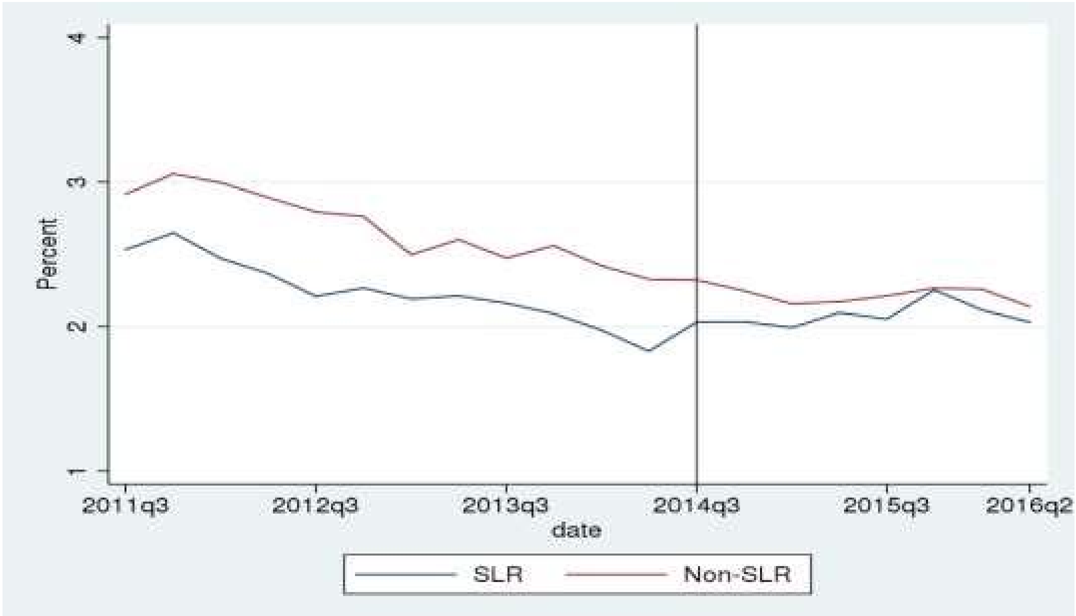
[2] See Santos and Plosser (2014) for evidence and references.

[3] We discuss our LCR proxy in detail later.

We study various risk measures at multiple levels. We first study risky (risk-weighted) asset shares for broad asset categories: securities, trading assets, and loans. That analysis relies on the very risk weights that are in question for advanced approach firms, so are potentially subject to the same doubts. Our next level analysis eliminates such concerns by studying (market-based) security yields. For that we accessed individual security holdings from confidential bank filings used for stress-testing, then matched with yields, when available, from multiple sources. Aggregate bank security holdings and their *ex post* returns are public, but individual holdings and *ex ante* yields, a better measure of intended risk taking, are not. Our unusually detailed data, spanning about 75,000 unique securities and 1.1 million bank-security-quarters, lets us test for leverage arbitrage via "reach for yield" directly at the book and bank-security level.

The figure below anticipates a main result; mean weighted (by volume) security yields at SLR banks were substantially lower than that at non-SLR banks but they decline in tandem until the leverage rule was finalized in 2014:Q3. Afterwards, yields at non-SLR banks leveled off while yields at SLR banks reversed trend and began rising, nearly reaching the level at non-SLR banks. Our diff-in-diff estimates, conditional on bank size, risk-based capital, liquidity rule exposure, and standard fixed effects, confirm that visual SLR effect.

Figure 1: Leverage Rule Leads to Reach for Yield?



Our detailed securities data also lets us compare how holdings of the same security by different banks change over time. That security-bank level analysis has the same identification advantages as the firm-bank analysis in Khwaja and Mian (2008), except here it controls for security supply rather than firm demand. Abbassi et al (2018) use security-bank level data to test for window dressing, a different type of regulatory arbitrage. We use the data to distinguish between the *passive* arbitrage described by Volcker (1987), where banks merely shed safe, low-yield assets, versus the *active* version in Quarles (2018), where they add risker assets. Banks arbitrage regulation to different degrees and many do not arbitrage at all (Boyson et al. 2018), so whether they actively arbitrage the SLR is of interest. As an act of commission, active arbitrage may reveal something about banker culture, which has also been questioned since the crisis.

We look lastly at measures of overall bank risk. Although we predict asset-side risk shifting around the leverage rule, the effect on overall risk is ambiguous because banks constrained by the rule must also de-lever. That was largely the insight from the theoretical literature spurred by the 1980s leverage ratio cited above and more recently by Acosta Smith et al. (2017), whose model embeds important regulatory changes since the 1980s (e.g. risk-based and leverage capital requirements). The overall risk measures we examine, book and market, capture changes in both asset risk and leverage.

Our portfolio-level findings are largely consistent with the risk-shifting conjecture. We find a sizable shift toward riskier securities and trading assets at SLR banks, but not, as expected, for loans. We also find a larger (relative) increase—about 30 basis points—in the average yield on securities held by covered banks and a larger increase for the more constrained SLR banks. Despite the evident reach for yield, we find no increase in the overall bank risk measures we examine (Z scores, CDS spreads, equity volatility, and others), not even for the most SLR-constrained banks. That apparent conflict is resolved by the fact that leverage ratios at the most constrained SLR banks have risen notably; the additional capital may have offset the shift to riskier assets.

Our findings extend recent studies of leverage rule arbitrage in the securities repo (repurchase) market (Allahrakha et al. (2016), Bicu et al. (2017), Kotidis and Van Horen (2018), and Bucalossi and Scalia (2016)). The first three studies find evidence of banks reducing repo activity in response to leverage limits in the U.S. or the U.K. Our findings of more active arbitrage beyond repo complements and extends those studies.[4] Acosta Smith et al. (2017) also look beyond repo. They find a similar shift to riskier assets at European banks but no increase in overall bank risk, consistent with our findings.

[4] Repo is fertile ground for identifying leverage rule effects because it is precisely the type of low risk/low yield/high volume activity leverage constrained banks might passively exit first. The securities holdings we study do not include securities held for repurchase.

Our findings contribute to the broader literature on regulatory arbitrage, notably Calomiris and Mason (2004), Acharya, Schnabl, and Suarez (2013), Boyson, Fahlenbrach, and Stulz (2016), Becker and Ivashina (2015), and Santos and Plosser (2014). The latter find evidence of banks gaming risk-based capital requirements, consistent with the concerns that motivated the leverage rule as a back stop. Our findings and the related repo market evidence suggests that the leverage rule solution may not have worked as intended.

Section II reviews the history of leverage limits in the U.S. from the first in 1981 to the latest. Section III describes our empirical strategy. Section IV presents our data and results. Section V concludes.

II. From Leverage Limits and Back Again

We trace the circle of capital regulation over the last 40 years from leverage limits to risk-based capital rules, then back, partly, to leverage limits.

Concerned about rising failures and falling capital levels across the banking system, U.S. bank regulators announced explicit, uniform capital requirements for the first time in 1981 (Volcker 1987).[5] The rules required at least 5.5 percent primary capital and 6 percent total capital relative to total, on balance sheet assets. While the requirements were conditional on capital quality, they were invariant to asset quality (risk), hence were leverage limits in our terms.

The new rules triggered an active debate whether, theoretically, risk-invariant capital requirements, i.e. leverage rules, might actually increase bank risk via asset substitution (Koehn and Santomero (1980), Kim and Santomero (1988), Furlong and Keeley (1989)). The only

[5] Capital adequacy before then was assessed bank-by-bank by supervisors so the shift to formal standards marked an important shift in regulatory policy. Regulators could still require higher capital at banks with substantial off-balance-sheet exposures or assets considered particularly risky (Gilbert et al. 1985, p. 16)

empirical test of that question at the time appears to be Furlong (1988). He compares changes in three risk measures between 1981 and 1986 for 24 "capital deficient" banks in 1981 per the new standards and 75 that were "capital sufficient" banks. He finds no significant differential changes in the market-based asset risk measure he constructs or in bank default risk (Z) scores, contrary to the risk-shifting conjecture.

