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Banks' Search for Yield in the Low Interest Rate Environment: A Tale of Regulatory Adaptation

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Abstract

This paper examines whether the low interest rate environment that has prevailed since the Great Recession has compelled banks to reach for yield. It is important to recognize that banks can take on a variety of risks that offer higher yields today but incur different forms of future losses. Some losses, such as mark-to-market losses due to yield increases, can be avoided with accounting treatments whereas others, chiefly credit losses, cannot. A simple model shows that a bank's incentive to take on risks for which potential future losses can be managed, such as interest rate risk, is countercyclical, especially if a bank is capital constrained. This study thus focuses on a bank's exposure to interest rate risk through a maturity mismatch between its assets and liabilities. It finds evidence that the banks that faced less enhanced regulation after the financial crisis, especially those institutions used to having a higher net interest margin before the crisis, took on assets with longer maturities or prepayment risk, even while their source of funding shifted toward more transaction and saving deposits as a result of the near zero short-term interest rates. In contrast, those banks designated as systematically important and thus subjected to expanded post-crisis regulations have substantially shortened the average maturity of their assets since the crisis. There is some evidence that greater maturity mismatch is slightly more associated with a higher net interest margin during the post-crisis years. After the taper tantrum in 2013, these two groups of banks also adjusted their securities holdings in different ways, consistent with the differential regulatory accounting treatment.

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I. Introduction

A growing number of studies explore the notion that financial firms have an incentive to hold assets that yield a higher current income, but these returns come at the expense of incurring greater expected losses in the future.[1] This practice is the so-called reaching-for-yield behavior, which is understood to mean that the actual return, when adjusted for the true risk, is not as high as it seems. In other words, the firm's actual risk is underestimated. This distortion arises because in the real world the measurement of risk is seldom precise, due to a wide array of frictions such as imperfect information.

Banks are compensated primarily through the net interest margin (NIM)—the difference between the return earned on their investments and the return paid to their depositors and other creditors—by carrying out maturity transformations and channeling funds from savers to firms or individuals making investments. Reaching for yield thus means that banks maximize the yield spread without paying adequate regard to risk, either by obtaining a higher return on their asset holdings, by paying a lower return to their creditors, or by engaging in both practices.[2] In the post-crisis environment when short-term nominal interest rates are near zero, banks can hardly lower the rates paid to their depositors, especially since the bound of zero rate stems from the option of holding cash, which is a particularly relevant consideration for retail depositors.[3] Under such circumstances, banks would need to try earning higher yields on their assets, which can only be achieved by taking on more risk.

Banks can invest in a diverse array of assets and thus gain exposure to a range of risks. Some risks, such as credit risk, can result in explicit losses down the road, whereas other risks, such as prepayment risk or even interest rate risk, do not necessarily entail explicit future losses. It is important to point out that the distortion for risk taking can be especially subtle when it comes to risks that do not necessarily create outright losses in the future, at least under specific accounting treatments, such as recording securities classified as held-to-maturity (HTM) at an amortized cost, an accounting practice which allows banks not to recognize declines in market values when interest rates rise. Whether or not a loss is recognized on the bank's balance sheet, the fall in market value represents a true economic loss: the lower asset price reflects the fact that the opportunity cost of funds has risen and that these securities are

[1] See, for example, Becker and Ivashina (2015); Aramonte, Lee, and Stebunovs (2015).

[2] A bank can also achieve wider spreads by increasing its market power in both the loan and the deposit markets, through acquisitions or mergers, for example. This is not the distortion studied here.

[3] A few foreign central banks (such as the European Central Bank) lowered their policy rates to below zero, but so far few banks have passed on the negative rates to their retail depositors, especially those with low balances.

now a less profitable use of a bank's funds, since the margin between the interest received and the interest paid is now compressed.

Even though a high term spread on long bonds (compared to yields on short-term debt) tends to coincide with recessions, along with expectations of rising yields and hence future capital losses, banks may have a greater incentive during downturns to take on term risk and other non-credit risks that offer a higher current yield and that do not necessarily impose explicit future losses. This is because the extra safe-yield today carries a high shadow value, especially if a bank is capital constrained or is afraid of becoming so. In such a case, the bank makes a tradeoff between earning some extra yield today and incurring a higher likelihood of losing profitable opportunities in the future, as its funds will be locked up in lower-paying assets when the general level of yields rises with tighter monetary policy as the economy approaches full employment. This tradeoff may help explain the high sensitivity of long yields to short rates, as explored in Hanson and Stein (2014). Conversely, banks may be more willing to take on credit risk during good times, when the near-term probability of default is low, whereas the term spread tends to be low along with heightened odds of further mark-to-market losses stemming from monetary policy tightening. Since the tradeoff between the magnitude of today's reward relative to tomorrow's potential losses for different risks varies over time, the distortion to incentives likely manifests in banks taking on different kinds of risks over the course of a business cycle.

By the logic elaborated above, any extra returns from term risk, prepayment risk in mortgage-backed securities (MBS), or the illiquidity risk in municipal securities, seem especially attractive in the low interest rate environment prevailing since the financial crisis. This paper will show that this logic is indeed consistent with the behavior of some banks, specifically those smaller banks not subjected to much greater regulatory scrutiny after the crisis. Some existing studies (such as Borio and Zhu 2012) have also argued that an extended period of low interest rates, stemming from accommodative monetary policy, may compel financial firms to take on more risk in order to boost yields, but they do not distinguish across the different types of risks. The same logic of favoring gains today also implies that should banks suffer losses on their securities holdings from an unanticipated increase in interest rates, such as what occurred during the so-called taper tantrum in May 2013, they may well retrench from term risk. The results offer some evidence that those smaller banks reversed the post-crisis trend of rising average maturity for non-MBS securities immediately after the taper tantrum.

For financial institutions, the parameters for risk taking are often also defined by regulators. This then creates an incentive for financial firms to take on more risk along those dimensions not proscribed or constrained by regulation. In the U.S. context, a key feature of the post-crisis world is the wide-ranging regulatory reforms, designed to make the nation's banking system safer, which impose more, and stricter, regulatory restrictions and supervisory oversight on banking organizations subject to the advanced approaches capital framework (generally those institutions with consolidated assets of $250 billion or more, or with on-balance-sheet foreign exposures of $10 billion or more). Since risk taking by financial institutions is a constrained optimization problem, this implies that since the crisis, the risk taking behavior of banks is also shaped by the new regulatory environment. Specifically, though banks, regardless of their size, may have an incentive to take on more risk in order to boost earnings, in the post-crisis era the largest banks are likely to have less leeway to actually implement such a strategy because they now face much more stringent regulatory constraints than the smaller banks. This paper will show that this is indeed the case—banks subject to the additional post-crisis regulations have changed the risk profile of their securities portfolios in a significantly different way compared with their smaller peers. Specifically, since the financial crisis the largest banks have noticeably cut down on holding long-term securities, and have also engaged much less in the extension of loan maturities. These practices contrast starkly with their pre-crisis behavior in the 2000s, when they substantially raised the maturity of their securities portfolios, a difference that is consistent with the understanding that the largest banks suffered significant losses during the crisis because they had taken on much more risk than officially measured.

To the extent that higher earnings help banks build their capital buffers, it is even conceivable that regulators may tolerate banks seeking higher current returns, especially if doing so does not entail incurring actual losses in the future. This tradeoff is especially attractive during recessionary periods when bank capital cushions, eroded by losses, have fallen too low, particularly during the Great Recession when most banks suffered loan losses to varying degrees. Moreover, all banks have been trying to build a thicker capital buffer, at least partly in anticipation of the new regulations to be implemented. This route to rebuilding capital, however, is curtailed for banks subject to the advanced approaches rules because of some new post-crisis regulations, in particular the removal of the accumulated other comprehensive income (AOCI) filter and the imposition of the liquidity coverage ratio (LCR).

The constraints on the largest banks' ability or willingness to hold long-term assets also serves as an example that illustrates the potential incompatibility between monetary policy and regulatory policy objectives. With short-term nominal interest rates constrained at the zero lower bound, central banks around the world experimented with a variety of innovative unconventional policy measures after the financial crisis to try jump-starting the economy. One crucial element of the new policy toolkit is bringing down long-term rates through large-scale asset purchases (commonly known as quantitative easing), as well as issuing forward guidance that promises to keep short-term rates low for an extended period.

Since the largest banks, those subject to the advanced approaches rules, account for three-quarters of the entire banking sector's overall assets, it seems reasonable to suspect that, due to the new regulations, the sector's restrained willingness to own long-term assets may have rendered the unconventional monetary policy measures less effective than otherwise would have been the case.

The remainder of the paper is organized into six sections. Section II reviews the post-crisis changes to the regulatory landscape that are most likely to influence the risk-taking behavior of the largest versus the smallest banks. Section III presents empirical evidence regarding the substantial differences between these two groups of banks in terms of asset maturity and maturity mismatch before and after the financial crisis. Section IV uses a simple model to illustrate the rationale for banks to favor taking on non-credit risk during downturns, and to show how, in the post-crisis period, this mechanism has been altered differently for the largest versus the smallest banks. It then presents empirical evidence consistent with the model. Section V examines if the post-crisis rise in maturity mismatch has helped banks' net interest margins. Section VI shows how, since the taper tantrum, banks have adopted a number of tactics to minimize the negative future impact of the greater term risk in ways consistent with the new regulations. Section VII concludes.

II. Bank Risk Taking and the Impact of Post-Crisis Regulatory Reforms

This section discusses studies of risk taking by banking institutions that are related to this paper.[4] The focus is on how the new or enhanced regulatory rules introduced after the financial crisis can potentially induce changes in banks' optimal approach to assuming and managing different types of risks, including term risk, prepayment risk, and liquidity risk, especially in the context of their choice of securities holdings.

First, there is a long-standing literature studying the factors that influence a bank's profitability, especially the net interest margin (NIM). Since it is impractical to conduct a full-scale review, just a few particularly relevant studies are mentioned here. Entrop et al. (2015) estimate how interest rate risk stemming from maturity transformation is priced in the rate earned and paid by banks, and in turn the NIM. English, Van den Heuvel, and Zakrajsck (2012) use high-frequency equity price reactions to monetary policy shocks to estimate banks' exposure to interest rate risk, and link this exposure to banks' maturity mismatch and derivatives holdings. Covas, Rezende, and Vojtech (2015) investigate empirically

[4] Except in the discussion of specific regulations, banks are used interchangeably with bank holding companies, or financial services holding companies, both in this section and in this study more generally.

why the NIMs of large U.S. banks have been compressed in recent years and find that the low-rate environment is largely to blame. On a related note, Claessens, Coleman, and Donnelly (2016) investigate the effect of low long rates on bank NIMs across the advanced economies.[5]

Second, there is a fast-growing literature on the so-called reaching-for-yield behavior, mostly exhibited by financial institutions. Borio and Zhu (2012) are among the first to emphasize the role of monetary policy, particularly the low interest rate environment engendered by expansionary policy to deal with the effects of the financial crisis. Dell'Ariccia, Laeven, and Marquez (2014) develop a model formalizing the linkage, with an emphasis on the role played by bank capital. Dell'Ariccia and Marquez (2013) provide a review of this topic. Altunbas, Gambacorta, and Marques-Ibanez (2014) use international bank panel data to investigate evidence for the impact of monetary policy on bank risk taking.[6] Using loan-level data, Aramonte, Lee, and Stebunovs (2015) examine if the low longer-term yields prevailing after the global financial crisis induced lenders in the syndicated loan market to reach for yield. Kandrac and Schlusche (2017) use a regulatory change enacted after the crisis to identify incentives for reaching for yield by banks affected differently by these new guidelines.

Third, and more closely related to this paper, are studies analyzing the incentives that financial firms have for taking different types of risk. Particularly pertinent is Becker and Ivashina's (2015) study of insurance companies' investment in corporate bonds.[7] They present compelling evidence that insurance companies hold bonds that offer higher yields for any given rating within the investment-grade category. Becker and Ivashina (2015) make the case that this behavior reflects the distortion induced by the risk-based capital requirement, which is set according to a bond's credit rating but not its overall systematic risk as assessed by the market.[8] The potential of distorted incentives for risk taking by banks is also quite plausible given that banks are subject to a broad array of regulations. Iannotta and Pennacchi (2012) demonstrate that the pricing of deposit insurance ignores systematic risk, thus encouraging banks to load up on systematic risk. Other regulations, including some introduced after the crisis, may also have unintended consequences or create conflicting incentives, as will be elaborated below.

Compared to regulation of credit or market risk, the regulation of interest rate risk on a bank's

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[5] Borio, Gambacorta, and Hofman (2015), by comparison, examine the effect of monetary policy on bank profitability more broadly.

[6] Some studies use macroeconomic approaches, such as factor-augmented vector autoregressions, to analyze how macro shocks affect banks (lending, risk exposure, etc.). See, for example, Buch, Eickmeier, and Prieto (2014).

[7] See Becker and Ivashina (2015) for reviews of other related previous studies on this topic, such as the model by Gurrieri and Kondor (2012) that derives cyclical risk-taking behavior of fund managers.

[8] This is distinct from a likely genuine mistake of underpricing aggregate risk by investors, as documented in Coval, Jurek, and Stafford (2009). Cognitive bias, as modeled in Gennaioli, Shliefer, and Vishny (2012), may lie at the heart of such mispricing.

books has been a more qualitative exercise, in that before the crisis the emphasis was on measures such as "effective corporate governance, policies and procedures, risk measuring and monitoring systems, stress testing, and internal controls" without imposing a specific capital requirement.[9] Moreover, judging by agency publications, interest rate risk did not come into focus until after the taper tantrum in May 2013.[10] This may help explain why the smallest banks, those below $10 billion in assets, had been able to increase their maturity mismatch noticeably until then.

Going forward, the regulation of interest rate risk will be enhanced. In April 2016, the Basel Committee on Banking Supervision issued the final standards for Interest Rate Risk in the Banking Book (first published for consultation in June 2015). The Committee recommended requiring banks to disclose (to regulators and in some cases also to the public) the impact of various interest rate shocks on the bank's economic value and income, including the economic value of the HTM portfolio, starting in 2017:Q4. This requirement obviates, at least at the margin and especially for the largest banks, the benefit of classifying securities as HTM, which they have done on a large scale over the past couple of years (as will be shown). Moreover, "supervisors must require mitigation actions and/or additional capital" on those banks identified as interest rate risk outliers, making the treatment of interest rate risk more comparable to those of other risks. The specific rules for the United States are yet to be crafted, which means that the timing of implementation is still uncertain. Nevertheless, given that in the past banks tended to become compliant ahead of schedule, soon we are likely to observe changes in how banks manage their interest rate risk.

The latest Basel III standards for interest rate risk primarily consider three types of risks: 1) gap risk, arising from the timing mismatch of rate changes for instruments on banks' book, 2) basis risk, referring to the possibility of meaningfully disparate changes in different rates of similar tenors, such as the three-month LIBOR versus the federal funds rate, and 3) option risk, including both option derivative positions and options embedded in instruments (such as the prepayment option in residential mortgages) held both on and off the balance sheet. Given the available data, this study will focus on analyzing how gap risk has evolved since the crisis, and will consider the option risk pertaining to mortgages.[11] It will not explicitly study basis risk, but will touch upon credit and liquidity risk, which are the key risks at the

[9] Page 1 of "The Advisory on Interest Rate Risk Management," issued on January 6, 2010, largely reiterated the principles laid out in the agencies' joint policy statement on interest rate risk issued in 1996. Each agency separately issued more detailed rules for implementing the advisory. See https://www.ffiec.gov/pdf/pr010710.pdf.

[10] For instance, it did not appear as one of the "Matters Requiring Attention" in the Office of the Comptroller of the Currency's *Semiannual Risk Perspective* until the Fall 2013 issue.

[11] Bai, Krishnamurthy, and Weymuller (2016) propose a measure of the overall liquidity mismatch in the banking system, beyond the more standard maturity mismatch, which more or less corresponds to the "gap risk" component.

root of basis risk.

Within the vastly expanded universe of bank regulations after the crisis, the removal of the AOCI filter for those institutions subject to advanced approaches capital regulation—chief among which are those designated as global systemically important banks (G-SIBs)—is likely the key change that has made it more costly for the covered banks to hold long-term securities, whose values fluctuate more in response to interest rate movements than do short-dated securities.[12] In addition, the Comprehensive Capital Analysis and Review (CCAR) may have also discouraged the G-SIBs from holding long-dated securities, but in a more qualitative way.[13] The two rule changes mandating that the largest banks must hold more high-quality liquid assets (HQLA) and seek more stable funding have most likely induced these banks to hold more high-quality liquid securities as a share of total assets, although the implication for maturity choices is not clear cut. A countervailing force, which discourages banks from holding HQLA that by nature offer low returns, is exerted by the risk-insensitive supplementary leverage ratio.

The capital cost of holding long-dated available-for-sale (AFS) securities has been raised for those banks designated as advanced approaches institutions because they have lost the ability to shield their capital from being hit by the unrealized losses on AFS securities. Prior to the crisis, in computing their capital, banks were allowed to exclude the AOCI, chief among which are unrealized gains/losses on AFS securities. Under the July 2013 Final Rule, this filter was removed starting 2015:Q1 for the advanced approaches institutions. Other banks were allowed to make a one-time election (on the 2015:Q1 regulatory filing) to continue to exclude unrealized gains/losses on AFS securities in the calculation of regulatory capital, and all chose to do so.[14]

The primary reason that removing the AOCI filter is likely to discourage banks from holding long-dated securities as AFS is that this removal leads to higher volatility in the balance of regulatory capital, and in turn the capital ratio for those covered institutions. This is because, starting formally in 2015:Q1, fluctuations in the fair value of AFS securities (typically equal to the market value for actively traded ones) directly alter a bank's amount of capital. To the extent that banks dislike fluctuations in their

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[12] Among the U.S. chartered bank or financial services holding companies, J.P. Morgan Chase, Bank of America, Citi Group, Wells Fargo, Bank of New York Mellon, State Street, Goldman Sachs, and Morgan Stanley are designated as G-SIBs. All the G-SIBs are required to adopt the advanced approaches capital rule, which also covers holding companies with at least $10 billion in total on-balance-sheet foreign exposure and their depository institution subsidiaries.

[13] The CCAR covered 19 domestic bank holding companies (BHCs) in 2011 and 33 BHCs as of 2016, including all the institutions subject to the advanced approaches capital framework.

[14] A bank holding company subsidiary of a foreign banking organization may, subject to regulatory approval, elect not to comply with the advanced approaches rule. See "Risk-Based Capital Standards: Advanced Capital Adequacy Framework — Basel II," Board of Governors of the Federal Reserve System, *Federal Register* / Vol. 72, No. 35 / Rules and Regulations, December 7, 2007, page 69, 299. TD Bank U.S. Holding Company, for example, chose to opt out.

capital ratios, they would have an incentive to reduce fluctuations in the fair value of their AFS securities. From corporate finance studies, there appears to be ample evidence that firms dislike fluctuations, even those stemming from normal operations, in their cash flow or dividends. One way to avoid variations in the values of their securities is to record these on the books as held-to-maturity, which are accounted for at the amortized cost (also referred to as book value) on the balance sheet. As will be shown, there is clear evidence that the largest banks substantially increased the share of their securities holdings in the HTM category in recent years. Another alternative is to hold short- or shorter-term securities, whose values do not change much in response to changes in market interest rates. Of course, the drawback to this solution is that short-term securities also tend to pay lower rates, especially in periods when the yield curve is steep, meaning when the term spread is wide.

When combined with the CCAR, the removal of the AOCI filter may lead to a higher level of capital if the macroeconomic scenario featuring the largest increase in long yields corresponds to the binding minimum capital ratio. In each CCAR, the Federal Reserve imposes a common set of three macro scenarios—baseline, adverse, and severely adverse— on all the covered bank holding companies (BHCs), which must hold enough capital under every scenario.[15] Three interest rates, the three-month, five-year and ten-year, are included in the scenarios.[16] The baseline scenario invariably involves the long rate rising to high threes or even above 4 percent in the first few years of the CCAR, while the adverse scenario in some earlier years had these rates rise even further. The consequence of such a rise in interest rates will cause a nontrivial fall in the fair value of long-dated AFS securities.

To obtain a ballpark figure for the potential capital impact resulting from unrealized losses on AFS securities, this paper uses the 2013 taper tantrum episode that saw the 10-year Treasury yield jump 82 basis points, from 1.70 percent at the end of April to 2.52 percent at the end of June. For comparison, the 10-year yield was projected to increase by 140 basis points over the planning horizon in the 2016 baseline scenario. According to the Call Reports, in 2013:Q2, the 11 BHCs subject to the removal of the AOCI filter suffered unrealized losses ranging from 2.2 to 12.5 percent of their 2013:Q1 tier-one capital on their AFS securities, with an average loss of 5.0 percent. If this loss is extrapolated linearly, then the 10-year yield increase in the 2016 baseline scenario will imply unrealized losses above 10 percent, and

[15] The CCAR considers four capital ratios. Three of these are risk-based ratios: tier-one capital, total capital, and tier-one common equity to risk-weighted assets. The fourth is the tier-one leverage ratio: tier-one capital to average assets. This one is the most likely to be binding, since most securities held by banks have zero or low risk weights.

[16] The five-year yield was first added in 2014. In earlier years, the three-month and ten-year yields were not supplied for some scenarios in some years. For example, the 10-year yield was only given for the adverse scenario in 2011.

perhaps even higher than 20 percent of tier-one capital.[17] This is clearly a nontrivial decline.[18] On the other hand, the severely adverse scenario, which tends to feature a decrease in Treasury yields owing to the easy monetary policy enacted to combat the adverse economic conditions, almost invariably leads to the lowest capital ratio. This means that the scenarios featuring increases in long yields, and hence unrealized losses on AFS securities, are unlikely to be the binding scenario in terms of a bank's capital ratio. Nevertheless, potential losses on AFS securities may still exert a qualitative influence. Those securities whose next repricing date falls beyond the planning horizon also imply compressed net interest margins in the supervisory scenarios, raising the risk, if only slightly, of restrictions on capital distribution based on a qualitative assessment of a bank's capital adequacy in stress scenarios.

Among the regulatory changes introduced after the financial crisis, the first of the new liquidity requirements is the liquidity coverage ratio (LCR), which is defined as the ratio of a banking firm's holdings of HQLA (the numerator) to its projected cash outflow minus its projected cash inflows (the denominator) during a stipulated stress period of 30 days.[19] The U.S. rule specifies two versions of the LCR that are applicable to two sets of domestic BHCs and their bank subsidiaries: 1) the more stringent full rule applies to those institutions subject to the advanced approaches capital rule and to these BHCs' insured depository institutions (IDIs) that have assets of $10 billion or more,[20] and 2) a less stringent, modified LCR is applied to those banking institutions that do not meet these thresholds, but have $50 billion or more in total assets.[21] The same size cutoff is also used in other enhanced regulations after the crisis, primarily the advanced approaches capital framework, as will be shown.

A key element of the Basel III regulatory framework, the LCR was first proposed by the Basel Committee in 2010, and revised in January 2013.[22] The proposed U.S. rule was published for comments on October 24, 2013. The final rule, approved in September, 2014,[23] is identical to the proposed rule along

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[17] The flip side is that these BHCs enjoy unrealized gains on AFS securities given the negative interest rates in the 2016 CCAR's severely adverse scenario. But what matters is the scenario that imposes a binding capital constraint.

[18] An unrealized loss of 10 to 20 percent of tier-one capital translates into a decline of a bank's capital ratio by nearly 1 to 2 percentage points, as the decline in numerator (capital) dominates. For reference, the average leverage ratio for the largest BHCs is about 9 percent. Yield increases over the projection horizon were even larger in earlier CCARs (for example, by 2.5 percentage points in the 2015 adverse scenario), implying the need for even wider capital buffers.

[19] The key features that determine the inflow and outflow rates for unsecured lending and funding, respectively, are counterparty risk, maturity, insurance, and tradability. The key features that determine the inflow and outflow rates for secured transactions are collateral quality, counterparty risk, and rehypothecation.

[20] Outside the G-SIBs, the U.S. banks subject to the LCR are: US Bank, PNC, Capital One, TD Bank, and Northern Trust.

[21] The modified LCR requires a less stringent calculation method and a longer phase-in period.

[22] It also fulfills Section 165 of the Dodd-Frank Act to establish an enhanced prudential liquidity standard.

[23] See http://www.federalreserve.gov/newsevents/press/bcreg/20140903a.htm for the joint press release. The U.S. rule is stricter than the Basel III guidelines, most notably by only allowing a narrower range of HQLA, choosing a higher

almost all the important dimensions, such as the applicability criteria and the type and size of the required HQLA.[24] Compliance with the full LCR rule will be phased in over three years: each institution must hold HQLA equal to 80 percent of its net cash outflow beginning on January 1, 2015, 90 percent in 2016, and 100 percent in 2017. However, 70 percent of the BHCs subject to the full rule were already compliant at the time of the final rule's release. This evidence suggests that the largest BHCs that reasonably expected to be subject to the rule had started preparing for the change probably as early as 2010, if not sooner. Some of them had in fact started adjusting the liquidity profile of their assets during the crisis in response to the unprecedented liquidity shock experienced, as will be shown. Therefore, it is not so much the initial increase in liquidity as the continuation of the change long after the crisis that is more attributable to the introduction of the LCR.

The LCR has almost certainly induced the largest BHCs to increase (as a share of assets) their holdings of HQLA, which include central bank reserves, government debt, and corporate securities that can be converted easily and quickly into cash. The LCR assigns the most favorable liquidity rating to debt with an explicit government guarantee, and the next rating class to MBS guaranteed by the government-sponsored enterprises (GSEs). Within each asset class (such as Treasuries) receiving the same liquidity rating, however, no distinction is made by maturity. This uniform treatment can create an incentive to hold more long-term securities relative to short-term ones, all else being equal. This treatment also enhances the appeal of agency and GSE securities, above and beyond their already favorable risk rating for calculating a BHC's risk-based capital ratio. In particular, GSE MBS tend to pay somewhat higher yields than maturity-matched Treasuries because of the embedded prepayment option. On average, this option leads to a respectable risk premium on these instruments, making them desirable to banks searching for current yield.

On the liability side, the LCR may have given banks an incentive to solicit more shorter-term retail time deposits than they would otherwise have chosen, since the LCR encourages using retail deposits, regardless of maturity, as a funding source (by imposing high cash outflow rates on 30-day or shorter wholesale funds deemed unstable). But this "supply" effect may be partially or fully offset by the "demand" effect stemming from the low short-term rates prevailing since the crisis, which naturally boosts households and nonfinancial firms' desire to hold "money-like" instruments such as demand

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net cash outflow measure, and moving forward the date for compliance by two years to 2017.

[24] Those adjustments mainly concern the range of corporate debt and equity securities included in the HQLA, a phasing-in of daily calculation requirements, a revised approach to addressing maturity mismatch during a 30-day period, and several changes to the implementation of the modified LCR. See the press release for details. For entities supervised by the Federal Reserve, state and municipal securities meeting liquidity standards were later allowed to be counted as HQLA up to some levels (see http://www.federalreserve.gov/newsevents/press/bcreg/20150521a.htm).

deposits and savings deposits, and at the same time encourages them to seek somewhat higher returns through longer-maturity time deposits.

The second major new liquidity rule is the net stable funding ratio (NSFR), which applies to the same set of banking firms subject to the LCR. The NSFR, intended to mitigate the risk of funding stress over a one-year horizon, requires banks to structure their liabilities in a manner consistent with the liquidity characteristics of their assets, derivatives, and commitments.[25] Thus, the NSFR also discourages a reliance on short-term wholesale funding while it encourages the holding of shorter-term, unencumbered, and highly liquid assets.

One post-crisis enhanced capital requirement, the supplementary leverage ratio (SLR) applicable to the advanced approaches institutions, may also encourage these institutions to hold assets offering higher returns, including longer-dated debt.[26] This is because the SLR is "risk-blind," in the sense that the same ratio is imposed on any asset regardless of risk, including the safest assets such as central bank reserves and U.S. Treasury securities. Thus, it is relatively more costly for banks to hold low-return assets, which tend to be safe, liquid, and short-term.[27] The SLR is intended to restrict banks from building up too much leverage, providing a backstop to the risk-based capital requirements.

Another new rule likely has an effect similar to the SLR on the largest banks' incentive to take on risk. In April 2011, the Federal Deposit Insurance Corporation (FDIC) broadened the base for assessing insurance premia from domestic deposits (less a few adjustments) to average consolidated total assets minus average tangible equity.[28] The intent of the revised assessment base is to strengthen the FDIC's insurance reserve fund and to impose a cost on the largest banks that is more commensurate with the risk they pose to the financial system, since these banks tend to obtain a higher share of funding from non-

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[25] The numerator of the NSFR measures the available stable funding on the liability side of bank balance sheets, assigning higher weights to stable funding sources such as capital and long-term debt, and zero weight to wholesale funds with less than six months to maturity. The denominator of the NSFR measures a bank's required stable funding based on the liquidity characteristics of a bank's assets and off-balance-sheet exposures.

[26] The SLR requires BHCs to maintain an additional buffer of tier 1 capital to total leverage exposure of 3 percent. The G-SIBs and their IDI subsidiaries are subject to the Enhanced SLR, which requires a minimum additional capital buffer of 5 percent for the BHCs and 6 percent for their IDIs. Total leverage exposure includes all on-balance-sheet assets and many off-balance-sheet exposures. Both the SLR and the Enhanced SLR are in addition to the 4 percent leverage ratio (featuring a different denominator and calibration) already required of U.S. banks.