Lingering concerns about risk-shifting and other unintended effects led the Federal Reserve in 1986 to propose replacing the leverage rule with risk-based capital requirements based on total assets, including off-balance sheet assets (Volcker 1987, Wall 1989).[6] That proposal, in cooperation with international bank regulators, evolved into the Basel I capital accord in 1990. Basel I defined standard risk weights for broad asset classes and set required capital minimums relative to risk-weighted assets. Basel II in 2004 elaborated more risk-sensitive capital requirements and allowed very large "advanced approach" firms the option of using internal models, subject to supervisory review, to estimate asset risk.

Concerns that advanced approach firms might be underestimating risk and exaggerating their capital strength, as well as the 2007-2008 financial crisis, led to the (partial) return of leverage ratios (see timeline below). In 2010, the Basel Committee recommended a new leverage rule (the Basel III leverage ratio) and U.S. regulators proposed their version—the Supplementary Leverage Ratio (SLR)—in 2012. The SLR rule requires advanced approach firms to maintain a minimum ratio of Tier 1 capital per total leverage exposures (including off-balance sheet assets) of 3 percent. The "enhanced" SLR (eSLR) rule finalized in 2014 required advanced approach firms designated as global systemically important banks (G-SIBs) to hold a minimum of 5 percent. The denominator of the SLR was finalized, after much discussion and public comment,

[6] Regulators were also concerned that banks were shifting assets off balance sheet to inflate their leverage ratio.

in September 2014—a key date in determining how binding the rule would be. Covered banks were required to begin disclosing their SLR on their Investor Relations webpages beginning January 2015.

SLR Timeline

12/2010: International (Basel) regulators propose text for LR
6/2012: U.S regulators propose SLR
7/2013: U.S. regulators finalize SLR rule; propose eSLR
4/2014: Finalize eSLR; propose revisions to SLR denominator
9/2014: SLR denominator finalized
1/2015: Mandatory disclosures SLR by covered banks
1/ 2018: SLR and eSLR compliance date

Under the new rule, the SLR is defined by

$$SLR = \frac{Tier\ 1\ Capital}{Total\ leverage\ exposure},$$

where the denominator includes both on-balance sheet assets and many off-balance sheet exposures. The risk-invariant aspect of the SLR is obvious; two banks with the same total assets (on- and off-balance sheet) face the same limit, even if one has much riskier assets than the other. By contrast, under the risk-based capital (RBC) requirement, the capital ratio is defined by

$$RBC\ ratio = \frac{Tier\ 1\ Capital}{Risk\text{−}weighted\ assets},$$

where assets are classified into risk classes with different associated risk weights for each. If two banks have the same total assets, but one has more assets in the riskier classes, its minimum required capital will be higher.

It was widely reported that the new leverage limits were *the* binding capital constraint for many banks, meaning their leverage requirement was more binding that their risk-based capital requirement (J.P Morgan 2014). Figure 2 confirms this: among the SLR banks, all had at least two percentage points of slack relative to the risk-based requirement in 2013:Q4. By contrast, eight had less than two percentage points of slack relative to their leverage requirement and six had negative slack.[7]

Banks bound by the leverage rule have two options: increase tier 1 capital or decrease total leverage exposures. If a bank chooses to raise more capital, they can offset any increased costs is by shedding safer, lower-yielding assets (passive arbitrage) and/or adding riskier, higher-yielding ones (active arbitrage). If it instead chooses to reduce its assets, the least costly way to do so would be by shedding assets with low yields, such as reserves. In both cases, the bank's share of risky assets relative to safe assets, and its average yield on assets, should rise.

III. Empirical Strategy

We test for risk shifting by SLR banks using difference-in-difference (DD) regressions:

$$\sigma_{it} = \alpha_i + \alpha_t + \beta * SLR_i + \Upsilon * post_t + \delta * SLR_i * post_t + \gamma * C_{it-1} + \varepsilon_{it}. \qquad (1)$$

The dependent variable is one of several risk measures for bank *i* at *t* (described below). The firm fixed effect (α_i) controls for constant risk differences across banks while the year-quarter fixed effect (α_t) controls for time-varying aggregate factors (macro, financial, or monetary) that might affect bank risk.

[7] We calculate the SLR before 2015 (when public disclosure) using "total exposures" from FR Y-15. We use 2013:Q4 (versus 2014:Q2) because only year-end data are available.

SLR_i equals 1 for the 15 banks subject to the rule and 0 for control banks, the 18, next-to-largest banks with assets between \$50 and \$250 billion.[8] Limiting the control group to other SIFIs limits sample size but avoids potential confounding effects from different business models and lighter regulatory treatment of banks under 50 billion, particularly their exemption from CCAR stress tests.[9] We take the SLR treatment as exogenous with respect to risk since coverage is determined entirely by bank size or foreign exposures

The $post_t$ indicator equals 0 until 2014:Q3 and 1 after. The rule was finalized in September 2014 after much back and forth between bankers and regulators over how encompassing the denominator would be i.e., which assets would be included. Bankers clearly knew the leverage rule coming before 2014:Q3 but did not know with certainty how much it would be until after.[10] The *SLR*post* coefficient equals the difference-in-difference (DD) in the risk measure. The risk-shifting hypothesis implies $\delta > 0$.

C_{it-1} denotes three bank-specific control variables, all lagged by one quarter. First is *log*(assets); controlling for size is standard in bank research but size may matter more here since the SLR banks are substantially larger than the control banks. Second is each bank's risk-based capital (RBC) ratio; shifting toward riskier assets to arbitrage the SLR would increase banks' risk-weighted assets and, given capital, reduce their RBC ratio so banks with higher RBC ratios will have more leverage arbitrage opportunities. Third is a proxy for the liquidity coverage ratio (LCR) rule at each bank. As discussed earlier, that stricter liquidity rule facing SLR banks bias our SLR effect estimates downward. Banks were not required to disclose their liquidity coverage

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8 We excluded the non-bank firms, i.e., Charles Schwab and General Electric. See Appendix A4 for a list of SLR and non-SLR banks.

9 CCAR (comprehensive capital and analysis review) stress tests covered only banks with assets above \$50 billion.

10 Anecdotally, bankers were already responding to the rule before January, 2015 disclosure date: "…banking organizations are already making changes to comply with the SLR given that the final rules require public disclosures beginning January 1, 2015." Bank of New York Mellon (2014), https://www.bnymellon.com/_global-assets/pdf/our-thinking/arriving-at-new-capital-ratios.pdf.

ratios until 2017 so as proxy for liquidity constraints under the LCR we include (inverse of) a "liquidity stress" ratio calculated by Federal Reserve Bank of New York.[11] While the assumptions and calculation underlying the proxy are intended to match the LCR, they do not fully capture the stricter rule SLR banks face so any remaining bias is likely downward.

IV. Data and Findings

We study portfolio risk measures (risk-weighted asset shares and securities yields) then overall risk measures. We first examine trends in each measure to check for pre-treatment differences, and then report DD estimates from model (1).

a. Risk-weighted Asset Shares

Risk-weighted (RW) assets equals the sum of assets across the regulatory risk classes weighted by the respective risk-factor for each class.[12] The RW asset *shares* are RW assets divided by total assets; a higher RW asset share implies a shift toward riskier assets.

We look at RW assets overall and by asset class: securities, trading assets, and loans. We expect any risk shifting to be more apparent for (more liquid) securities and trading assets than for loans.[13] Table 1 reports the mean and standard deviation of each by subsample: SLR vs. non-SLR; pre-treatment vs. and post-treatment. The unconditional difference-in-difference (DD) are

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[11]The FRBNY Research liquidity stress ratio (LSR) is defined analogously to the LCR:

$$LSR = \frac{\text{potential liquidity inflow}}{\text{potential liquidity outflow}} = \frac{\text{liquidity adjusted assets}}{\text{liquidity adjusted liabilities and off balance sheet exposures}}.$$

The liquidity adjustments reflect the estimated liquidity ("run") risk of each liability type or off-balance sheet exposure (Choi and Zhou 2016). The proxy may overestimate actual LCR slack for SLR banks because the outflow adjustments used for the LSR do not fully capture the stricter LCR outflow assumptions SLR banks.

[12] Bank holding companies report risk weighted assets in FR Y-9C, Schedule HC-R Part II.