[27] In several respects, the U.S. version of the SLR is also more stringent than the Basel standard, and hence the rules adopted in Europe and other countries. Not only does the SLR in the United States require an extra 2–3 percent capital buffer for the G-SIBs, but also it mandates that risk exposures are measured using daily averages instead of the quarter-end balance.

[28] Importantly, the revised assessment base now includes central bank reserve balances. Since the new rule applies only to domestic IDIs and not to branches and agencies of foreign banking organizations, it is identified as the main reason for foreign bank branches' much greater share in the arbitrage trade to take advantage of the risk-free spread between the interest on (excess) reserves (IOER) and short-term market rates such as the fed funds or eurodollar rate.

deposit sources. Similar to the SLR, the revised assessment base is also insensitive to credit risk within a prescribed range of assets.[29] Like the SLR, this new rule thus also has the effect of dampening domestic banks' willingness to hold short-term, safe, liquid, and thus low-return assets, all else being equal.

These new regulatory requirements have been implemented gradually over the years since the global financial crisis. Given the volume and the complexity of the new rule making, it is not surprising that both the banking industry and regulators are still digesting the implications of the new regulations. Lacking a good instrument besides the cutoff based on asset size for the application of the new regulations, it is difficult to definitively prove that, as conjectured above, some of these new rules have caused the differential post-crisis change in behavior between the largest BHCs (that is, those subject to the advanced approaches capital rule) and the smaller BHCs. Other conditions relevant for banking operations, chiefly the low interest rate environment since the crisis, have also differed from the historical norm. But no theory has established that these other conditions should induce the observed differential change in term risk assumed by the largest versus the smaller banks. The difference-in-differences analysis in the rest of the paper will try to build a case that the post-crisis regulatory environment has caused the differential change in risk taking.

III. Maturities of Assets and Liabilities, and Maturity Mismatch

3.1 Data and Sample Construction

The primary data source for this study is the Call Reports, the regulatory filings all FDIC-insured banks are required to make each quarter. The sample period goes from 1997:Q2 through 2015:Q4. The start of the sample period is dictated by data availability: the reporting of balances by detailed maturity bins only began in 1997:Q2. The balances and flows at all the banks within each BHC are aggregated and all the analysis is carried out using these constructed BHC-level observations.[30] This approach essentially assumes that all strategic decisions regarding how banks manage risk are made at the BHC level, which is consistent with the standard practice used in most banking studies. In light of the drastically different change in the regulatory treatment of banks of different sizes after the crisis, the sample BHCs are divided into four groups based on their regulatory treatment (which is highly correlated with total

[29] Some asset categories are explicitly targeted as high-credit-risk, such as certain securitization of assets including mortgages, and thus subject to higher FDIC insurance premia under the new rule.

[30] The regulatory reports, Form Y-9C, filed directly at the BHC level do not contain the necessary variables. Hence, BHC-level data have to be constructed from data of the bank subsidiaries. Adding up balances across the banks within a given BHC can lead to some double counting, but mostly in terms of "due tos" or "due froms" across the subsidiary banks. The balances of securities and loans are less subject to this issue.

assets): 1) advanced approaches BHCs (most with total consolidated assets exceeding $250 billion as explained above; these are referred to as "Above $250 Billion" in the rest of the paper for brevity), 2) those subject to the modified LCR (generally the BHCs with total assets between $50 and $250 billion as explained above; henceforth referred to as "$50–250 Billion"), 3) those BHCs with assets above $10 billion but below $50 billion (referred to as "$10–50 Billion"), and 4) all BHCs with less than $10 billion in assets (referred to as "Below $10 Billion").

Because there have been many mergers and acquisitions in the U.S. banking sector over the sample period, especially during the late 1990s, the data are adjusted for all cross-BHC mergers and acquisitions: the first quarter after every merger is removed for computing growth rates. For this reason, BHCs with assets above $10 billion that became direct targets of the largest BHCs are assigned to group 1) in order to engineer a grouping with reasonably stable membership. The same treatment applies to the membership of group 2).[31] As shown in Figure A1 in the data Appendix A, these pro forma combinations result in a reasonably stable share of BHCs in each size group as a percent of total banking sector assets in the United States. After this treatment, the merger quarters are kept for the maturity figures by group size to avoid injecting excessive volatility into the top three size bins, which all have a fairly small number of BHCs (see Appendix A for more details). Also, see the data appendix for a detailed description of the approach to the data cleaning and sample construction, plus some summary statistics.

The Call Reports introduced in 1997:Q2 contain more detailed data on the maturity composition or the repricing frequency of a bank's loans and investment debt securities (that is, the securities held on the bank's balance sheet, not those used for trading purposes). These debt securities are divided into three broad categories: 1) pass-through MBS backed by closed-end first lien 1–4 family residential mortgages, 2) other MBS (consisting of structured products such as collateralized mortgage obligations, or CMOs), and 3) all the other securities, primarily consisting of Treasury and agency securities, and municipal securities, but also a small fraction of other debt such as corporate bonds. Except for the second category, the balances are further divided into six bins defined by the maturity of fixed-rate securities or the next repricing date for variable-rate securities. Hence, the data are defined to reasonably match the concept of interest rate risk: the frequency of rate resets.[32] These six maturity or repricing bins are: i) three

[31] Group 3) turns out to be a rather small set, but additional analysis (not shown) shows that their behavior is sufficiently different from the smallest BHCs in group 4), whereas those BHCs with assets between $1 and $10 billion behave quite similarly to those with assets below $1 billion, especially in the post-crisis years. We thus choose to single out Group 3) for this set of figures. We combine them with the Group 2) BHCs for some of the regression analysis later.

[32] The next repricing date obviously does not equal the repricing frequency for some contracts, but on average the two measures should coincide.

months or less, ii) over three to 12 months, iii) over one year to three years, iv) over three to five years, v) over five to 15 years, and vi) over 15 years. For the other MBS category, only two maturity bins are available: i) three years or less, versus ii) over three years.

Likewise, the Call Reports provide data by ranges of maturity or repricing frequency for two categories of loans: 1) closed-end first-lien mortgage loans secured by 1–4 family properties (which will be referred to simply as first-lien mortgages), and 2) all other loans. Obviously, the first category is much narrower and more homogeneous. Within each category, a separate balance is reported for each one of the same six maturity bins as listed above for pass-through MBS and non-MBS securities: : i) less than three months, ii) three to 12 months, iii) one to three years, iv) three to five years, v) five to 15 years, and vi) over 15 years.

I also use yields on various fixed-income instruments, such as U.S. Treasury and agency securities, MBS, corporate bonds, and municipal bonds, all downloaded from Haver. For estimating mark-to-market value adjustments, quarter-end yields are used. For comparison with the average interest rate received on bank assets, quarter-averages of yields are used. For a few variables only directly reported for each consolidated BHC, mainly the balance of assets and liabilities with maturity or the next repricing date under one year, the FR Y-9C data is used.

3.2 Empirical Estimates of Weighted-Average Maturities

3.2.1 Weighted-Average Maturities of Loans, Securities and Total Assets

This section presents the estimates of balance-weighted-average maturities of securities and loans using the Call Reports data organized at the BHC level as described above.[33] Denote the weighted-average maturity of an asset category i as M_i, consisting of n maturity bins, and denote the volume in each bin j as V_{ij}, j's share s_{ij}, $s_{ij} = V_{ij}/V_i$ with V_i being the sum, so that M_i can be expressed as

$$M_i = \sum_{j=1}^{n} s_{ij} M_{ij} = \left(\sum_{j=1}^{n} V_{ij} M_{ij} \right) \Big/ \left(\sum_{j=1}^{n} V_{ij} \right) \ . \qquad (1)$$

The weighted-average maturity of a category of liabilities is defined analogously. To analyze what the latest Basel rule on interest rate risk refers to as the gap risk, the maturity mismatch (*MM*) is estimated as follows, with the BHC and time subscripts added (b and t respectively):

$$MM_{b,t} = \sum_{i=1}^{N^A} s^A_{b,i,t} M^A_{b,i,t} - \sum_{i=1}^{N^D} s^D_{b,i,t} M^D_{b,i,t} \ , \qquad (2)$$

where M^A (M^D) denotes the maturity of assets (liabilities), and $s^A_{b,i,t}$ ($s^D_{b,i,t}$) denotes the share of category i

[33] For brevity, "maturities" is used to refer to maturity of fixed-rate debt securities and the next repricing date for variable-rate securities, with the latter omitted here and in all future references.

in all the assets (liabilities) considered for the mismatch definition. I compare the maturity mismatch based on two different categories of assets and liabilities: 1) assets and liabilities with explicitly stated maturities in the Call Reports as detailed in Section 3.1, versus 2) total assets and total liabilities, which also include cash and overnight instruments (that is, the fed funds sold and reverse repos) on the asset side, and transaction plus savings deposits as well as the fed funds bought and repos on the liability side.

For most of the analysis, it is assumed that the average maturity for each of the first five bins of pass-through MBS and non-MBS securities is the mid-point of the range, and that the average for the longest maturity bin is 20 years. Both categories of loans are treated likewise. Different maturity assumptions for the longest bin do not matter for the qualitative result concerning the comparison across banks because, holding as fixed the average maturities of the other bins, the overall maturity of an asset category is a monotonic linear function of the maturity in the longest bin, as can be seen from equation (1). Nonetheless, I experiment with a few assumptions (from 18 to 30 years) to estimate the quantitative impact. For the other MBS, a maturity of five years is assumed for the longer bin for most analyses, but a range of four to seven years is experimented with for sensitivity.

For securities, the overall balance at each BHC is the sum of the amortized cost (also referred to as book value, or BV) of held-to-maturity securities and the fair value (FV) of available-for-sale securities, using the raw data for both measures as reported in the Call Reports. This is done because the analysis (presented in the next subsection) shows that adjustments to correct for movements in the FV due to changes in market interest rates do not alter the qualitative difference in behavior between large and small banks before and after the crisis. Since these adjustments can only be done inaccurately given the available data, the original Call Reports data are used to maximize comparability with other studies.

To offer a summary view, Table 1 reports the share of each major category of assets and liabilities and its maturity, if relevant, for three quarters (2007:Q2, 2013:Q2, and 2015:Q4), along with the change over each period in between. 2007:Q2 marks the beginning of the financial crisis, while the middle date 2013:Q2 is chosen because of the nontrivial losses some banks suffered on their AFS securities due to the taper tantrum, which prompted banks to alter how they invest in securities (as will be shown later). 2015:Q4 is the last quarter of the sample. In Table 1, Panels A and B report statistics for the largest and the smallest size classes of BHCs respectively. All the maturity values are weighted-averages across the available maturity bins, with the balance in each bin as the aggregation weight, as shown in Equation (1). All future references to maturity mean such weighted-averages unless otherwise noted.

For a summary of the underlying data—the share of an asset category's balance in each maturity bin—for the three select quarters, see Appendix C, Table C1. It shows intuitively that the increase in maturity for any asset category is due to an increase in the shares of the longer maturity bins. Table C1 also reveals that the share of trading assets and trading liabilities on the books of the BHCs above $250 billion has fallen noticeably since the crisis, likely because of the protracted weak growth and slump in market trading following the crisis and these BHCs preparing for the implementation of the Volcker rule in the Dodd-Frank Act, as well as the enhanced capital charge for market risk more recently enacted. By comparison, holdings of trading assets or liabilities have been negligible throughout the sample years for BHCs below $10 billion.

A clear pattern is visible in Table 1: the smallest BHCs, those below $10 billion in total assets, have lengthened the maturity for most asset categories since 2007:Q2, with most if not all the maturity extension having taken place by 2013:Q2. Note that the maturity increase is greater for those securities that are not MBS. This means that carrying out the comparison using the effective duration (to be estimated later) instead of the stated maturity is unlikely to alter the qualitative conclusions, since the stated maturity can differ substantially from the effective duration only for MBS but not for non-MBS debt securities typically held by banks. Over the 2007:Q2 to 2013:Q2 period, this group of BHCs also shifted their asset holdings toward categories with typically longer maturities (based on the average of the three quarters covered), mainly pass-through MBS and first-lien 1–4 family mortgages, although they at least partially reversed this shift for MBS after 2013:Q2. Both changes contribute to the maturity extension for assets on the whole, since a change in the overall maturity of an asset category is approximately the sum of the weighted-average maturity change for each component and the change in shares weighted by each component's initial maturity (as the product of the maturity change and the share change is generally small enough to be omitted), as implied by (1):

$$\Delta M_{it} \equiv M_{it} - M_{i,t-1} \approx \sum_{j=1}^{n} s_{ij,t-1}\left(\Delta M_{ij,t}\right) + \sum_{j=1}^{n}\left(\Delta s_{ij,t}\right) M_{ij,t-1} BV_{t,\tau}^{A} E_1 \geq kL_0 / (1+k) . \quad (3)$$

The last term contributes positively (negatively) when the share of longer-dated assets rises (falls).

In contrast, the largest banks, those subject to the advanced approaches rule, entered the financial crisis with a longer maturity structure, especially for securities, but then both shortened the maturity for all asset types except the 1–4 family mortgages and reduced the share of two of the asset categories with the longest maturities on average (pass-through MBS and 1–4 family mortgages) between 2007:Q2 and 2013:Q2. Over the same period, this group of BHCs increased their share of non-MBS securities, which include major types of HQLA (such as Treasury and agency securities) needed to satisfy the LCR.

One notable feature illustrated in Table 1 is that, on average, maturities are much longer for securities than for loans, especially among the BHCs above $250 billion.[34] Perhaps for this reason, the absolute magnitude of maturity reduction among these largest BHCs is greater for securities, close to four years (from 12 years down to eight years), compared with a reduction of close to one year for loans. By comparison, the magnitude of the maturity increase is about equal for securities and loans among the smallest BHCs, those below $10 billion in assets.

An arguably more important distinction between the loans and securities held by banks must be noted. The maturity of loans presumably reflects the joint choice of the bank and its borrowers, a natural outcome of lending relationships and the associated bilateral bargaining on the price and terms of a loan. Post-crisis changes in loan characteristics, whether or not these appear to deviate from patterns in the previous cycle, may be due to changes in borrowers' maturity preferences. Qualitatively, this is the same perennial identification problem that afflicts studies of the bank lending channel. In contrast, a bank's choice of the maturity structure for its securities portfolio should be entirely driven by its own preference or constraints, unless a bank is sufficiently important to the market for specific subsets of securities that the terms of those securities are jointly determined by the bank and the issuers.