[13] "Trading assets" includes securities bought and held "principally for the purpose of selling in the near term." "Securities" includes debt securities banks have the "positive intent" to hold to maturity and also securities that that the bank may retain for long periods but that may also be sold. See Financial Accounting Standards Board, Summary of Statement No. 115 (https://www.fasb.org/summary/stsum115.shtml).

positive and significant for total assets, securities, and trading assets. The unconditional DD for loans, by contrast, is much smaller and insignificant.

To check for any difference in trends before the SLR treatment, we plot the difference in the mean of each RW asset share (SLR banks less non-SLR banks) in Figure 3. The difference for total assets and securities is constant before 2014:Q3 implying parallel trends. The difference for trading is rising slowly pre-treatment, but increases sharply after. The difference for loans is constant throughout.

Table 2 reports the DD estimates for each RW asset share. The estimate for loans is small and insignificant, consistent with the summary statistics. The estimate for trading assets is larger (relative to its standard deviation) but also insignificant. By contrast, the estimates for total assets and securities are positive and significant at the five percent level, consistent with the risk-shifting hypothesis. The 5.4 percent estimate for securities is sizable, about one half a standard deviation in RW securities share for SLR bank over the pre-treatment period.

Although we view the SLR vs non-SLR comparison above as a more exogenous treatment assignment, we also tested if the SLR effect was larger for SLR banks more constrained by the leverage limit:

$$\sigma_{it} = \alpha_i + \alpha_t + \beta_1 * SLR\ Tighter_i * post_t + \beta_2 * SLR\ Looser_i * post_t + \gamma * C_{it-1} + \varepsilon_{it}. \quad (2)$$

where $SLR\ Tighter_i$ equals 1 for SLR banks with leverage slack (relative to required) at 2013:Q4 below the median for all SLR banks and 0 otherwise. $SLR\ Looser_i$ is defined accordingly (above median slack). Sorting by leverage *ex ante* (three quarters before the treatment) reduces endogeneity concerns. The coefficients β_1 and β_2 measure the DD in each

RW asset share for the more or less constrained SLR banks relative to non-SLR banks. We predict $\beta_1 > \beta_2 \geq 0$.

The results are reported in Table 3. *SLR Tighter* and *SLR Looser* are positive but insignificant for loans and trading assets, consistent with the main effects in Table 2. For securities, *SLR Tighter* and *SLR Looser* are both positive and significant and while the former point estimate is larger (5.9 versus 5.0) we cannot reject their equivalence by a Wald test. For total assets the results are as predicted; only *SLR Tighter* is significant, the estimate is about four times larger than for *SLR Looser* (5.3 and 1.3), and we can reject their equivalence.

We obtained a similar pattern of results after adjusting RW assets reported by banks to account for a notable change in risk-weights starting in 2015:Q1 (Table 4).[14] The DD estimate for total assets is insignificant using the adjusted risk weights but the estimate for *SLR Tighter* remain significant and about the same magnitude, consistent with risk shifting by the more constrained SLR banks. The size and significance of the estimates for securities are consistent using adjusted or unadjusted risk weights.

b. Reach for Yield?

This section studies whether the apparent shift toward riskier securities above corresponds to higher yields. Our unique data on securities yields enables us to test the "reach for yield" conjecture directly and is immune to any doubts about the risk-weights used above.

While returns on assets for banks are readily available, *ex ante* yields, a better risk measure, are not easily obtainable. We first gathered amounts of every security held by banks in our sample in a confidential report (FR Y-14Q Schedule B) filed quarterly by all banks subject to

[14] Some risk weights changed after 2015:Q1 under the transition to Basel III capital requirements. We adjusted any that changed after that to match those before as closely as possible (see Appendix A1).

Federal Reserve stress tests, i.e. Comprehensive Capital Analysis and Review. We then matched security holdings with yields from various sources, depending on the security class, e.g. Treasuries, municipal bonds, corporate bonds, agency MBS, etc.[15] Of 185,497 unique (by CUSIP) securities identified over 2011:Q3-2016:Q2, we found matching yields for 43 percent (by volume) for SLR and 40 percent for non-SLR banks. The match rates were also comparable pre and post-treatment.[16]

To study yields at the portfolio level, we first calculated weighted average yields for each security class, weighted by each security's share of a bank's holdings of that class. Then, to mitigate concerns about sample selection of matched yields, we calculate each bank's overall average yield weighted by the share of each class of securities in the full Y-14Q data set (See Appendix A3 for details).

Mean weighted average yields ("yields") for the various subsamples (winsorized at the 1st and 99th percentile) are reported in Table 5.[17] The mean overall was about two percent, reflecting the low interest rates prevailing over this period. Yields at SLR banks were lower than at non-SLR banks in both periods, but the gap narrowed markedly after the leverage rule was finalized in 2014. Figure 1 showed that the trends in yields declined in parallel before the treatment date.

Table 6 reports the combined results: the main DD estimates and the split sample estimates for *SLR Tighter* and *SLR Looser*. The main estimates imply that SLR banks narrowed the yield gap relative to non-SLR banks by 34 basis points (significant at the five percent level) after the treatment, a substantial "reach" in a low rate environment. The split sample results

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15 See Appendix A2 for details.

16 The match rates pre and post-treatment were 38 percent and 49 percent for SLR banks and 42 percent and 37 percent for non-SLR banks.

17 The pre-sample here starts two quarters later (2011:Q3) when complete Y-14Q data became available.

suggest the more constrained SLR banks were reaching more aggressively as only the estimate for *SLR Tighter (*42 basis points) is significant.

c. Robustness

Since bigger banks faced myriad new regulations since the crisis, one concern is that the evidence of risk shifting by SLR banks thus far actually reflects more general size or regulatory effects, rather than the leverage rule in particular.[18] Table 7 presents the results from three robustness tests to address those concerns.

The top panel reports results from a placebo test using the next largest set of U.S. banks; banks with assets between $10 billion and $50 billion (the cutoff for "community bank" regulatory exemptions). We divided that cohort into the 20 largest ("treated") banks with above median assets (as of 2011:Q1) and the 19 smallest ("control") banks and estimated model (1) using risk-weighted asset shares.[19] The DD estimates are either insignificant or "wrong" signed, i.e. contrary to the concern that larger banks generally, not SLR banks in particular, are shifting toward riskier assets.

The middle panel reports results of a Dodd-Frank placebo test. For this test we study banks with assets above $50 billion (as in the main results) but look for risk-shifting by banks with assets above $250 billion after the Dodd-Frank Act was signed into law but before the leverage rule was finalized in 2014. Virtually all of the regulations mandated by Dodd-Frank were size-based and some, such as the stricter liquidity rule, were triggered at $250 billion in

[18] Of course, the most notable size/regulatory difference between the SLR banks and the non-SLR control banks is the stricter liquidity rule facing the former, and that tends to attenuate the SLR effect.
[19] Security yields are not available for this set of banks. We exclude the liquidity rule proxy as banks with assets under $50 billion are not subject to that rule. We alternatively sort "treated" banks based on the $20 billion asset size threshold, which gives us 12 treated and 27 non-treated banks. Here, none of the DD estimates is significant (results available upon request).

assets. If other sized-based regulations were driving our results, we would see evidence of risk shifting after the Dodd-Frank Act was passed and before the leverage rule. In fact, we see no differential shift toward riskier (risk-weighted) assets by SLR banks (with assets above $250 billion).

The bottom panel present results when we include an additional interaction term in model (1): *Post* × *log(assets)*. That term allows for the possibility that the risk-shifting we are identifying with the leverage rule might actually reflect additional risk-taking by larger banks generally in the post-SLR period. This is fairly demanding test (since SLR treatment and bank size are highly correlated), yet the evidence of a shift to riskier, higher yield securities is qualitatively unchanged if slightly less significant.

d. Active or Passive Arbitrage?