This possibility cannot be ruled out, especially for securities issued by states, local governments, and municipalities, which are predominantly purchased by local banks. In addition, banks may specialize in certain securities, just as they specialize in particular types of borrowers, because it is costly to develop the specialized knowledge.[35] However, specialization seems hardly relevant for a relatively homogeneous instrument with a deep market, such as agency and GSE pass-through MBS. And yet a wide cross-section dispersion in maturity change is observed between 2007:Q2 and 2013:Q2 across the BHCs below $10 billion in asset value, as shown in Figure 1, Panel A. The figure also compares the post-crisis maturity change among these smallest banks with a comparable period around the 2001 recession—2000:Q4 being the last quarter before the Federal Reserve started lowering the fed funds rate, while 2004:Q2 was the first

[34] A likely explanation is that the securities held by banks are generally not subject to credit risk, so banks are willing to bear greater term risk if they are equalizing, at the margin, the total risk of an asset. This practice would be consistent with the implication of the model developed in the next section. On the other hand, it is possible that banks assess the degree of term risk using the effective duration, not the stated maturity, of MBS, which is much shorter due to the prepayment option. Presumably, this logic applies to mortgage loans held in banks' loan portfolios as well, so there is a smaller but still notable difference between securities and loans in terms of effective duration.

[35] A nontrivial fraction of banks below $10 billion in assets do not own securities other than agency and municipal debt, as can be seen in Table C2 in Appendix C, which summarizes the percent of banks within each size class that hold none of a category of securities (the first row in each block), none in AFS (the second row) or none in HTM (the third row). In particular, until the crisis, an increasing share (from about 10 percent in 1997:Q2 to over 80 percent in 2008) of banks below $10 billion did not own any Treasuries, as shown in Figure C2. This is consistent with the thesis in Hanson et al. (2015) that banks tend not to hold highly liquid, and thus low return, securities, such as Treasuries. Larger banks also cut back on Treasuries until the crisis, although these banks essentially hold every type of security.

quarter when the Fed started raising rates.[36] Panel A shows that although 20 percent of these BHCs kept virtually the same average maturity for pass-through MBS over both periods, the post-2007:Q2 changes are clearly more positive on average than the changes over the comparable period after 2000:Q4, as confirmed by the t-test value of 8.14 for the null hypothesis of an equal mean between the two distributions (accounting for possible correlations between observations for the same BHC, which in fact makes little difference). Furthermore, the Kolmogorov-Smirnov test of equality between the two distributions, performed after removing the respective mean of each period, is also rejected.

For comparison, Figure 1, Panel B plots analogous histograms that compare the distributions of maturity changes over the two periods for non-MBS securities. A higher fraction of BHCs altered the maturity of non-MBS rather than pass-through MBS securities, which is perhaps not surprising since the non-MBS category encompasses several diverse types of securities. Nevertheless, the relative pattern remains the same: changes over 2007:Q2 to 2013:Q2 are on average more positive than changes over the earlier period (the t-test of equal means = 18.59). For further comparison, Figure 1, Panel C plots the maturity change distribution for loans over each of the two periods. A similar pattern emerges: the mean of changes over the later period is clearly positive and significantly greater than that over the earlier period (the t-test = 22.71, the higher value in part due to the smaller standard deviations of the distributions than for securities).

Interestingly, the 2007:Q2-to-2013:Q2 maturity change is essentially uncorrelated between loans and securities (or between either category of loans). This finding is consistent with the interpretation that a bank's maturity choice for loans is driven more by borrower preferences or other dimensions of a credit decision (such as borrower creditworthiness, industry, or location), which can have little correlatation with the bank's own choice of maturities for securities.

Moreover, for issuer preference to explain the systematic post-crisis difference between the largest BHCs and the smallest BHCs in terms of maturity extension in securities, it must exactly coincide with the pattern of the differential changes across banks of different sizes. There is no obvious conceptual reason for such a cross-section coincidence, nor is it supported by empirical evidence (according to the specialization pattern in Table C2). The differential change in the maturity of securities held by the largest (advanced approaches) banks and the banks below $10 billion thus constitutes fairly strong evidence of deliberate reaching-for-yield behavior on the part of some small banks.

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[36] Altering the beginning and the end quarter for this period, for example, from 2001:Q1 to 2004:Q4 or even 2005:Q4, makes no difference for the qualitative conclusion. In fact, if the end quarter for the first period is extended to 2005:Q4, the mean difference between the two distributions is even greater, because banks cut back on maturity after the Fed started tightening policy in 2004:Q2.

The post-crisis lengthening of maturity on the asset side is not offset with a similar change on the liability side. Banks also increased the maturity of time deposits, but only by between three to five months, much less than the increase in maturity for assets. Importantly, the shares of transaction deposits (TD) and savings deposits (SD), neither with a stated maturity, have risen substantially at all U.S. banks since 2007, largely as the by-product of the low interest rate environment resulting from expansionary monetary policy. To see how the maturity change for total deposits depends on the effective maturity assumed for transaction and savings deposits, applying Equation (2) to total deposits (D), with s denoting share, M maturity, and CD (certificate of deposits) denoting time deposits:

$$\Delta M_D = \Delta\left[s_{TD} M_{TD} + s_{SD} M_{SD} + \left(1 - s_{TD} - s_{SD}\right) M_{CD} \right] = \Delta M_{CD} - \Delta\left[s_{TD}\left(M_{CD} - M_{TD}\right)\right] - \Delta\left[s_{SD}\left(M_{CD} - M_{SD}\right)\right] . \quad (4)$$

Given the linearity of Equation (4), M_D falls (rises) monotonically in the share of TD (s_{TD}) if M_{CD} is longer (shorter) than M_{TD}, and likewise for s_{SD}. It seems a reasonable notion that transaction and savings deposits have shorter maturities than time deposits on average. Further, if no change in M_{TD} or in M_{SD} is assumed, then the last two terms are both negative, offsetting the small positive contribution of ΔM_{CD}. Under the typical assumption of zero maturity for transaction and savings deposits, the negative terms dominate so that the maturity of total deposits falls, $\Delta M_D < 0$.

It can be argued that the stated maturity is distinct and possibly quite different from the "stickiness" concept as expounded in Hanson et al. (2015). Retail transaction and savings deposits are generally considered to be sticky. To wit, as the key elements of a bank's core deposits (which also include insured time deposits), both are funding sources encouraged by the LCR. This means that $M_{TD} > 0$ and $M_{SD} > 0$ in Equation (2) if M instead measures stickiness. However, the standard theory of money demand (for example, see Ireland 2009) suggests that it may not be prudent to count on the same degree of "stickiness" on retail transaction and savings deposits going forward. This is because the unprecedented near-zero interest rate environment, owing partly to accommodative monetary policy by the Federal Reserve and other central banks, lowered the opportunity cost of holding money-like assets such as transaction and savings deposits. The resulting elevated money holding is unlikely to be sustained as the Federal Reserve raises the policy rate over the coming years. In Equation (2), this implies that $\Delta(M_{CD} - M_{TD})$ and $\Delta(M_{CD} - M_{SD})$ are most likely positive if we use the concept of stickiness, which contributes negatively to ΔM_D. In short, higher shares of transaction and savings deposits since the crisis are more likely than not to have shortened the effective maturity of overall bank deposits.

With longer asset maturities combined with shorter liability maturities, maturity mismatch on bank balance sheets has clearly risen between 2007:Q2 and 2013:Q2, especially for those BHCs below $10 billion in assets. In Figure 1, Panel D plots the distribution of the change in total maturity mismatch over this period for the BHCs below $10 billion, confirms that the changes have a statistically significant positive mean, and shows that the post-2007:Q2 shift is significantly greater than the shift from 2000:Q4 to 2004:Q2. Moreover, it shows substantial cross-BHC dispersion in the change in maturity mismatch, echoing the pattern for maturity changes in loans and securities.

Next, time series plots are used to explore how the differential post-crisis changes in maturity composition between the largest and the smallest BHCs compare with those changes observed during the previous cycle, after the 2001 recession. In Figure 2, Panels A and B depict the maturity of loans and securities, respectively, over the sample years, with 2013:Q2 marked with a vertical grey line. The plots confirm the findings from Table 1, and further show that the increase in asset maturity among banks with less than $10 billion in assets has been fairly monotonic since around 2007:Q2. More importantly, a striking contrast emerges: the relative maturity relationship between the banks in the top and the bottom size classes prior to the crisis is exactly the opposite to the relationship observed afterward. Before 2007, the largest BHCs steadily lengthened the maturities of both loans and securities. Since 2007, these largest banks have trimmed the maturities of their asset holdings, especially securities (to basically the same level as in 2001). The relative increase in maturity among the smallest BHCs is more pronounced for loans, in that their average loan maturity has exceeded that of the largest BHCs since around 2012.

Appendix C shows that among loans (Figure C2), the relative increase in maturity by the smallest BHCs have been concentrated in loans other than first-lien mortgages.[37] In contrast, the largest BHCs have cut the maturity of such loans down to the level last seen in 1997, while maintaining their relatively higher maturities on mortgages. Figure C3 then confirms that among the three categories of securities for which maturity data are available, the relative maturity increase among the BHCs below $10 billion is most pronounced for securities other than MBS. Interestingly, the maturity of these banks' non-MBS securities shows a sharp change in trend occurring exactly in 2013:Q2 (marked by the vertical grey line). The discussion in Section VI will show that the mark-to-market losses suffered by some of the smallest BHCs prompted them to shorten the maturity of their securities portfolio. Similar to the pattern for loans, the largest BHCs maintained a longer maturity among pass-through MBS than the smallest BHCs. Other

[37] But the absolute maturity increase is about the same across the two loan categories because the first-lien mortgages tend to have much longer stated maturities. In Figure C2, the larger relative increase in "all other loans" is likely partly attributable to auto loans: A news search using (variants of) keywords "auto, loans, longer, term" turned up over 40 articles from as early as December 2012 reporting that lenders lengthened the terms of auto loans in recent years, from an average of around 60 months in 2010 to 68 months or longer in 2015, in order to cap borrowers' monthly payment despite higher loan balances. Reportedly, this lengthening of loan terms helped sustain the auto lending boom, extending funds even to borrowers with blemished credit records, and resulted in riskier loans. A precise inference, however, is not feasible given the available data.

MBS, largely consisting of structured instruments such as CMOs, tend to have fairly short maturities because they are engineered to limit term and prepayment risk (as shown in Panel C of Figure C3).

With both loans and securities exhibiting different post-crisis changes in behavior between the largest and smallest banks, it is not surprising that their sum, the bulk of interest-earning assets, displays a similar maturity extension by BHCs in the smallest size group versus maturity contraction by the largest BHCs. As shown in Panel C of Figure 2, the average maturity of loans and securities at BHCs smaller than $10 billion has caught up with the largest BHCs, and has exceeded the BHCs in the two middle size groups.

Table 1 confirms that cash holdings in the form of reserves increased significantly in the first few years after 2008 (as documented in Ennis and Wolman 2015), owing to expansionary monetary policy. The largest banks have a greater incentive to increase their holdings of reserves, which are among the most favored HQLA in the LCR rule. The larger post-crisis increase in the share of cash on their balance sheets thus further lowered the maturity of their total assets relative to the banks in the other three groups, for a zero maturity is assigned to cash instruments.[38] This can be seen in Panel D of Figure 2, which depicts the maturity of total financial assets—the sum of loans, securities, and cash—of BHCs in each size class. This figure sums up the difference-in-differences behavior across BHCs in the top versus the bottom size classes before and after the financial crisis.

To recap, the largest BHCs (those subject to the advanced approaches) substantially increased the maturity of their assets (from three to five years) prior to the crisis, mostly during the 2001 recession and shortly after. Within a year after the onset of the financial crisis, they cut the average maturity down to four years. Their asset maturity has been stable since then. In contrast, the smallest BHCs, those below $10 billion in size, kept their asset maturity within a narrow range prior to the crisis, but have since consistently increased it from 3.5 years to five years, in fact exceeding the asset maturity of the largest BHCs since 2012. The asset maturity of BHCs with $50–$250 billion in assets rose slowly from 3.5 to four years before the crisis, dipped slightly during the crisis, and resumed the shallow upward trend afterward.[39]

On the liability side, in Figure 3, Panel A shows that the rise in the maturity of time deposits after

[38] Cash instruments here include those reported in Schedule RC-A of the Call Reports, the fed funds sold, and reverse repos. The latter shrank notably during and after the crisis because of illiquidity or credit concerns in the repo market, and volume contraction in the fed funds market owing to the massive increase in reserve balances, which obviate the need to trade in the funds market for most banks.

[39] By comparison, the third group of BHCs by size shows a more erratic time path in its asset maturity, but this is a result of the small sample size, so that any change in one or two major constituent BHCs causes large jumps in a series.

2007:Q2 is comparable in magnitude with the rise in maturity seen during the recovery after the 2001 recession. The largest BHCs, after having raised their time deposits' maturity by more than the other three BHC groups shortly after 2007:Q2, undid half of that increase after 2012.[40] Combined with a substantial increase in shares of transaction and savings deposits (as shown in Figure C4, Panels B and C), which are assigned a maturity of zero, the maturity of total deposits has trended down for all banks since 2007:Q2 (see Figure 3, Panel B). The pattern remains qualitatively the same as long as a shorter maturity is assumed for transaction and savings deposits than for time deposits on average, as explained above. A qualitatively similar pattern also emerges for total liabilities (see Panel D of Figure C5).[41] In part, this similarity results from the fact that the maturity of other borrowed money has barely risen since the crisis (see Figure C5, Panel C).[42] Moreover, deposits constitute the bulk of liabilities (as shown in Figure C4, Panel A), especially for the smallest banks, while all banks increased the share of deposits among their funding sources after the crisis.[43]

Finally, time series plots also confirm that banks, especially those with assets less than $10 billion, have increased the maturity mismatch on their balance sheet, as shown in Figure 4, Panels A and B. Panel A plots the maturity difference between total financial assets and total liabilities, while Panel B plots the maturity difference between assets and liabilities with non-zero maturities.[44] Both panels clearly show that the relative "catching up" by those BHCs below $10 billion is robust to the use of either measure. These findings are consistent with the conjecture that banks, if able, searched for yield after the crisis. In

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[40] Table 1 and Figure C5 (in Appendix C) make clear that the increase in the maturity of time deposits is mostly driven by those deposits that fall below the insurance limit (considered part of a bank's core deposits). By comparison, the largest BHCs lengthened the maturity of their uninsured time deposits slightly after the recession but have since cut it to the historically low level seen just before the crisis. This behavior suggests that the relative cost of extending the maturity of funding is greater for uninsured depositors, who may be high net worth individuals or firms, possibly because these depositors rely on the short maturity to effect the safety they demand in such investment, as argued in Stein (2012) and Hanson et al. (2015).

[41] Prior to 2009, the maturity of subordinated debt can only be inferred imprecisely by extrapolating the data for each BHC. Fortunately, the share of subordinated debt is small for all but the largest BHCs, and vanishingly small for the BHCs below $50 billion (those outside of the top two size bins).

[42] A major component of this category is borrowing from the Federal Home Loan Banks (FHLBs). As Ashcraft, Bech, and Frame (2010) show, the FHLBs became the lender of next-to-last resort during the crisis. The decrease in the maturity of other borrowed money in 2006:Q3 is due to a definitional change from only maturity to a separation between maturity and the next repricing date.