This section investigates whether banks are merely shedding safer securities or are actively adding riskier ones. Both forms imply higher risk, but active arbitrage is an act of *commission* and may reveal something about bank culture. Stultz et al. (2017) find that while some banks arbitrage capital regulations more than others, many do not arbitrage at all, so whether SLR banks *actively* arbitrage the rule is not obvious.[20]

Our portfolio results thus far cannot distinguish active from passive arbitrage, so for this analysis we bore down to the security level and compare how holdings of the *same* security by different banks changed after the SLR rule was finalized. Including a bank-security fixed effect confers the same identification power as the bank-borrower fixed effect in Khwaja and Mian

[20] Stultz et al (2017) investigate whether (and if so, why) banks arbitrage risk-based capital requirements by issuing Trust Preferred Securities that regulators consider "low quality" capital. The recent research on leverage rule arbitrage in the repo market does not attempt to distinguish active vs passive arbitrage; those findings can be mostly explained by passive arbitrage, i.e. banks reducing low-yield, low-risk repo activity.

(2008) except here it controls for change in demand for credit by bond issuers rather than bank loan borrowers. A finding that SLR banks demanded more of a specific high-yield security than non-SLR banks suggests more active arbitrage. Security level analysis also reduces concerns that the portfolio level results merely reflect differential changes in security prices that banks are passively marking to market.[21]

The regression for this analysis is:

$$H_{sit} = \alpha_i \times \alpha_s + \alpha_i \times \alpha_t + \beta * SLR_i * Post_t * High\,Yield_{st} + \gamma * C_{it-1} + \varepsilon_{sit}, \quad (3)$$

where H_{sit} is the log of holdings of security *s* by bank *i* holdings at time. The bank-security fixed effects ($\alpha_i \times \alpha_s$) allow for correlated holdings over time by each bank while the bank-time fixed effects ($\alpha_i \times \alpha_t$) accounts for correlated holdings over time across banks (due to common changes in security values for example). We report clustered (by security) standard errors.

The indicators SLR_i and $Post_t$ are defined as before. $High\,Yield_{st}$ equals one if the yield on security *s* at *t* was in the top quartile of all yields that quarter, as in Abassi et al (2018). Since holdings and *High Yield* are both measured at quarters' end, we alternatively define *High Yield* relative to the distribution of yields the previous quarter. Allowing for slightly delayed reach for yield may actually be more plausible.

The coefficient of interest, *β,* measures the extent to which SLR banks added more high-yield securities (relative to non-SLR banks) after the leverage rule was finalized. Including a bank × security fixed effect means that *β* is identified only by differential changes in holdings of a given high-yield security. Passive arbitrage—merely shedding safer, low-yield assets—does

[21] The change in security prices would have to differ systematically across SLR banks and the control banks to explain the portfolio results. That said, even security level analysis is not entirely free of this concern because only "available-for-sales" securities are marked to market in regulatory reports. "Held-to-maturity" securities are not.

not affect β. Since passive arbitrage can explain our results thus far, we take "passive arbitrage only" ($\beta = 0$) as the null hypothesis.[22]

Figure 4 shows the trends in (normalized) mean holdings of high-yield securities for both sets of banks. Despite some volatility over the pre-treatment period, the trends look essentially parallel until a few quarters before the SLR was finalized when SLR banks began adding high-yield securities.

The results in Table 8 confirm that SLR banks added high-yield securities after the SLR was finalized. The β estimates are positive and significant (one percent level) using either *High Yield* definition (current quarter or previous). The estimate in column 2 implies holdings of high-yield securities by SLR banks increased by 7.4 percentage points relative to non-SLR banks. The effect is significant even for the less constrained, *SLR Looser* banks (column 4) but is over three times larger for the *SLR Tighter* banks. Decomposing the crossed-fixed effects into separate security, bank, and time fixed effects yields qualitatively similar results (columns 1 and 3). Defining *High Yield* alternatively relative to the yields the quarter before holdings are measured accentuates the differences between SLR Tighter and SLR Looser (columns 7 and 8).

e. Overall Bank Risk

While the leverage rule may have tilted banks toward riskier assets, the effect on overall risk is theoretically ambiguous as banks may also be less levered than they would have been otherwise. In the model in Acosta Smith et al (2017), the latter effect—greater loss absorbency—dominates the risk shifting, so the leverage limit makes banks more stable on net.

[22] While β could be positive if non-SLR banks simply shed high-yield securities without SLR banks actually adding them, Figure 4 suggests SLR banks were in fact adding high-yield securities.

This section tests how overall measures of bank risk changed at SLR banks. We study three book measures: ROA, ROA volatility, and Z scores; and four market measures: equity volatility, CDS spreads, implied volatility, and put option delta. The market measures and Z scores (an inverse risk measure) should reflect both asset risk and leverage. Sources and calculation of these variables are standard (see Appendix A2 for details).[23]

Summary statistics are reported in Table 9. The unconditional DD are mixed, with significantly positive estimates for ROA, ROA volatility, and CDS spreads and significantly negative estimates for Z scores and equity volatility.

The conditional DD reported in Table 10 Panel A are nearly all insignificant. The only significant estimate is for CDS spread. Panel B reports estimates where we divide SLR banks by tightness of the leverage limit. Equity volatility actually declined more for the more constrained SLR banks (-0.23 and significant vs. -0.04 and insignificant). The only other significant result in Panel B is the positive estimate for CDS for less constrained SLR banks. Since the corresponding estimate for more constrained SLR banks is less than half as large (0.26 vs. 0.51) and insignificant, that single result does not suggest higher overall risk.

f. How Did Leverage Change?

If SLR banks sidestepped the rule by tilting toward riskier assets, why did overall risk *not* rise? Perhaps because banks strictly constrained by the rule that choose not to shrink assets also had to increase capital. Figure 5 shows that the trend in (inverse) leverage at the most

[23] The book risk measures (ROA, ROA volatility, and Z score) are calculated from banks' Y-9C reports. Equity volatility equals the quarterly standard deviation of the log of daily difference in stock price. Implied volatilities (on a 50% out-of-the-money option that expires in 1 year) for each entity-quarter are pulled from Bloomberg; together with Treasury rates data from FRED these are also used to calculate implied deltas using the Black-Scholes formula. Banks' 5-year CDS spreads are from Markit.

constrained SLR-banks paralleled the trend at less constrained SLR banks and non-SLR banks until 2015, when more constrained SLR banks started deleveraging markedly. The shift commenced in 2015:Q1, the SLR disclosure date.

In Table 11, we report leverage summary statistics. Both SLR and non-SLR banks increased leverage ratios (i.e. de-levered) over the sample period, but this is more pronounced at SLR banks. Table 12 shows that the conditional DD in the leverage ratio at SLR banks was 0.83, and the estimate is twice as large (and significantly different) at *SLR Tighter* banks (1.17 versus 0.55). This confirms that the leverage rule was associated with de-levering by SLR banks, which may have offset the risk-shifting induced by the rule, thus leaving overall risk unchanged.

V. Conclusion

Leverage rules are supposed to limit bank risk but could increase it if banks sidestep the rule by shifting to riskier assets. Though as old as leverage limits themselves, that conjecture is relatively untested as previous U.S. leverage rules applied universally to all banks and were rarely binding. The SLR requirement, by contrast, applies only to the very largest U.S. banks and is tightly binding for some, affording an opportunity to revisit that question.

Our evidence is consistent with the risk-shifting conjecture but not the perverse consequences. Banks subject to the new rule, particularly those most bound by it, appear to have rebalanced their portfolios toward riskier, higher yielding securities. We find no evidence of higher overall bank risk, however, even at the most constrained banks, suggesting that the higher capital required under the new rule offsets the effect from the shift to riskier assets, or vice-versa. While other recent studies have found consistent evidence in the repo market, ours suggests broader, active arbitrage with banks adding riskier securities rather than passively shedding safer ones.