[43] Compared to the smallest BHCs, the BHCs in the top three size classes raised their share of funding from deposits more, a decision likely driven by the newly instigated liquidity requirements. These rules are clearly applicable to the top two sizes of BHCs, while the third size class may be anticipating that the rules will become relevant to them as they grow or because they are expecting investors to measure their liquidity strength using similar standards.

[44] Non-zero-maturity assets equal loans plus securities, while non-zero-maturity liabilities exclude transaction and savings deposits. This measure is free of any assumption regarding the effective maturity of these deposits without stated maturities. The similar pattern between the two measures also reveals that the increase of cash instruments on the asset side partially offsets the increase of transaction and savings deposits on the liability side.

the first few post-crisis years, they did so by loading up on risks that would not necessarily incur explicit future losses, mainly prepayment risk and interest rate risk through maturity mismatch. As argued above, the systematic difference in the post-crisis maturity change for securities held by the largest and the smallest BHCs constitutes more persuasive evidence that the latter group actively chose to increase their asset maturities and in turn their maturity mismatch, regardless of their borrowers' preferences.

3.3 Balances of AFS Securities Adjusted for Changes in Fair Value Stemming from Yield Movements

As noted above, the balance reported for each maturity bin is the sum of the book value (BV) for held-to-maturity (HTM) securities and the fair value (FV) for available-for-sale (AFS) securities whose maturities fall within the relevant range. If these balances are used directly as weights, a bank with a longer initial weighted-average asset maturity can appear to extend its assets' maturity during the ZLB period even if it has kept its portfolio constant. This erroneous inference arises because the prices of longer-dated debt generally move more than the prices of shorter-dated debt for any given change in yield. This means that during the ZLB period, when short rates were constrained near zero while long yields had declined in part owing to the Federal Reserve's unconventional monetary policy, the FV of AFS securities would rise more, on average, for portfolios with longer initial repricing intervals. The resulting potential bias can be nontrivial because it is more typical for banks to classify securities as AFS instead of HTM (as shown in Table C2), presumably because of the liquidity advantage afforded by the former category—banks can easily sell AFS securities to raise funds but face hurdles if they want to sell HTM securities.

Note, however, the truly important question for the analysis here is to what extent this bias can account for the *differential* post-crisis development of the average maturity of securities when the largest banks are compared to the rest of the banking industry, especially to those banks with less than $10 billion in assets. The short answer is none, even if all the on-balance-sheet debt behaved like Treasuries. This is because prior to the crisis, the largest banks used to hold securities with much longer maturities. All else being equal, the largest banks should have seen the average maturity of their debt portfolios rise more than the other banks, but this prediction is exactly opposite to the post-crisis development observed in the data. This contradiction strengthens the case that the increase in the maturity of securities held by the smallest banks is the result of an active choice on their part.

3.3.1 Fair Value Adjustments for Debt Securities without Embedded Options

Nevertheless, it is prudent to assess to what extent the cross-section comparison of post-crisis maturity changes is affected by price changes alone. This potential bias should be most relevant for those debt securities without embedded options, such as the Treasury and agency securities included in category 3) above, which will be the focus for this analysis. It is well understood that for debt without embedded options, the percentage increase (decrease) in price in response to a parallel downward (upward) shift in the yield curve is proportional to the bond's duration to a first-order approximation:[45]

$$r_{nt} \approx D_n y_{n,t-1} - (D_n - 1) y_{n-1,t}, \tag{5}$$

where r_{nt} is the holding-period (log gross) rate of return from t–1 to t, while $y_{n,t-1}$ and $y_{n-1,t}$ denote, respectively, (log gross) yields of the debt in time t–1 and t (when its duration shrinks by one period). The time to maturity is denoted by n and the duration is denoted by D_n. For coupon bonds, n and D_n have the approximate relationship: $D_n \approx (1-Y_{nt}^{-n})/(1-Y_{nt}^{-1})$, where $Y_{nt} = \exp(y_{nt})$ is the gross yield. Thus, n always exceeds D_n and, for any given maturity, the higher the coupon rate or yield, the lower the duration. For long-dated bonds, when n and D_n are measured in quarters, Equation (5) simplifies to reveal that the price's growth rate, equal to the total rate of return net of coupon yield, is the (negative) yield change scaled by duration:

$$dP_{nt}(Y_{nt})/P_{nt} = r_{nt} - y_{nt} \approx -D_n(y_{nt} - y_{n,t-1}) . \tag{6}$$

This demonstrates the potential bias in maturity comparisons for the ZLB period, as mentioned above.

As detailed in Appendix B, the best measure of revaluation due to yield changes is using (normalized) unrealized gains/losses, equal to the proportional difference between the FV change and the BV change: $\Delta FV_t/FV_{t-1}$ - $\Delta BV_t/BV_{t-1}$. This is because the FV and the BV should change (inversely to yield moves) by different amounts almost entirely because of the marking-to-market of the quarter-end outstanding balance:

$$\begin{aligned}&\left[\sum\nolimits_{i=1}^{N} FV_{t,T,i}^{A} \Big/ \sum\nolimits_{i=1}^{N} FV_{t,0,i}^{A}\right] - \left[\sum\nolimits_{i=1}^{N} BV_{t,T,i}^{A} \Big/ \sum\nolimits_{i=1}^{N} BV_{t,0,i}^{A}\right] \\ &\approx \sum\nolimits_{\tau=0}^{T} w_{t,\tau}^{FV} \ln\left[\sum\nolimits_{i=1}^{N} w_{t,i}^{FV} \exp\left(-D_{t,i}\sum\nolimits_{\tau=1}^{T}\Delta y_{t,\tau,i}\right)\left(1-\bar{\delta}_{t,i}\right)\right] - \sum\nolimits_{\tau=0}^{T} w_{t,\tau}^{BV}\left[\left(T-\tau\right)\left(y_t^{\tau}-c_t^{\tau}\right) - \sum\nolimits_{i=1}^{N} w_{t,\tau,i}^{BV}\bar{\delta}_{t,\tau,i}\right].\end{aligned} \tag{7}$$

$FV_{t,T,i}^{A}$ ($BV_{t,T,i}^{A}$) denotes the quarter-end FV (BV) of AFS securities in maturity bin i, while $FV_{t,0,i}^{A}$ ($BV_{t,0,i}^{A}$) denotes the FV (BV) of the initial portfolio in quarter t (see Appendix B for details).

To remove the effect of yield changes on the balance of debt in each maturity bin, the total unrealized gains/losses on each category of AFS securities is apportioned across the maturity bins. Since a precise allocation is not feasible given the existing data, the most conservative approach is used here—attributing as much to the longest maturity bin as is consistent with the balance change in that bin and the

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[45] See Campbell, Lo, and MacKinlay (1997), p. 408. Also see Equation (A.3) in the appendix.

yield change in that quarter (see the derivations in Appendix B). Specifically, the following imputation is carried out: first allocate the total AFS unrealized gains/losses for category 3) securities to the longest maturity bin if the quarterly change in balance for that bin is of the opposite sign to the quarterly change in the 10-year Treasury yield. Any remaining gains/losses are then sequentially assigned to the next bin of successively shorter maturity ranges according to the same criterion—if the balance moves inversely to the quarterly change in maturity-matched Treasury yields. While the focus here is on securities other than MBS, the same imputation method is applied to MBS to obtain the adjustment for total securities.

Table 2 reports the impact of the resulting imputed balances by maturity bin on the estimated maturities of the three categories of securities, comparing the largest with the smallest size group of BHCs. It is clear that the FV adjustments have a minimal impact on the maturity estimates. Most importantly, these adjustments leave intact the pattern of relative post-crisis changes in the maturity of securities between these two groups of banks.

3.3.2 Fair Value Adjustments for MBS—Debt with the Embedded Prepayment Option

Compared to Treasuries, MBS are less subject to the bias due to FV appreciation because of their negative convexity owing to the prepayment option.[46] Convexity is defined as $\partial D_{nt} \big/ \partial Y_{nt} = \partial^2 P_{nt} \big/ \partial Y_{nt}^2 P_{nt}$; it thus shows up in the second-order term in the Taylor series approximation of a bond's price change as a function of yield change (by comparison, Equation (6) above contains only the first-order approximation):

$$r_{nt} - y_{nt} \approx -D_n (y_{nt} - y_{n,t-1}) + \tfrac{1}{2}\text{convexity}(y_{nt} - y_{n,t-1})^2 . \tag{8}$$

The terms are defined the same as in Equation (6). A negative convexity means that the second-order term always causes the price to fall whenever the yield moves. This reinforces the first-order impact of a yield increase on a bond's price but dampens the impact of a yield decline. Note that this mechanism would also show up for mortgage loans held on a bank's balance sheet if these loans were also required to be recorded at FV. The implication for the period since the financial crisis, when long yields have largely trended lower, is that because of the negative convexity, the boost to MBS valuation has been less than would be implied by the linear term alone.

Not only does the prepayment option lead to negative convexities on MBS, but it also shortens the effective duration of MBS and mortgage loans on average. As shown in Figure 5, Panel A , the option-

[46] That is, an MBS's price does not rise as much as the duration-matched Treasury bond when yields fall because borrowers tend to refinance, effectively shortening the maturity of the MBS bond. On the flip side, the bond price falls more than the duration-matched Treasury when yields rise as the prepayment rate drops.

adjusted modified duration of the Barclays Capital U.S. MBS Index fluctuates between a minimum of 0.91 (in 2002:Q3) and a maximum of 5.62 (in 2013:Q4), and averages 3.42 years during the 1997:Q2–2015:Q4 period.[47] These values are clearly much shorter than the average stated maturity of 10 to 15 years for pass-through MBS held on banks' books. For comparison, Panel B plots the Mortgage Bankers Association's Refinance Index (detrended using the Hodrick-Prescott filter) against the Barclays MBS duration. As would be expected, refinancing and duration are negatively correlated. This explains why the duration peaked after the taper tantrum in 2013:Q2, as markets anticipated that yields would return to higher, more normal, levels. But declines in yields over mid-2014 to mid-2016 have driven up refinancing activity and driven down duration. Going forward, if yields trend up as the Federal Reserve normalizes policy, mortgage duration will rise, likely to the mid-2013 levels, which is high by historical standards. MBS will then behave more like long-term Treasury bonds in terms of interest rate risk.

Because of the prepayment option embedded in MBS, a more precise measure of the sensitivity of MBS FV to yield changes is needed than the maturity reported in the Call Reports. It seems natural to directly estimate the beta (loading) of unrealized gains/losses (the best measures for mark-to-market value changes as noted above) with respect to the price return of the Barclays Capital U.S. MBS Index, which encompasses the complete response to a yield change, as shown in Equation (8).[48] To allow this exposure measure to vary over time, the beta of unrealized gains/losses on AFS pass-through MBS securities is estimated in each quarter t for a merger-adjusted BHC i using a four-quarter rolling window from t–3 to t:[49]

$$\beta_{it} = \mathrm{cov}_{s=t-3\to t}\left(\Delta FV_s / FV_{s-1} - \Delta BV_s / BV_{s-1}, \Delta \ln\_P_s^{MBS}\right) \Big/ \mathrm{var}\left(\Delta \ln\_P_s^{MBS}\right). \quad (9)$$

In Figure 5, Panel C plots the asset-weighted-average estimated betas of the AFS pass-through MBS for the largest BHCs and the smallest BHCs. It shows that the largest BHCs have a reasonably stable MBS price beta of near one, which suggests that they tend to hold a portfolio that mirrors the market. This is probably not surprising: given their size, it would be hard for the largest BHCs to skew heavily toward any specific MBS pool without incurring nontrivial transaction costs. By comparison, the smallest BHCs on average have a lower beta, suggesting that they tend to buy MBS that are less sensitive to yield movements. This finding is qualitatively consistent with the overall difference between these two groups

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[47] The Barclays Capital U.S. MBS Index is a widely used benchmark index. It covers pass-through MBS guaranteed by the U.S. housing agencies (Ginnie Mae, Fannie Mae, and Freddie Mac), backed by conventional fixed-rate mortgages. See Hanson (2014) for more details. In Figure 5, Panel A also plots the convexity of the Barclays MBS index (on the right axis). It is clearly negative throughout the sample.

[48] This is similar to the analysis by Begenau, Piazzesi, and Schneider. (2015), which assesses the risk exposure of bank asset portfolios by using the sensitivity of bank assets' fair value to market yield factors.

[49] The same qualitative time series of beta estimates are obtained if an eight-quarter window is used instead.

in terms of the pass-through MBS maturities listed in the Call Reports: the largest BHCs on average have a (much) longer maturity (meaning longer duration) and thus greater value sensitivity. The correlation at the BHC level between the estimated beta and the reported maturity, however, is rather low, especially during the refinancing boom that took place around 2003. The lack of a monotonic relationship between the reported maturity and price sensitivity is not too surprising because the coupon rate also matters: a long-maturity high-coupon MBS can appreciate less than a shorter-maturity, lower-coupon MBS when yields fall because the mortgages underlying the former are prepaid at a much faster rate.[50]

For comparison with Panel C in Figure 5, Panel D presents the direct loading of unrealized gains/losses on yield, which serves as a proxy for duration, since the first-order term in Equation (8) dominates variations in price (which implies that the duration estimate approximately equals the product of the price beta in Panel C and the duration of the MBS index). The durations of the largest BHCs' MBS portfolios are longer than those of BHCs below \$10 billion on average. The largest BHCs' durations were longer than that of the market portfolio in the MBS index in the late 1990s and early 2000s, but fell below the market portfolio in recent years. In comparison, the durations of the smallest BHCs fluctuate within the same lower range over the sample years.

3.4 Conditional Estimates of Weighted-average Maturities of Assets and Maturity Mismatch

This section shows that the change in aggregate economic conditions, in particular the overall interest rate level as well as slope of the yield curve, cannot explain the above unconditional finding that, since the recession, the smallest banks have raised the maturity of their assets, and in turn the degree of maturity mismatch on their balance sheet. To this end, the relationship between a BHC's asset maturity and current and lagged levels of long and short yields is estimated using a fixed-effects panel regression:

$$M_{it} = \alpha_i + \beta y_t + \gamma^{+} \Delta y_t \bullet 1_{\Delta y \geq 0} + \gamma^{-} \Delta y_t \bullet 1_{\Delta y < 0} + \varepsilon_{it} \,. \tag{10}$$

M_{it} denotes the maturity of an asset or liability category of BHC i in quarter t. It is modeled to depend on the current yield y_t and the quarterly change in yield, Δy_t. The effect of a yield increase is allowed to differ from that of a yield decrease, with 1_x being an indicator variable equal to one when condition x is met and zero otherwise. The model developed in the next section will suggest that bank asset maturity may evolve differently when market yields rise than when yields decline. This is equivalent to allowing the coefficients on both current and lagged yields to differ, since

$$\beta y_t + \gamma^{+} \Delta y_t * 1_{\Delta y \geq 0} + \gamma^{-} \Delta y_t * 1_{\Delta y < 0} = \left[\left(\beta + \gamma^{+} \right) y_t - \gamma^{+} y_{t-1} \right] * 1_{y(t) \geq y(t-1)} + \left[\left(\beta + \gamma^{-} \right) y_t - \gamma^{-} y_{t-1} \right] * 1_{y(t) < y(t-1)} \,. \tag{11}$$

[50] Besides, there is cross-BHC dispersion in the duration of MBS reported in the longest maturity bin of over 15 years.