Big banks faced many new regulations since the crisis, of course, so it is possible that the risk shifting we are identifying with the leverage rule is confounding the effects of some other regulatory change. With that caveat in mind, the findings here and in other studies suggest that regulators' concerns that the leverage rule was distorting banks' portfolio decisions in unintended, undesirable ways were not unjustified.[24]

[24] See https://www.federalreserve.gov/newsevents/pressreleases/bcreg20180411a.htm

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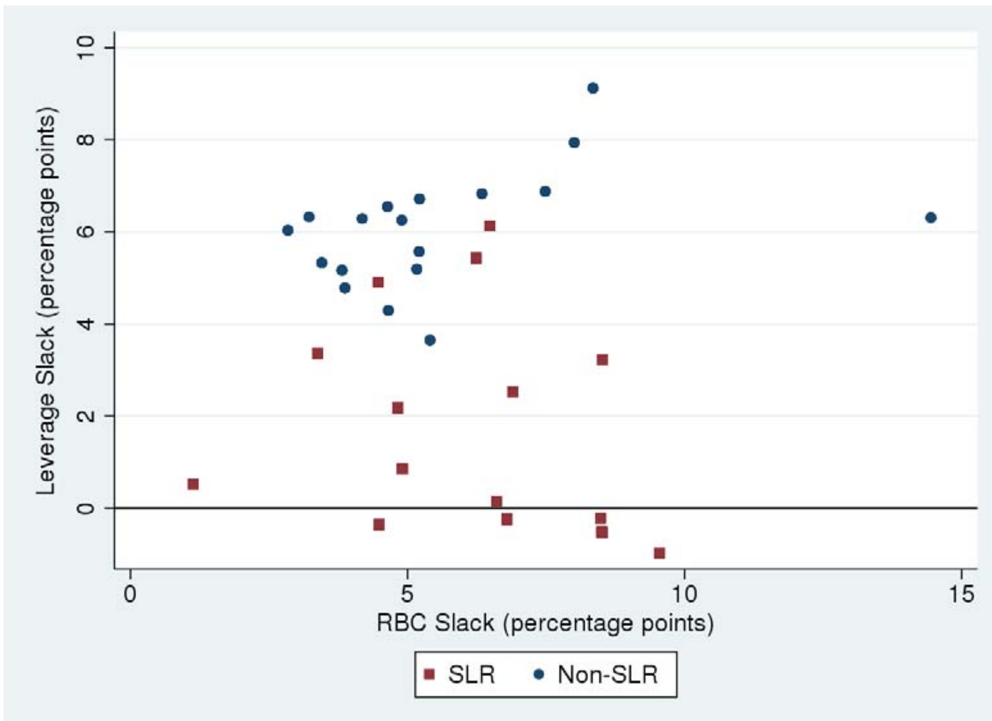
Figures and Tables

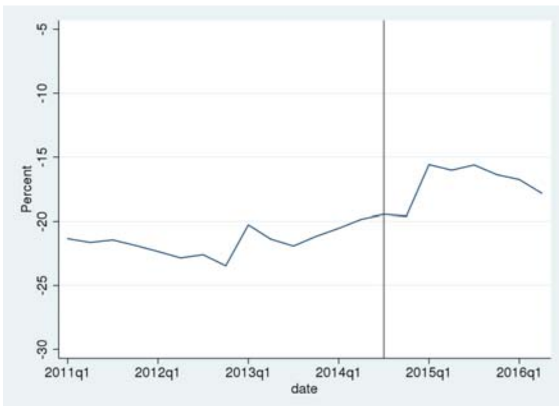
Figure 2: Leverage Ratio More Binding than Risk-Based Capital Ratio.



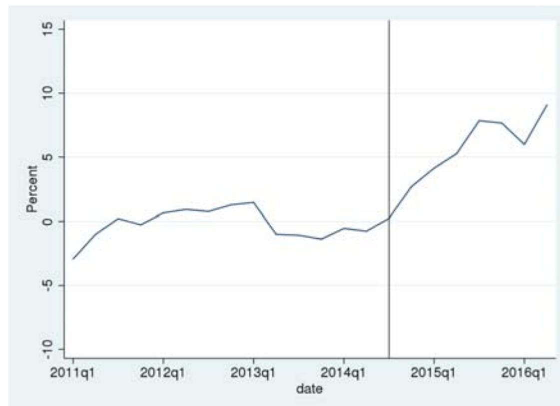
Note: SLR banks are the 15 banks with at least $250 billion in total assets or $10 billion in foreign exposures. Non-SLR banks are the next-largest 18 banks with $50 to $250 billion in total assets. Leverage slack = leverage ratio at 2013:Q4 less required minimum. For non-SLR banks, leverage requirement is tier 1 capital/total assets $\geq$ 4 percent. For SLR banks, requirement is tier 1 capital/total leverage exposures $\geq$ 3 percent (5 percent for G-SIBs). RBC Slack = tier 1 capital/RWA at 2013:Q4 less required minimum (6 percent); see https://www.occ.gov/newsissuances/ news-releases/2013/2013-110a.pdf

Figure 3: Difference in risk-weighted asset shares, SLR less non-SLR, by asset type.

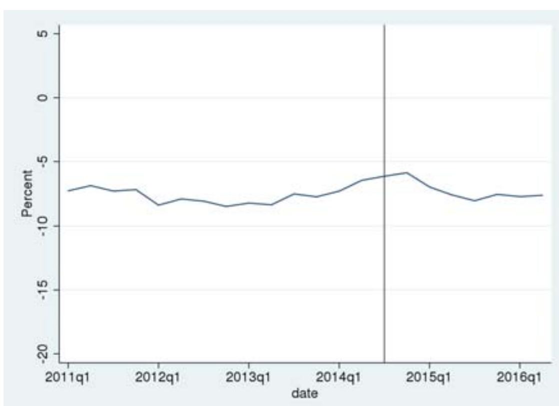
Panel A: Total Assets



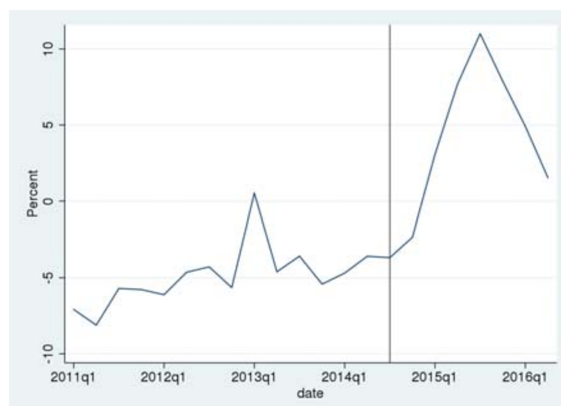
Panel B: Securities



Panel C: Loans



Panel D: Trading Assets



Note: SLR banks are the 15 banks with at least \$250 billion in total assets or \$10 billion in foreign exposures. Non-SLR banks are the next-largest 18 banks with \$50 to \$250 billion in total assets. To check for parallel trends pre-treatment (2014:Q3), we plot the mean difference (SLR − non-SLR) in each outcome in each period. Vertical line at treatment date.

Figure 4: Share of High Yield Securities Holdings for SLR and Non-SLR Banks

Note: SLR banks are the 15 banks with at least $250 billion in total assets or $10 billion in foreign exposures. Non-SLR banks are the next-largest 18 banks with $50 to $250 billion in total assets. To check for parallel trends pre-treatment (2014:Q3), we plot the aggregate share of high yield securities holdings for each group of banks in each period. "High Yield" denotes the security is in the top quartile of yields in the current quarter. Percentage point deviation normalized to 0 at 2014:Q2. Vertical line at treatment date.

Figure 5: Mean leverage ratio by bank type

Note: SLR banks are the 15 banks with at least $250 billion in total assets or $10 billion in foreign exposures. Non-SLR banks are the next-largest 18 banks with $50 to $250 billion in total assets. *SLR Tighter* indicates that the SLR slack was below median among the SLR banks in 2013:Q4; *SLR Looser* is above median. Leverage ratio = tier 1 capital divided by total assets. Vertical line at treatment date (2014:Q3).

Table 1: Means of Risk-Weighted Asset Shares, By Subsample

	SLR		Non-SLR		Diff-in-diff
	(1) Post	(2) Pre	(3) Post	(4) Pre	(5) [(1) − (2)] − [(3) − (4)]
Total Assets	63.36	59.12	80.50	80.39	4.14***
	(13.85)	(16.00)	(12.17)	(9.57)	
Securities	21.34	23.79	15.92	23.84	5.46***
	(8.38)	(10.78)	(5.44)	(11.79)	
Trading Assets	16.85	9.38	12.98	11.34	5.31***
	(28.01)	(24.90)	(15.30)	(14.03)	
Loans	83.24	80.91	90.45	88.54	0.42
	(9.38)	(11.60)	(4.94)	(5.37)	
Observations	120	210	144/128[1]	252/238[2]	

Note: Risk-weighted share equals risk-weighted x per total x for each asset class (x). Standard deviations in parentheses. All shares are winsorized at the 1% and 99% levels. *Pre*: 2011:Q1 to 2014:Q2; *Post*: 2014:Q3 to 2016:Q2.
*, **, and *** indicate significance at the 10%, 5%, and 1% level, per t-test.
[1]128 observations for trading assets; 144 for all others. [2]238 observations for trading assets; 252 for all others.

Table 2: Difference-in-Differences in Risk-weighted Asset Shares

	(1) Total Assets	(2) Securities	(3) Trading Assets	(4) Loans
SLR Bank × Post	3.14**	5.42**	6.52	0.07
	(1.22)	(2.63)	(5.06)	(1.51)
Observations	684	684	634	684
R-Squared	0.97	0.66	0.78	0.91

Note: Reported are OLS estimates of δ from model (1) using panel data on all banks with at least $50 billion in assets over 2011:Q1 to 2016:Q2. Robust, clustered (by bank) standard errors are in parenthesis. *Post* indicates post-SLR treatment (2014:Q3); *SLR* indicates treated banks (firms with at least $250 billion in assets or over $10 billion in foreign exposures). The regression model includes log assets, the risk-based capital ratio, and a proxy for the liquidity coverage rule exposure (all lagged one quarter) and fixed effects (bank and year-quarter). Dependent variables are winsorized at the 1% and 99% levels.
*, **, and *** indicate significance at the 10%, 5%, and 1% level.

Table 3: Difference-in-differences in Risk-Weighted Asset Shares by SLR "Tightness"

	(1) Total Assets	(2) Securities	(3) Trading Assets	(4) Loans
SLR Tighter × Post	5.31***	5.90*	4.15	0.07
	(1.30)	(2.97)	(4.38)	(3.23)
SLR Looser × Post	1.31	5.00*	8.34	0.06
	(1.37)	(2.64)	(7.13)	(0.85)
Observations	684	684	634	684
R-Squared	0.97	0.66	0.78	0.91
F-test p-value	0.01	0.65	0.56	1.00

Note: Reported are OLS estimates of β_1 and β_2 from model (2) using panel data on all banks with at least $50 billion in assets over 2011:Q1 to 2016:Q2. Robust, clustered (by bank) standard errors are in parenthesis. *Post* indicates post-SLR treatment (2014:Q3); *SLR* indicates treated banks (firms with at least $250 billion in assets or over $10 billion in foreign exposures). *SLR Tighter* indicates that the SLR slack was below median among the SLR banks in 2013:Q4; *SLR Looser* is above median. The Wald test p-value of the equivalence of the two coefficients is reported in the last row. The regression model includes log assets, the risk-based capital ratio, and a proxy for the liquidity coverage rule exposure (all lagged one quarter) and fixed effects (bank and year-quarter). Dependent variables are winsorized at the 1% and 99% levels.
*, **, and *** indicate significance at the 10%, 5%, and 1% level.

Table 4: Difference-in-Differences in Adjusted Risk-weighted Asset Shares

	Total Assets		Securities		Trading Assets		Loans	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SLR Bank × Post	1.47		5.83**		8.36*		0.19	
	(3.15)		(2.66)		(4.84)		(1.44)	
SLR Tighter × Post		5.65**		5.86*		5.83		0.24
		(2.31)		(3.02)		(3.88)		(3.05)
SLR Looser × Post		-2.06		5.81**		10.30		0.14
		(4.28)		(2.70)		(7.03)		(0.86)
Observations	684	684	684	684	634	634	684	684
R-Squared	0.83	0.84	0.67	0.67	0.80	0.80	0.92	0.92
F-test p-value		0.05		0.98		0.52		0.97

Note: Reported in odd-numbered columns are OLS estimates of δ from model (1) using panel data on all banks with at least $50 billion in assets over 2011:Q1 to 2016:Q2. Reported in even-numbered columns are OLS estimates of β_1 and β_2 from model (2) using the same panel. Robust, clustered (by bank) standard errors are in parenthesis. Risk-weighted asset shares are adjusted to create a consistent time series after a reporting change affected risk weights in 2015:Q1. *Post* indicates post-SLR treatment (2014:Q3); *SLR* indicates treated banks (firms with at least $250 billion in assets or over $10 billion in foreign exposures). *SLR Tighter* indicates that the SLR slack was below median among the SLR banks in 2013:Q4; *SLR Looser* is above median. The Wald test p-value of the equivalence of the two coefficients is reported in the last row. The regression model includes log assets, the risk-based capital ratio, and a proxy for the liquidity coverage rule exposure (all lagged one quarter) and fixed effects (bank and year-quarter). Dependent variables are winsorized at the 1% and 99% levels.
*, **, and *** indicate significance at the 10%, 5%, and 1% level.

Table 5: Means of Weighted Average Security Yield, By Subsample

	SLR		Non-SLR		Diff-in-diff
	(1) Post	(2) Pre	(3) Post	(4) Pre	(5) $[(1)-(2)]-[(3)-(4)]$
Average Securities Yield	2.08	2.24	2.20	2.61	0.28^{***}
	(0.79)	(0.84)	(0.46)	(0.61)	
Observations	108	145	140	114	507

Note: The weighted average yield is calculated by first obtaining (for each asset class) the average yield weighted by the amount of the bank's holding in that class. Then the overall average is obtained by weighting by the amount of holdings in each asset class in the original Y-14Q. See Appendix A1 for details. Standard deviations in parentheses. Yield is winsorized at the 1% and 99% levels. *Pre*: 2011:Q3 to 2014:Q2; *Post*: 2014:Q3 to 2016:Q2.
*, **, and *** indicate significance at the 10%, 5%, and 1% level, per t-test.

Table 6: Difference-in-differences in Weighted Average Yield of the Securities Portfolio

	(1)	(2)
SLR Bank × Post	0.34^{**}	
	(0.15)	
SLR Tighter × Post		0.42^{*}
		(0.24)
SLR Looser × Post		0.26
		(0.16)
Observations	467	467
R-Squared	0.85	0.85
F-test p-value		0.55

Note: Reported in column (1) are OLS estimates of δ from model (1) using panel data on all banks with at least \$50 billion in assets over 2011:Q3 to 2016:Q2. Reported in column (2) are OLS estimates of β_1 and β_2 from model (2) using the same panel. Robust, clustered (by bank) standard errors are in parenthesis. *Post* indicates post-SLR treatment (2014:Q3); *SLR* indicates treated banks (firms with at least \$250 billion in assets or over \$10 billion in foreign exposures). *SLR Tighter* indicates that the SLR slack was below median among the SLR banks in 2013:Q4; *SLR Looser* is above median. The Wald test p-value of the equivalence of the two coefficients is reported in the last row. The weighted average yield is calculated by first obtaining (for each asset class) the average yield weighted by the amount of the bank's holding in that class. Then the overall average is obtained by weighting by the amount of holdings in each asset class in the original Y-14Q. The regression model includes log assets, the risk-based capital ratio, and a proxy for the liquidity coverage rule exposure (all lagged one quarter) and fixed effects (bank and year-quarter). Dependent variables are winsorized at the 1% and 99% levels.
*, **, and *** indicate significance at the 10%, 5%, and 1% level.

Table 7: Placebo and Robustness Tests

Placebo Test: Bank Assets Between \$10 and \$50 Billion; "Treated" Banks Above Median Assets				
	(1) Total Assets	(2) Securities	(3) Trading Assets	(4) Loans
"Treated Bank" × Post	-2.82*	-1.33	7.90	1.13
	(1.67)	(1.91)	(17.25)	(1.08)
Observations	742	742	533	742
R-Squared	0.93	0.83	0.79	0.94

Note: "Treated Banks" have assets above \$15 billion. We also omit the LCR proxy control.

Placebo Test: Dodd-Frank Treatment (2010:Q3) for Banks Above \$50 Billion in Assets				
	(1) Total Assets	(2) Securities	(3) Trading Assets	(4) Loans
SLR Bank × Post DF	-2.34	2.81	-0.19	1.61
	(1.69)	(2.51)	(2.17)	(1.18)
Observations	607	606	561	607
R-Squared	0.96	0.79	0.87	0.95

Note: Sample 2009:Q3 to 2014:Q2.