The estimation sample covers 1997:Q3 to 2007:Q2. Quasi-out-of-sample forecasts of asset maturity are then generated using the realized values of these yields since 2007:Q3.[51] The forecast maturity of bank assets and maturity mismatch are reported in Figures 6 and 7, each consisting of two panels for BHCs in the top and the bottom size class respectively.

It is clear that the pattern of the actual values versus the forecast values confirms the systematic difference between the largest and the smallest BHCs before and after the crisis. Specifically, the actual values for the largest BHCs since the crisis are within two standard deviations of the point forecasts, meaning they are statistically the same. In contrast, the actual time series since the crisis is significantly outside of the two-standard-deviation band of the predicted values for the BHCs below $10 billion. The pattern for the two middle two size groups are comparable to that observed for the largest BHCs: the post-crisis actual is not significantly different from the forecast.

I experimented with varying lags of the long and short yields, as well as with using yield curve factors instead. But similar to the findings in Bolotnyy, Edge, and Guerrieri (2015), the difference in the root mean square errors is limited, and the specifications with shorter lags (and hence a lower likelihood of overfitting) tend to produce somewhat better out-of-sample forecasts. More importantly, none of these variant forecasts change the qualitative message of the relative relationship between the behavioral changes in the largest versus the smallest banks since the crisis.

IV. How Banks Reach for Non-Credit Risk: Theory and Empirical Evidence

4.1 Modeling How Banks Reach for Non-Credit Risk

This section develops a simple model of banks' investment and funding choices to identify the conditions—particularly those related to business cycle downturns when the slope of the yield curve is steep relative to the average level of yields—that prompt banks to take on more risks to obtain a higher yield today at the expense of incurring likely future losses in economic value, albeit losses that need not be recognized under the standard accounting rules. For brevity, this type of risk, which encompasses interest rate risk, prepayment risk, and liquidity risk, is referred to as non-credit risk; the key distinction centers on how future losses in value are recognized—explicitly written off or masked by selecting suitable accounting methods.

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[51] The unbalanced nature of the panel makes out-of-sample forecasting more challenging. The following steps ensure that the in-sample fitted line is consistent with the out-of-sample forecast line: 1) for each post-merger BHC, the weighted-average of the estimated fixed effects is used for the acquirer and the target, 2) any post-2007:Q2 sample BHC is excluded from the out-of-sample forecast if it does not have a predecessor in the estimation sample, either as a party to a merger or as a bank before it was incorporated as a BHC.

The model features two periods, t = 1 and 2. Banks can invest in three types of assets: the first is a risk-free, one-period (that is, short-term) debt instrument S, which pays interest rate r_t^{RF} , t = 1, 2. Note that r_2^{RF} is unknown, and thus is a random variable at t = 1. The second asset is a credit-risk-free two-period (that is, long-term) bond A, whose interest rate r^A is set at $t = 1$ and paid in each period. Its fair value will fall if the level of the interest rate rises; that is, if $r_2^{RF} > r_1^{RF}$. The third asset is a risky one-period debt L, which represents the loans held by the bank; its contractual interest rate r_t^L , t = 1, 2, is set at the beginning of each period, but the realized rate will be lower if the borrower defaults. If the fraction of the overall loss due to default is denoted as δ^L, then the bank's realized net return is $(1 + r^L)(1 - \delta^L) - 1 \approx r^L - \delta^L$, assuming that both r^L and δ^L are small so that their product can be ignored. Banks are assumed to obtain funding solely from deposits D, which are all one-period contracts paying rate r_t^D in each period t. Each bank is endowed with capital E_1 at t = 1, and this period also starts with a legacy asset, L_0, that must be financed through t = 2; think of L_0 as a long-term loan or a commitment that must be honored. L_0 is subject to default in each period, with the fraction of loss denoted as d_t^L , t = 1 and 2. The rate L_0 pays is denoted as r_0^L .

Each bank's optimal investment decision is now analyzed. For clarity of notation, the bank-specific subscript is omitted. Each bank maximizes the present discounted value of the profit earned over the two periods, subject to the balance sheet identity and the capital requirement in each period.

$$\max \mathbf{E}_1 \left\{ \begin{array}{l} \left[\left(r_0^L - d_1^L\right) L_0 + r_1^{RF} S_1 + \left(r^A - \delta_1^A\right) A_1 + \left(r_1^L - \delta_1^L\right) L_1 - r_1^D D_1 \right] \\ + \beta \left[\left(r_0^L - d_2^L\right)\left(1 - d_1^L\right) L_0 + r_2^{RF} S_2 + r^A A_1 - \delta_2^A A_2 + \left(r_2^L - \delta_2^L\right) L_2 - r_2^D D_2 \right] \end{array} \right\}, \tag{12}$$

$$\text{subject to } L_0 + S_t + A_t + L_t = D_t + E_t,\ t = 1, 2, \text{ and } A_2 \le \left(1 - \delta_1^A\right) A_1, \tag{13}$$

$$E_t \ge k D_t,\ t = 1, 2, \tag{14}$$

$$D_1 + E_1 \ge L_0 \text{ and } D_2 + E_2 \ge \left(1 - d_1^L\right) L_0 + A_2, \tag{15}$$

$$r_t^D = r_t^{RF} - p\left(D_t\right), \text{ with } p_t(0) = r_t^{RF}, p(\bar{D}) = 0, \text{ and } p_t'(.) < 0,\ t = 1, 2, \tag{16}$$

$$\text{and } E_2 = E_1 + \left[\left(r_0^L - d_1^L\right) L_0 + r_1^{RF} S_1 + \left(r^A - \delta_1^A\right) A_1 + \left(r_1^L - \delta_1^L\right) L_1 - r_1^D D_1 \right]. \tag{17}$$

Equation (12) is the bank's objective function, with expectation (**E**) taken at $t = 1$. The terms in the first and the second square brackets tally up the bank's net return at the end of periods 1 and 2, respectively. In each period, the interest earned on assets is net of the interest paid on deposits, as well as losses, if any, in the long bond's FV (denoted δ^A) and losses on loans due to default (d^L and δ^L). Note that unlike default losses on loans, losses in the FV of long bond A due to a yield increase does not reduce the interest earned in period 2. More important for our purpose, Equation (9) can accommodate both HTM and AFS accounting treatments of the long bond, with $\delta^A = 0$ if A is classified as HTM. Obviously, δ^A, d^L, and $\delta^L \in [0, 1]$. The payoff in period 2 is discounted by a factor β, which is taken as exogenously given.[52]

Equation (13) is the balance-sheet identity along with the evolution of the long bond's balance, which may be marked to market if it is accounted for as AFS. The long bond A can be sold if necessary (to satisfy the bank's required capital ratio); liquidity is an important feature that distinguishes securities from loans. Equation (14) is the capital requirement—a bank's debt cannot exceed a multiple ($1/k$) of its equity capital.[53] Note that Equation (14) best approximates the leverage ratio, not the risk-weighted, capital requirement. If the latter is used instead, it will only strengthen the result by raising the capital-adjusted return on safe long bonds relative to risky loans when a bank is capital constrained, which tends to occur during downturns. Equation (15) defines the minimum need for funding due to outstanding long-term assets. Equation (16) describes the demand curve for bank deposits: the bank has market power and thus can pay a rate lower than the market risk-free rate up to a certain amount of deposits ($\bar{D}$). Equation (17) describes the capital accumulation, which is assumed to come only from internal funds.[54] It is reduced by losses due to default (some of which are on the legacy loans) and revaluation.

To solve for the bank's optimal choice of asset mix and leverage, by using Equation (17) to substitute out E_2 in Equation (13) and by using Equation (13) to substitute out S_t, the following Lagrangian is obtained:[55]

$$\mathcal{L} = \mathbf{E}_1 \left\{ \beta \left[\left(r_0^L - d_2^L\right)\left(1-d_1^L\right)L_0 + r_2^{RF}\left(\Pi_1 + E_1 + D_2 - A_2 - L_2 - \left(1-d_1^L\right)L_0\right) + r^A A_1 - \delta_2^A A_2 + r_2^L\left(1-\delta_2^L\right)L_2 - r_2^D D_2 \right] \right\}$$
$$+ \Pi_1 + \lambda_1\left(E_1 - kD_1\right) + \lambda_2\left(\Pi_1 + E_1 - kD_2\right) + \theta\left[D_2 + \Pi_1 + E_1 - \left(1-d_1^L\right)L_0 - A_2\right], \quad (18)$$

where $\Pi_1 \equiv \left(r_0^L - d_1^L\right)L_0 + r_1^{RF}\left(E_1 + D_1 - A_1 - L_1 - L_0\right) + \left(r^A - \delta_1^A\right)A_1 + \left(r_1^L - \delta_1^L\right)L_1 - r_1^D D_1$ denotes the period 1 net return. In Equation (18), λ_1 and λ_2 are the Lagrangian multipliers for the capital requirement in $t = 1, 2$ and measure the shadow value of capital. Here θ is the multiplier for the bank's period 2 funding needs, which measures the shadow cost of the legacy loans. The first-order conditions (FOC) for A_1, L_1, D_1, L_2,

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[52] In standard finance models, β depends on the systematic risk of the bank's asset portfolio, which varies over the business cycle. However, it can be argued that a bank's assessment of risk is more determined by the regulatory risk weights. Then one can use a constant β while explicitly assigning risk weights in the capital requirement.

[53] If the capital requirement is replaced with a value-at-risk (VaR) constraint, the amount of a bank's assets exposed to risk that will incur explicit future losses will be directly tied to the amount of capital, although the shadow value of capital will always be positive.

[54] Implicitly it is assumed that capital is always positive, as long as the bank owns any assets.

[55] It is assumed that the initial capital in period 1, E_1, is sufficient to fund the legacy loans; that is, $E_1 \geq kL_0/(1+k)$.

and D_2 are:

$$\partial \mathcal{L}/\partial A_1: \quad \left(r^A - r_1^{RF} - \delta_1^A\right) + \beta \mathbf{E}_1\left[r_2^{RF}\left(r^A - r_1^{RF} - \delta_1^A\right) + \left(r^A - r_2^{RF} - \delta_2^A\right)\left(1-\delta_1^A\right)\right] + \lambda_2\left(r^A - r_1^{RF} - \delta_1^A\right) = 0, \quad (19)$$

$$\partial \mathcal{L}/\partial L_1: \quad \left(r_1^L - r_1^{RF} - \delta_1^L\right) + \beta \mathbf{E}_1\left[r_2^{RF}\left(r_1^L - r_1^{RF} - \delta_1^L\right)\right] + \lambda_2\left(r_1^L - r_1^{RF} - \delta_1^L\right) = 0, \quad (20)$$

$$\partial \mathcal{L}/\partial D_1: \quad r_1^{RF} - \left(r_1^D D_1\right)' + \beta \mathbf{E}_1\left[r_2^{RF}\left(r_1^{RF} - \left(r_1^D D_1\right)'\right)\right] - \lambda_1 k + \lambda_2\left[r_1^{RF} - \left(r_1^D D_1\right)'\right] = 0, \quad (21)$$

$$\partial \mathcal{L}/\partial L_2: \quad \beta \mathbf{E}_1\left(r_2^L - r_2^{RF} - \delta_2^L\right) = 0, \quad (22)$$

$$\partial \mathcal{L}/\partial D_2: \quad \beta \mathbf{E}_1\left[r_2^{RF} - \left(r_2^D D_2\right)'\right] - \lambda_2 k = 0. \quad (23)$$

In all the above equations, $\left(r_t^D D_t\right)' \equiv \partial\left(r_t^D D_t\right)/\partial r_t^D$, t = 1, 2, denotes the marginal cost of deposits, which is increasing if the bank faces a downward-sloping demand curve for deposit accounts.

The FOC (19) and its comparison with Equations (20) and (22) are key to understanding the bank's rationale of using safe long bonds to reach for yield. The reasoning rests on the tradeoff between the positive yield spread earned on long bonds, $r^A - r_1^{RF}$, versus the expected value loss δ_1^A in t = 1. For the bond market to be in equilibrium, the term spread should be exactly offset by the expected change in valuation.[56] If the capital constraint, Equation (11), is not binding at t = 2, meaning the shadow value of capital λ_2 is 0, the bank should be indifferent between holding the risk-free one-period bond and the long-dated bond if the expectation hypothesis holds: $2r^A \approx r_1^{RF} + r_2^{RF}$ and $\delta_1^A = \delta_2^A = 0$.[57] However, if a positive term premium exists, then the bank will invest only in the long bond and not in the short bond (because of the linear structure). A special consideration for a bank's choice of assets is that if a positive term spread exists in period 1, that is, if $r^A > r_1^{RF} + \delta_1^A$, this spread confers extra value when the bank expects to be capital constrained in period 2, as the extra return in period 1 contributes to satisfying its capital requirement in period 2, and thus is valued at $\lambda_2 > 0$.

Regarding the short-term loan, the marginal tradeoff is qualitatively the same: the bank needs to charge a rate higher than the expected return in order to cover the expected loss due to default. On average the bank should earn the risk-free rate since this model ignores the credit risk premium. But this also means that the bank earns a positive spread on solvent loans but loses on loans that default. This

[56] Note this means the model implicitly assumes that, in market equilibrium, the long bond does not offer a higher expected rate of return relative to the one-period risk-free debt, whose rate acts as the marginal return for the long bond as well. In other words, the strict form of the expectations hypothesis holds.
[57] This equality holds exactly if the r's are log gross returns.

marginal tradeoff would apply equally to loans made in both periods if not for the potential capital constraint occurring in $t = 2$. A comparison between the FOC for loans in period 1, described in Equation (20), and in period 2, described in Equation (22), highlights the difference: the within-period tradeoff is the same but the net margin on loans in period 2 does not confer any extra value from relaxing the bank's potential capital constraint in the next period.

In terms of the choice in period 1 between investing in the risk-free long bond and the risky loan, assets which both offer a higher yield than the risk-free short debt in period 1, the bank should choose whichever instrument offers a higher yield spread net of its expected cumulative loss at the end of period 2—if the bank does not anticipate capital to be constrained at the beginning of period 2.[58] If, however, the bank anticipates the capital requirement to be binding at the start of period 2, then the net yield spread it earns in period 1 confers extra value. Suppose that $\delta_1^A = 0$, either because the bank can account for the bonds as HTM on its book or because the Fed offered sufficiently clear forward guidance about not raising rates for an "extended period" until a specific date (period 2 in this case). At the same time, suppose that $\mathbf{E}_1\left(\delta_1^L\right) > 0$, which is more likely to occur during an economic downturn. Then there is more incentive for the bank to invest in the long bonds relative to making the short-term loan when $\lambda_2 > 0$, even if the long bond offers the same expected cumulative rate of return as loans made over the two periods.