Robustness Test: Including Post × log(Assets)					
	(1) Total Assets	(2) Securities	(3) Trading Assets	(4) Loans	(5) Securities Yield
SLR Bank × Post	1.22	4.18*	2.81	-0.58	0.35
	(1.59)	(2.09)	(7.87)	(1.70)	(0.21)
Observations	684	684	634	684	467
R-Squared	0.97	0.66	0.78	0.91	0.86

Note: The sample includes banks above \$50 billion in assets over 2011:Q1 to 2016:Q2 and we use the SLR treatment date (2014:Q3). We include Post × log(assets) as an additional control.

Note: The above panels present the main model in Table 2 with separate modifications. In all panels, dependent variables are winsorized at the 1% and 99% levels.
*, **, and *** indicate significance at the 10%, 5%, and 1% level.

Table 8: SLR Banks Increased Holdings of High-Yield Securities

	High Yield Definition:							
	Current Quarter				Previous Quarter			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SLR Bank × Post × High Yield	0.028*	0.074***			0.031**	0.070***		
	(0.016)	(0.016)			(0.014)	(0.014)		
SLR Tighter × Post × High Yield			0.080***	0.132***			0.097***	0.147***
			(0.026)	(0.027)			(0.023)	(0.024)
SLR Looser × Post × High Yield			0.005	0.038***			-0.000	0.020*
			(0.014)	(0.014)			(0.012)	(0.012)
Security, Bank, Time FE	Yes	No	Yes	No	Yes	No	Yes	No
Bank × Security FE	No	Yes	No	Yes	No	Yes	No	Yes
Bank × Time FE	No	Yes	No	Yes	No	Yes	No	Yes
Observations	748377				722325			
R-Squared	0.996	0.996	0.996	0.996	0.996	0.997	0.996	0.997
F-test p-value			0.001	0.000			0.000	0.000

Note: Reported are OLS estimates of β from model (3) using panel data on security holdings of all banks with at least $50 billion in assets over 2011:Q3 to 2016:Q2. Robust, clustered (by security) standard errors are in parenthesis. *Post* indicates post-SLR treatment (2014:Q3); *SLR* indicates treated banks (firms with at least $250 billion in assets or over $10 billion in foreign exposures). *SLR Tighter* indicates that the SLR slack was below median among the SLR banks in 2013:Q4; *SLR Looser* is above median. The Wald test p-value of the equivalence of the two coefficients is reported in the last row. "High Yield" is an indicator for whether the security is in the fourth quartile of yields of the current quarter or the previous quarter. The regression model includes log assets, the risk-based capital ratio, and a proxy for the liquidity coverage rule exposure (all lagged one quarter) and fixed effects (different sets depending on the specification). Dependent variables are winsorized at the 1% and 99% levels.
*, **, and *** indicate significance at the 10%, 5%, and 1% level.

Table 9: Means (Standard Deviations) of Overall Risk Measures, By Subsample

	SLR		Non-SLR		Diff-in-diff
	(1)	(2)	(3)	(4)	(5)
	Post	Pre	Post	Pre	$[(1)-(2)]-[(3)-(4)]$
Z Score	139.76	94.90	160.53	92.11	-23.55***
	(55.94)	(40.94)	(53.42)	(30.28)	
Equity volatility	1.49	1.68	1.62	1.65	-0.17***
	(0.16)	(0.34)	(0.15)	(0.31)	
5-year CDS spread	0.71	1.22	1.11	1.83	0.12***
	(0.18)	(0.47)	(0.57)	(0.84)	
Implied vol.	38.54	45.87	38.08	45.47	-0.60
	(2.54)	(4.00)	(3.22)	(7.59)	
Put option Delta	-0.02	-0.07	-0.02	-0.07	-0.00
	(0.01)	(0.01)	(0.01)	(0.02)	
Observations (see note)					

Note: Equity volatility equals the quarterly standard deviation of the log difference in daily stock price for public firms. Implied volatilites are on a 50% out-of-the-money option that expires in 1 year. Implied deltas are calculated using the Black-Scholes formula. All variables are winsorized at the 1% and 99% levels. *Pre*: 2011:Q1 to 2014:Q2; *Post*: 2014:Q3 to 2016:Q2.
*, **, and *** indicate significance at the 10%, 5%, and 1% level, per t-test.

Number of observations by column and variable:
Column 1: 120 obs. for Z score; 104 otherwise.
Column 2: 210 obs. for Z score; 196 for 5-year CDS spread; 182 otherwise.
Column 3: 144 obs. for Z score; 88 for 5-year CDS spread; 96 otherwise.
Column 4: 252 obs. for Z score; 154 otherwise.

Table 10: Difference-in-Differences in Overall Risk Measures

	Panel A: Difference-in-differences				
	Book Risk	Market Risk			
	(1) Zscore	(2) Equity Volatility	(3) 5-year CDS Spread	(4) Implied Vol.	(5) Put Option Delta
SLR Bank × Post	-21.97	-0.11	0.40*	1.28	-0.01
	(35.31)	(0.08)	(0.20)	(1.47)	(0.00)
Observations	550	500	492	487	487
R-Squared	0.46	0.89	0.76	0.88	0.95

	Panel B: Difference-in-differences by SLR "Tightness"				
	Book Risk	Market Risk			
	(1) Zscore	(2) Equity Volatility	(3) 5-year CDS Spread	(4) Implied Vol.	(5) Put Option Delta
SLR Tighter × Post	-43.48	-0.23***	0.26	0.94	-0.00
	(30.42)	(0.08)	(0.23)	(1.62)	(0.00)
SLR Looser × Post	-3.99	-0.04	0.51**	1.52	-0.01*
	(43.98)	(0.08)	(0.21)	(1.54)	(0.00)
Observations	550	500	492	487	487
R-Squared	0.46	0.89	0.77	0.88	0.95
F-test p-value	0.25	0.04	0.21	0.62	0.30

Note: Reported in Panel A are OLS estimates of δ from model (1) using panel data on all banks with at least $50 billion in assets over 2011:Q1 to 2016:Q2. Reported in Panel B are OLS estimates of β_1 and β_2 from model (2) using the same panel. Robust, clustered (by bank) standard errors are in parenthesis. *Post* indicates post-SLR treatment (2014:Q3); *SLR* indicates treated banks (firms with at least $250 billion in assets or over $10 billion in foreign exposures). *SLR Tighter* indicates that the SLR slack was below median among the SLR banks in 2013:Q4; *SLR Looser* is above median. The Wald test p-value of the equivalence of the two coefficients is reported in the last row. The regression model includes log assets, the risk-based capital ratio, and a proxy for the liquidity coverage rule exposure (all lagged one quarter) and fixed effects (bank and year-quarter). Dependent variables are winsorized at the 1% and 99% levels. *, **, and *** indicate significance at the 10%, 5%, and 1% level.

Table 11: Means (Standard Deviations) of Leverage Ratio, By Subsample

	SLR Banks		Non-SLR Banks		Diff-in-diff
	(1) Post	(2) Pre	(3) Post	(4) Pre	(5) $[(1)-(2)]-[(3)-(4)]$
Leverage Ratio	8.54	7.61	10.17	9.87	0.62^{***}
	(1.73)	(1.74)	(1.35)	(1.52)	
Observations	120	210	145	260	726

Note: Leverage ratio is calculated as tier 1 capital divided by total assets. Data are collected from the Y-9C. *Pre*: 2011:Q1 to 2014:Q2; *Post*: 2014:Q3 to 2016:Q2.
*, **, and *** indicate significance at the 10%, 5%, and 1% level, per t-test.