In fact, the same argument suggests that banks also have an incentive to lengthen the maturity of its loan portfolio to the extent that this extension reduces δ_1^L because it lowers the amount amortized per period (and hence the cash outlay relative to the exogenously given borrower income), all else being equal. This maturity extension then generates a higher net margin for the bank in period 1, helping to relax the anticipated capital constraint at the start of period 2. This logic is easily illustrated by recasting the long bond in the model as a two-period loan. The bank's incentive is further strengthened if by lengthening the maturity of its loan portfolio, the bank could also use the long bond's yield r^A as the reference rate and charge a higher rate on the loan, thus generating a higher margin as long as the loan is not yet in default. Note that in this model, the bank should be indifferent to the loan maturity as long as the bank obtains the same cumulative return, unless it expects to become capital constrained in the future. In that case, the bank prefers to pull forward its net cash inflow.

A similar argument suggests that another reason banks may hold more long bonds during

[58] This corner solution would be replaced by an interior solution if the bank were assumed to face a downward-sloping demand for loans. Then the bank would always make some loans and only be indifferent at the margin between holding risky loans and the credit-risk free long bond.

economic downturns is if they face diminished loan demand. In the model, this drop in loan demand would translate into a lower r^L (or a lower loan demand schedule in place of a uniformly lower loan rate).[59] This lower expected return would lead banks to favor long bonds. On the flip side, banks are likely to favor issuing short-term loans relative to holding long bonds during booms, when δ_1^L tends to be low, and perhaps especially low relative to the expected mark-to-market losses on long bonds due to the anticipated tightening of monetary policy. At the same time, the term spread tends to be low during economic booms because short rates tend to be high relative to long rates, which equal the average of future short rates. On the other hand, the likelihood of a bank encountering a binding capital requirement should also be lower during booms, in which case banks should evaluate the merits of holding long bonds relative to short-dated loans based on the expected cumulative return.

It is clear from the model that, in the cross-section (that is, across BHCs), there is not necessarily a monotonic relationship between the average rate earned on a bank's assets and the average maturity of these assets, as long as the loan rate r^L in period 1 exceeds the two-period bond's yield r^A, likely due to the bank's market power, the credit risk premium, or both. Similarly, in a time series, if the short rates rise in period 2, then the average yield earned on all assets ($\bar{r}$) generally rises, even while the assets' average maturity ($\bar{M}$) declines, since $\bar{M}_1 = 1 + s_{A_1}$ is greater than $\bar{M}_2 = 1$. The average yield is unconditionally higher in t = 2 if $r_2^{RF} > r_1^{RF}$, but the bank's total return may be lower due to recognizing mark-to-market losses. Specifically, if $r_2^{RF} > r^A > r_1^{RF}$, then the share of long bonds in period 2 needs to be capped by $s_{A_1,2} < \left[s_{A_1,1}\left(r^A - r_1^{RF}\right) + \left(r_1^{RF} - r_2^{RF}\right)\right] \Big/ \left(r_2^{RF} - r^A\right)$ for the realized return not to fall.

To obtain the opposite relationship in the time series, meaning that the average rate earned falls while the average maturity rises, the legacy asset can instead be interpreted as a securities portfolio. Denote the outstanding balance of the two-period bond purchased the prior period (t = 0) as A_0, so that the balance sheet identity for period 1 becomes $A_0 + S_1 + A_1 + L_1 = D_1 + E_1$. Clearly, if $r_1^A < r_0^A$, meaning that the long yield has fallen, then we can have $\bar{r}_1 < \bar{r}_0$ and yet $\bar{M}_1 > \bar{M}_0$.

Another factor that may predispose a bank toward seeking a higher yield by taking on more risk during an extended period of low interest rates is whether the bank used to earn a wider net interest margin in previous cycles. The underlying logic can be likened to habit formation: a bank's performance metrics are benchmarked to its past margins so that managerial and employee compensation rises in the

[59] This lower demand occurs for any given level of borrower risk. During recessions, the observed contractual loan rates may rise because borrowers also become more risky.

relative margin today, generating an incentive for yield-seeking behavior at a time when the bank's funding cost cannot fall further because of the zero lower bound (ZLB). Another reason could be that some banks have committed to delivering a level of outflows, such as paying dividends commensurate with their past levels of net margin, and that these promised outflows can no longer be sustained under the generally compressed margins that occurred in the post-crisis years unless a bank takes on more risk in hopes of earning higher yields. Since the 2008–2009 financial crisis, another source of lost income for some banks is fees. In particular, some banks used to rely relatively more on earning credit or debit card interchange fees, which have been severely curtailed by the Durbin Amendment included in the Dodd-Frank Act. Those banks affected by this rule change may thus seek to make up for the lost income for the same reasons discussed above. The mechanisms studied in the model then become relevant when these banks choose among different types of risks.

In short, to explain banks' reaching-for-yield behavior, the model highlights the importance of a bank's capital buffer, its past net income, and an asset's current yield spread versus the treatment of its possible future losses in value: banks have a greater incentive to seek current yield when their capital ratio is close to the minimum required, and they favor taking risks that do not result in explicit write-offs in the future; banks are also more likely to reach for yield if they used to earn a higher net margin.

4.2 Empirical Evidence that BHCs Reached for Non-Credit Risk

Guided by the theoretical model delineated above, this subsection presents empirical tests of banks' risk-taking behavior since the 2008–2009 crisis. The analysis will focus on how the smallest BHCs, those with less than $10 billion in total assets, which have faced less regulatory scrutiny since the crisis, have altered the maturity structure of their assets, and in turn the maturity mismatch between 2007:Q2 and 2013:Q2. The following cross-section regressions are estimated:

$$\Delta M_{i,\text{07Q2-13Q2}} = \alpha + \beta \Delta M_{i,\text{00Q4-04Q2}} + \boldsymbol{\theta} \mathbf{Z}_{i,2005/06} + \boldsymbol{\Gamma} \Delta \mathbf{X}_{i,\text{07Q2-09Q4}} + \varepsilon_i . \qquad (24)$$

In Equation (24), $\Delta M_{i,\text{07Q2-13Q2}}$ is the change in the maturity mismatch or asset maturity for BHC i that occurred between 2007:Q2 and 2013:Q2, while $\Delta M_{i,\text{00Q4-04Q2}}$ is the corresponding change over a comparable period during the previous business cycle (2000:Q4 to 2004:Q2). $\mathbf{Z}_{i,2005/06}$ is a vector of regressors measured at the average value over 2005 and 2006. $\Delta \mathbf{X}_{i,\text{07Q2-09Q4}}$ is a vector of changes over the Great Recession (2007:Q2 to 2009:Q2). If not for $\Delta \mathbf{X}_{i,\text{07Q2-09Q4}}$, Equation (24) can be regarded as a difference-in-difference estimator, since all the other regressors are pre-"treatment" values.[60] The dependent variable is already defined as the difference within each BHC between two quarters, which means that any unobserved BHC-specific component that is constant over time is removed. So any concerns about the omitted variables problem can only be about a BHC's unobserved cyclical attribute. It can be argued that this last downturn, induced by the global financial crisis, was so severe and thus sufficiently outside of the typical business cycle fluctuations that banks were unlikely to have prepared for it. So the pre-crisis values for $\mathbf{Z}_{i,2005/06}$ can be regarded as fully predetermined. So can $\Delta\mathbf{X}_{i,07\text{Q}2\text{-}09\text{Q}4}$, to the extent that it is determined by a BHC's decisions prior to the crisis. Nonetheless, $\Delta M_{i,00\text{Q}4\text{-}04\text{Q}2}$ is included as a further control of BHC-specific cyclical characteristics.

For $\mathbf{Z}_{i,2005/06}$ and $\Delta\mathbf{X}_{i,07\text{Q}2\text{-}09\text{Q}4}$, I consider variables suggested by the model. First, the past NIM is included; in an alternative specification, its two components—interest received versus interest paid per dollar of earning or total financial assets—both enter, in order to investigate which is more important. A bank's pre-crisis capital ratio is included as another explanatory variable. Interpreting the coefficient may be challenging, in the sense that even though it is predetermined, the coefficient is nonetheless jointly determined by how much risk resides on a bank's balance sheet and the bank's attitude toward risk. A bank with a high capital ratio relative to the required minimum can be an indicator of either a more risky portfolio or greater risk aversion. Regarding the change in a BHC's capital ratio during the recession, the growth of capital (the numerator) versus assets (the denominator) are included separately in order to explore whether their effects differ. Also included are pre-crisis ratios (over total assets) of non-performing loans (NPL) along with their changes during the recession, which can be interpreted as expectations about potential future reductions in capital when some fraction of the delinquent loans will have to be charged off.[61] The NPL ratios by loan category are included separately to allow for different slope coefficients. This specification can reduce the chance of misspecification if the transition rate of NPLs to charge-offs differs across categories.

For other control variables outside of the model itself, the average bank size is included, as in most other banking studies. Also included as a control is the (log) asset level before, and its growth

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[60] To be precise, the dependent variable needs to be defined as the difference from the pre-treatment period, which would be the average over 2005 to 2006, given how the regressors are defined. But the discrepancy can be viewed as a measurement error, which causes no problem for the dependent variable.

[61] Instead of the change in the NPL loan ratio, an alternative measure of the change in NPL loans was used to isolate the effect of just the change in the numerator, instead of the joint change in the NPL and lending activity; this was defined as the change in the NPL balance over the initial balance of loans in that category in 2007:Q2. This alternative measure tends to result in the NPL measure becoming less significant or insignificant (the results are not reported).

during, the recession, because the former is a measure of a BHC's business model while the latter controls for the bank's growth capacity during the downturn. The change in the maturity of deposits or the composition of deposits during the same time period enters as an additional explanatory variable for the maturity of an asset category. Since this is a contemporaneous change, the main purpose for its inclusion is to examine if banks make adjustments to their liabilities to (partially) offset the maturity change on the asset side.

To further control for a bank's business model, the pre-crisis shares of major asset categories are included, which for the BHCs below $10 billion primarily include commercial and residential real estate (CRE and RRE) loans. These loan shares also serve as "demand" controls in these regressions because the last recession was induced by a housing bust and those banks that specialized in CRE or RRE loans may have faced a more severe decline in overall loan demand than did other banks. Instead of using the level of loan shares shortly before the crisis, as an alternative measure I include the growth of the major loan categories over the boom years in the mid-2000s. These can serve as better measures of changing demand, since these measures net out the BHC fixed effects in terms of BHC-specific lending specialization. As several papers (including Huang and Yang 2012) show, those counties that experienced the most house price appreciation during the boom years also tended to suffer the most severe losses in house values during the downturn. Thus, it is likely that those banks that expanded RRE and CRE lending the most during the boom suffered the greatest subsequent contraction in demand during the recession.

Table 3 reports the estimates used to assess which attributes help explain the change in the smallest BHC's maturity choice between 2007:Q2 and 2013:Q2. Panel A presents the estimates pertaining to the change in the average maturity mismatch, Panel B reports the maturity change for securities other than MBS, and Panel C shows the change in loan maturity. Loans and securities are examined separately because the rationale for extending their maturities may differ, since most securities are free of default risk. Among the securities held by banks, here the focus is on those other than MBS, which experienced the longest post-crisis maturity extension, as shown in the Section 3. For every dependent variable, three comparable specifications are presented: the first column can be considered as the baseline specification, the second column replaces the NIM with its two components, while the third column replaces the pre-crisis loan category shares with the loan growth rates experienced during the boom years.

One variable that is uniformly important for all the dependent variables is the average NIM that prevailed during the 2005–2006 period. Those banks that earned a higher NIM prior to the downturn increased the maturities on their loans and non-MBS securities and their maturity mismatch in the five years after the crisis and recession. This finding is consistent with the conjecture discussed in the previous subsection that having earned higher net margins in the past appears to induce banks to reach for yield through lengthening asset maturity and in turn increasing maturity mismatch. When the NIM's two components are included separately, the average rate earned on interest-earning assets emerges as the driving force: earning a higher rate before the crisis is associated with more maturity extension during the post-crisis years. The interest rate paid helps explain only the maturity extension in non-MBS securities: paying a lower rate is associated with a post-crisis maturity extension, augmenting the effect of receiving a higher rate.

The other variable that emerges as being similarly important for all the dependent variables is the average NPL ratio on RRE loans during 2005 and 2006. Those banks that had higher RRE NPL ratios extended their asset maturity and maturity mismatch less over the post-crisis years. However, the model predicts instead that, all else being equal, a higher NPL ratio, to the extent it projects charge-offs and an erosion of capital in the future, should induce banks to seek higher yields by taking on more term risk. One plausible countervailing force not considered in the model is supervisory scrutiny. If these banks have received stricter oversight since the crisis because credit problems manifested on their books earlier than on others banks' balance sheets, then this group of banks would be more constrained in their ability to take on more of any risk, including term risk. Supervisory oversight is a factor that can explain why most of the coefficients on NPL ratios, either the pre-crisis average or the change over the recession average, are either insignificantly different from zero or are negative.

On the other hand, a more negative change in a bank's tier-one capital leverage ratio during the recession is associated with a greater maturity extension of its non-MBS securities, a result that is consistent with the model's prediction. The sign of this explanatory variable's coefficient is also uniformly negative for the other two dependent variables, albeit not significantly different from zero. Likewise, the sign of the pre-crisis tier-one capital ratio is uniformly negative for all the dependent variables but is mostly insignificant as well. In sum, there is some weak evidence that a higher probability that a bank would violate the capital requirement before and during the crisis is associated with greater maturity extension, especially with securities, during the post-crisis period.

Regarding the other explanatory variables, there is some evidence of BHC-specific behavior over the business cycle: the extent to which a BHC changed its maturity mismatch and loan maturity since the Great Recession is positively related to its behavior over a comparable period since the 2001 recession (see Table 3, Panels A and C), whereas the change in the maturity of non-MBS securities is not correlated across the two business cycles (Table 3, Panel B). Those BHCs that increased their CRE loan portfolio more over the boom years also increased their loan maturity and maturity mismatch more since 2007:Q2, while the coefficient sign on RRE loan growth in the mid-2000s is reversed. The increase in overall loan maturity can be attributed to an increase in the share of RRE loans since then, which tend to feature longer maturities than other types of loans. This finding suggests that those BHCs that specialized in CRE lending shifted into RRE when CRE collapsed during the deep downturn, whereas those BHCs that used to specialize in RRE lending had to curtail this lending during the recession. In terms of the effect of bank size, the smaller BHCs among those with less than $10 billion in assets lengthened their loan maturity more since the recession (Panel C), but size has no effect on the change in maturity mismatch or non-MBS securities maturity. By comparison, faster asset growth during the downturn is associated with a larger increase in the maturity of securities and maturity mismatch, but not loan maturity.