Table 12: Difference-in-differences in Leverage Ratio

	(1) Leverage Ratio	(2) Leverage Ratio
SLR Bank × Post	0.83^{***}	
	(0.27)	
SLR Tighter × Post		1.17^{***}
		(0.28)
SLR Looser × Post		0.55^{*}
		(0.31)
Observations	684	684
R-Squared	0.91	0.91
F-test p-value		0.05

Note: Reported in column (1) are OLS estimates of δ from model (1) using panel data on all banks with at least $50 billion in assets over 2011:Q3 to 2016:Q2. Reported in column (2) are OLS estimates of β_1 and β_2 from model (2) using the same panel. Robust, clustered (by bank) standard errors are in parenthesis. *Post* indicates post-SLR treatment (2014:Q3); *SLR* indicates treated banks (firms with at least $250 billion in assets or over $10 billion in foreign exposures). *SLR Tighter* indicates that the SLR slack was below median among the SLR banks in 2013:Q4; *SLR Looser* is above median. The Wald test p-value of the equivalence of the two coefficients is reported in the last row. The leverage ratio is calculated as tier 1 capital divided by total assets. The regression model includes log assets, the risk-based capital ratio, and a proxy for the liquidity coverage rule exposure (all lagged one quarter) and fixed effects (bank and year-quarter). Dependent variables are winsorized at the 1% and 99% levels.
*, **, and *** indicate significance at the 10%, 5%, and 1% level.

Appendices

A1: Adjusted risk-weights

Starting 2015 Q1, banks commenced reporting regulatory capital based on the new capital rule adopted by the federal banking agencies. The changes include components of regulatory capital (Schedule HC-R, Part I) and reporting of risk-weighted assets (Schedule HC-R, Part II).[1] The rule also revised certain risk-weights, so risk-weighted assets under the new rule are not necessarily comparable to those under the old rule.

To enable such comparisons, we adjusted the data by (in brief) (1) applying previous risk-weights to assets using the revised risk-weights; (2) merging securitization exposures with balance sheet assets; (3) excluding off-balance sheet exposures that weren't previously included in total risk-weighted assets. Note that these adjustments are approximations, as for certain exposures banks simply report "risk-weighted asset amount" for which we can't infer the underlying risk-weights applied.

Below is a detailed summary of the adjustments:

(1) Replace revised risk-weights with the closest risk-weight used prior to 2015Q1.
- Columns D (2%) and E (4%) are merged into column C (0%)
- Column J (150%) is merged into column I (100%)
- Columns L,M,N (300, 400, 600%) are assumed to be with 200% risk weights

(2) Merge "securitization exposures" into "Balance Sheet Assets"

This revision mostly affects our measurement of risk-weighted securities and risk-weighted trading assets. The new rule applies a different formula to calculate risk-weights for securitization exposures and requires separate reporting from balance sheet assets. We add them into balance sheet assets, while there still remains an issue of different methods used for these exposures.

(3) Exclude off-balance sheet exposures that weren't previously included in total risk-weighted assets

- Unused commitment with maturity less than 1 year (item 18a)
- Unsettled transactions (item 22)

[1] See https://www.ffiec.gov/pdf/FFIEC_forms/FFIEC031_FFIEC041_20150225_Presentation.pdf for the summary of changes

A2: Data Sources and Calculations

Variable	Source and Calculation
Risk-weighted asset shares	*Source*: FR Y-9C Consolidated Financial Statements for Holding Companies for each quarter from 2011:Q1 to 2016:Q2. *Calculation*: Holdings in each risk-weight bucket are reported. RWA for each category (total assets, securities, trading assets, and loans) is calculated as the sum of the holdings weighted by the risk weights. This is then divided by total holdings in the category to obtain the risk-weighted asset share
Securities holdings and yields	*Source*: FR Y-14Q Capital Assessments and Stress Testing reports for each quarter from 2011:Q3 to 2016:Q2. Yields are collected from sources listed below and collected nearest to quarter-end to match the reporting cycle of the Y-14.
MBS yields	*Source*: Calculated from prices and maturities reported in the Y-14. *Calculation*: Using Securities Industry Financial Markets Association (SIFMA) standard formulas.
Treasuries yields	*Source*: The Center for Research in Security Prices (CRSP) database.
Municipal bond yields	*Source*: The Municipal Securities Rulemaking Board (MSRB). In periods where these are unavailable, the reported yield in the Y-14 is used.
Corporate bond yields and yields on structured products (e.g. AMBS, CDO)	*Source*: OneTick One Market Data.
ROA	*Source*: FR Y-9C Consolidated Financial Statements for Holding Companies
ROA volatility	*Calculation*: The rolling four-quarter standard deviation excluding quarters where pre- and post-treatment dates overlap
Z Score	*Source*: Components collected from the FR Y-9C. *Calculation*: Standard formula.
Equity volatility	*Source*: Stock prices for publicly traded firms are collected from CRSP *Calculation*: For each quarter, the standard deviation of the daily difference

	in the stock price.
Implied volatilities	*Source*: Bloomberg; implied volatilities on a 50% out-of-the-money option that expires in 1 year
Treasury rates	*Source:* Federal Reserve Economic Data (FRED).
Implied deltas	*Calculation*: Standard calculation using the Black-Scholes formula along with the implied volatilities and treasury rates defined above.
CDS spreads	*Source*: 5-year CDS spreads are collected from Markit.
SLR	*Source*: Actual SLR gathered from banks' investor relations sites beginning in 2015:Q1. Prior to this, computed as total assets divided by total exposures (collected from the FR Y-15 Banking Organization Systemic Risk Report).
Capital ratio and log assets controls	*Source*: FR Y-9C.
LCR proxy	*Source*: FRBNY Research calculation *Calculation*: The inverse of the LSR, where $LSR = \frac{\text{potential liquidity inflow}}{\text{potential liquidity outflow}} = \frac{\text{liquidity adjusted assets}}{\text{liquidity adjusted liabilities and off balance sheet exposures}}$

A3: Constructing *Average Securities Yield*

Calculating the weighted average yield by combining all asset types may skew the average yield due to differences in asset class composition between our matched sample and the full Y-14 data. To mitigate this concern, we construct the weighted average yield in a two-step process. First, for each bank-quarter, within each asset class[2] we calculate the value-weighted average yield, i.e. weighted by the market value of each security in the class. We then weight the weighted average yield for each class by the value share the asset class represents within the bank-quarter in the overall Y-14 data.

For example, suppose a bank's securities portfolio in a given quarter, as reported in the Y-14, is composed of 10% corporate bonds and 90% Treasuries by value. Suppose the value-weighted average yield of corporate bonds in our sample is 4% and that of Treasuries is 2%. Then our final yield would be:

$$(0.1 \times 4\%) + (0.9 \times 2\%) = 2.2\%.$$

The following notation formalizes this calculation. For each security *s*, asset class *c*, bank *b*, and quarter *t*, we first calculate the sum:

$$\sum_{s} r_{scbt} \times v_{scbt} = w_{cbt}$$

where *r* is the security's yield and *v* is the ratio of the security's market value to the total market value of asset class *c*. Thus, *w* is the value-weighted average yield for each asset class *c*. Then, we calculate the sum:

$$\sum_{c} w_{cbt} \times k_{cbt} = y_{bt}$$

where *k* is the share of the bank's portfolio belonging to class *c* as reported in the Y-14. Thus, y_{bt} is our final bank-quarter weighted average yield observation.

[2] The asset classes are: Agency MBS; Auction Rate Securities; Auto ABS; CDO; CLO; CMBS; Common Stock (Equity); Corporate Bond; Covered Bond; Credit Card ABS; Domestic Non-Agency RMBS (incl HEL ABS); Foreign RMBS; Municipal Bond; Other ABS (excl HEL ABS); Preferred Stock (Equity); Sovereign Bond; Student Loan ABS; US Treasuries & Agencies; and Other.

A4: List of SLR and Non-SLR Banks

SLR Banks	**Non-SLR Banks**
American Express	Ally Financial
Bank of America	Bancwest Corp.
Bank of NY Mellon	BB&T Corp.
Capital One	BBVA Compass
Citigroup	Bank of Montreal F&C
Goldman Sachs	Citizens Financial Group
HSBC North America	Comerica
J.P. Morgan Chase & Co.	Deutsche Bank Trust Corp.
Morgan Stanley	Discover Financial Services
Northern Trust Corp.	Fifth Third Bank
PNC Financial Services	Huntington Bankshares
State Street	Keycorp
T.D. Bank U.S. Holding Co.	M&T Bank Corp.
U S BC	MUFG Americas Holding Corp.
Wells Fargo	Regions Financial Corp.
	Santander Holdings USA
	Suntrust Bank
	Zions Bank