In sum, there is fairly robust evidence that a high NIM experienced prior to the 2007–2009 crisis predicted a post-crisis increase in a bank's maturity mismatch. There is some evidence that the smaller BHCs among those below $10 billion in assets more actively lengthened their maturity mismatch. In addition, a low capital ratio just before the crisis and slower capital growth during crisis are associated with more reaching for mismatch, albeit weakly.

V. Did Greater Maturity Mismatch Help Strengthen Net Interest Margins?

Having now established that some BHCs extended the degree of maturity mismatch on their books, a natural follow-up question is: did this practice help improve those banks' net interest margins? To answer this question, the effect of maturity mismatch on the NIM is estimated to assess if it has changed since the financial crisis. Specifically, the maturity mismatch is added as a variable to explain the NIM. While the maturity mismatch is not often considered in NIM regressions, it is the focus here, and I test if the coefficient on the maturity mismatch has changed since 2007:Q2.[62] I also examine if the maturity mismatch contributes more to the regression's explanatory power. A similar analysis is then carried out on the two components of the NIM—the interest rate received on assets versus the interest rate paid on deposits. Because the NIM is excessively smooth relative to market rates, this suggests that banks try to match the rate received with the rate paid, both of which respond more to changes in market rates.

The typical set of explanatory variables for determining the NIM include long- and short-term Treasury yields (or alternatively, the yield curve slope along with a short rate), interest rate volatility, and

[62] Some may suspect that the flatter yield curve present during the ZLB period, owing to unconventional monetary policy, means that the coefficient on the maturity mismatch may be smaller; however, the average slope of the yield curve is in fact steeper during the ZLB (2.5 percent from 2009:Q3 through 2015:Q4) than its average over a comparable period during the previous cycle (1.9 percent from 2001:Q1 through 2006:Q4), and even more so than the overall pre-ZLB average for our sample (1.3 percent from 1997:Q3 through 2009:Q2).

deposit market competition (see Bolotnyy, Edge, and Guerrieri 2015 for a fairly detailed review). These explanatory variables are included as control variables. Interest rate volatility is measured using the Merrill Lynch six-month swaption-implied volatility index of Treasury yields, while deposit market competition is measured by the deposit-weighted-average of the Herfindahl–Hirschman Index (HHI) of deposit concentration by county. I also adopt the lag specification in Bolotnyy, Edge, and Guerrieri (2015), who find that just one lag of the NIM, along with the long and short yields (current and one lag), produces the best out-of-sample forecast of the NIM. In addition, the share of securities in a bank's asset portfolio is included as a control because the analysis detailed above shows that securities tend to have longer maturities, while featuring lower yields than loans on average. Including a BHC's securities share thus prevents this correlation from inducing bias.

The coefficients are allowed to differ depending on whether yields have risen or fallen, given the findings in previous banking studies, such as Neumark and Sharpe (1992), that bank deposit rates respond asymmetrically to increases versus decreases in market yields. To model this asymmetry in a parsimonious way, I include the current yield along with the quarterly change in yield, while allowing a positive change to have a different coefficient than a negative change. This approach is equivalent to allowing the coefficients on both the current and lagged yields to differ (as noted for Equation (10)). Furthermore, the maturity mismatch is allowed to interact with these yield control variables because, as shown in the theoretical model, the effect of maturity mismatch can differ depending on the sequence of yields.[63] To allow for changes in behavior both during the financial crisis and separately during the ensuing ZLB period, all the explanatory variables interact with an indicator (dummy) variable for each of these two subperiods.[64] The equation for determining the NIM is summarized below:

$$\begin{aligned} R_{it} &= \alpha_i + \rho R_{i,t-1} + \beta M_{i,t-1} + \theta y_t + \gamma^+ \Delta y_t^+ + \gamma^- \Delta y_t^- + \theta_1 M_{i,t-1} y_t + \gamma_1^+ M_{i,t-1} \Delta y_t^+ + \gamma_1^- M_{i,t-1} \Delta y_t^- \\ &+ \sum\nolimits_{T=GFC}^{ZLB} (\rho_T D_T R_{i,t-1} + \beta_T D_T M_{i,t-1} + \theta_T D_T y_t + \gamma_T^+ D_T \Delta y_t^+ + \gamma_T^- D_T \Delta y_t^- \\ &+ \theta_{1,T} D_T M_{i,t-1} y_t + \gamma_{1,T}^+ D_T M_{i,t-1} \Delta y_t^+ + \gamma_{1,T}^- D_T M_{i,t-1} \Delta y_t^-) + \mathbf{\Phi X}_{it} + \varepsilon_{it}. \end{aligned} \tag{25}$$

In Equation (25), R_{it} denotes the NIM of BHC i in quarter t, while $M_{i,t-1}$ is the lagged maturity mismatch. The expressions $\Delta y_t^+ \equiv \Delta y_t * 1_{\Delta y \geq 0}$ and $\Delta y_t^- \equiv \Delta y_t * 1_{\Delta y < 0}$ denote the positive and negative changes in the yield curve slope, respectively, with 1_x being the indicator variable as defined in Equation (10). D_T is the indicator for subperiod T, with T = *crisis* (that is, the financial crisis, equal to one in the 2007:Q3 –2009:Q2 period and zero otherwise), and T = *ZLB* (equal to one since 2009:Q3 and zero otherwise). $\mathbf{X}_{it}$ is the vector

[63] These interactions will add terms—involving mismatch—to those in equation (10) for coefficients on the yield variables.

[64] For example, Acharya and Mora (2012) show that banks priced deposits differently during the crisis.

of controls: the Merrill Lynch Index of Treasury Volatility (both the current level and the quarterly change), the weighted-average HHI of each BHC's deposit markets, and each BHC's securities share.

Analogous specifications are applied to the NIM's two components: the interest rate a bank received versus the interest rate it paid; both components are divided by the asset balance used to normalize the NIM. In Equation (25), $M_{i,t-1}$ is then replaced with the lagged maturity of assets (for the dependent variable of rate earned) and liabilities (for rate paid). Instead of using the yield curve's slope however, y in Equation (25) is replaced with the 10-year Treasury yield to explain the rate earned, and with the three-month yield to explain the rate paid, given the regularity of longer maturities for assets and short maturities for liabilities.[65] In addition, the BHC's shares of transaction and savings deposits, both of which tend to pay lower rates, are used in $\mathbf{X}_{it}$ (instead of securities share) for the dependent variable of the interest rate paid. To test the robustness of the coefficients of interest, two alternative specifications are examined: 1) both the long and short rates are included as explanatory variables for the NIM as well as its components, and 2) the first two principal components (often referred to as the level and slope factors) of all the yields, spanning the range of available maturities (from three months to 30 years). As will be shown, the qualitative conclusions are not affected.

Table 4 reports the coefficients from these panel regressions for the four BHC groups. The estimates for the dependent variable of the NIM are presented in Panel A, the estimates for the interest rate received on earning assets (average balance as reported in Schedule RC-K) are reported in Panel B, while the rate paid (also per dollar of earning assets) appears in Panel C.[66, 67] The goodness of fit is much higher for the two components of the NIM rather than for the NIM itself, in large part because banks adjust their rates received and paid in tandem, resulting in much smoother movements in the NIM. For the smallest BHC group (that is, BHCs below $10 billion in assets), the NIM as well as its two components tend to be more persistent than for the three other groups and, owing to the much larger sample size for

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[65] The three-month yield and all its interaction terms are omitted over the ZLB period. An alternative specification for the rate paid is also explored using the three-year yield, which includes all the interaction terms. The goodness of fit is in fact slightly worse, and the qualitative pattern remains the same.

[66] All the regressions also include the quarterly dummies (not shown) to account for seasonality. The standard errors are clustered at the merger-adjusted BHC level to account for serial correlation.

[67] Due to space, the coefficients on the control variables ($\boldsymbol{X}_{it}$) are not reported for the NIM and interest rate received as the dependent variables. The coefficient on the securities share is negative for BHCs in the top three size classes, but is positive for the smallest group of BHCs. In the NIM regression, the volatility index's coefficient is positive for the three largest size groups but is negative (albeit much smaller in magnitude) for the smallest group of BHCs, while the coefficient on the volatility change is uniformly negative but is significant only for the smallest size group. In the rate-received regression, higher volatility is associated with lower rates received in the same quarter for the smallest BHCs but with a one-quarter lag for the three largest groups. The deposit HHI index is insignificant for all four groups in both the NIM and the rate-received regressions.

these small BHCs, more of the coefficients are significant for this group. The negative coefficient on the lagged maturity mismatch is thus marginally significant in the NIM regressions for the pre-crisis period and for the ZLB period. But the magnitude is rather small: extending the maturity mismatch by one year lowers the NIM by a mere 0.6 of a basis point. In contrast, the two middle-sized BHCs have a NIM that rises with maturity mismatch, and feature larger (albeit insignificant) coefficients, on the order of 3 basis points for each additional year of maturity mismatch. In short, the direct relation between the NIM and the maturity mismatch is minimal before the crisis.

The direct association between the interest rate earned by a BHC and its lagged asset maturity has the same sign as that between the maturity mismatch and the NIM for all BHCs, but has a slightly larger magnitude. The effect of a longer maturity of liabilities on the interest rate paid is of the same sign (and of comparable magnitude) as that of a greater mismatch on the NIM for all BHCs except for those in the second-smallest group, those BHCs with assets between $10 and $50 billion. As expected, in these regressions, the shares of transaction and savings deposits are both associated with a lower rate paid.

Note that the maturity mismatch's overall effect on the NIM includes not only its own coefficient but also the interactive effects. The overall effect is positive: given the standard deviation of 1.15 percent for the yield slope, and about 0.43 percent for the quarterly change in the yield slope, the interaction effects add up to between 0.7 and 1.3 basis points, more than offsetting the negative 0.6 basis point effect on the NIM stemming from mismatch alone. Regarding the interactive effects, a wider maturity mismatch renders those BHCs under $10 billion in assets more sensitive to the yield slope and changes in this slope, as evidenced by the positive coefficients on the interaction terms between the slope variables and the lagged maturity mismatch. The coefficients on these variables are more mixed for the larger BHCs and are largely insignificant. By comparison, a longer asset maturity helps BHCs of all sizes receive a higher rate when the long yield is high, and makes the rate received respond a little more in the same quarter to a yield increase but less to a yield decrease; that is, slightly diminishing the asymmetry in reaction. Likewise, a longer maturity of liabilities also offsets somewhat the direct effect of the short yield and its change, although the effect is mostly small, and again is insignificant for the larger BHCs.

During the crisis, the direct effect of maturity mismatch on the NIM turned positive for the BHCs below $10 billion but did not change during the ZLB period that followed. The changes seen for larger BHCs are, however, mostly negative. These estimates imply that the post-crisis change in maturity mismatch in fact helped raise the NIM for both the largest and the smallest BHCs, since the maturity mismatch fell for the largest BHCs but rose for the smallest BHCs. Similarly, for the rates earned by banks, the effect of asset maturity turned universally less negative, and in fact largely positive, during the crisis and the ZLB periods. Over these same periods, a longer liability maturity is associated with paying a higher rate than before for the smallest BHCs (albeit very slightly) but with paying a lower rate by the larger BHCs. This differential effect suggests that those larger BHCs that lengthened the time deposit maturities more also increased the percent of their funding obtained from transaction deposits, especially savings deposits, by such an extent that they paid rates that were no higher or even lower on average.

By comparison, during the crisis and the ZLB periods, the coefficients on the interaction between the long yield and the maturity mismatch tend to be more positive except for the smallest BHCs during the crisis, meaning that a wider mismatch became more helpful to the NIM when bond yields were high after the crisis. In contrast, for all BHCs since the crisis, a longer asset maturity helped less with the rate earned when the long yield was high. There is a less clear pattern regarding how the maturity of liabilities affected the rate paid by banks, depending on their size, in response to changes in the short yield after the crisis. For the smallest BHCs, a longer maturity for liabilities means paying a higher rate than their peers during the crisis when the yield was high, although it also means that the rate paid responded more during the same quarter when the yield fell. The patterns of the post-crisis changes for the larger BHCs are different and varied, although many of the coefficients are not statistically significant.

There is fairly consistent evidence of asymmetry in how the interest rates received and paid by banks evolve in response to changes in the market yield. This asymmetry is most obvious for the rate earned on assets: the same-quarter response to a market yield increase is more muted compared to a yield decrease, as the coefficient on the quarter-*t* yield is largely offset by the coefficient on yield increases, which is more negative than the coefficient on yield declines (with the latter being positive for the smallest BHCs). In other words, when yields rise, the rates earned by banks follow with a lag, whereas when yields fall, bank rates fall immediately. This asymmetric reaction of the rates that banks receive on assets mirrors the asymmetry for the rates that banks pay on deposits, as documented by Neumark and Sharpe (1992), among others. Such an asymmetry is indeed seen for the rate paid before the crisis, but only for the smallest BHCs. The lack of this asymmetry for the larger BHCs likely results from their greater reliance on market-based funding. The driving factor for this asymmetry in the rates earned by banks likely lies in banks holding assets with embedded (prepayment) options such as MBS and mortgages, which render banks more sensitive to falling yields than to rising yields. The same asymmetry is inherent to the NIM as well, albeit the effect is significant only for the two smallest groups of BHCs.

This asymmetry has diminished to varying degrees since the crisis. Many of the coefficients on interaction terms between the yield slope changes and the maturity mismatch are attenuated (meaning closer to zero) during the crisis and the ZLB period. A similar pattern is observed for the coefficients on the long-yield change interacted with asset maturity. One reason for these results may be changes in the information content of long yields, as well as the yield slope, during the ZLB period: with short rates pinned near zero, lower long yields and hence a lower yield slope now mean easier monetary policy, whereas previously in a more normal business cycle, long yields could decline even while the Fed was tightening policy. This difference can dampen the pre-crisis relationship, including the asymmetry.

To measure the maturity variables' marginal contribution to explaining the NIM, I use the change in a regression's goodness of fit after the inclusion of the variables concerned. Since the object of interest here is the change, if any, in the behavior of NIM after the crisis, identical specifications are needed before (inclusive) and after 2008:Q2. Table 5 reports the comparisons from regressing the NIM on the first two yield curve factors. Alternative specifications using long and short yields (with the latter omitted for the ZLB period) produce the same qualitative results. The basic message is clear: for the largest and the smallest BHCs, the marginal explanatory power of the maturity variables is generally low, but it is slightly higher over the ZLB period. The regression's overall fit in fact improves for the largest BHCs, those subject to the advanced approaches, but falls for the smallest BHCs after 2008:Q2. The estimates for the two middle size groups of BHCs (not reported) point to essentially no change in the marginal contribution of the maturity variables to explaining the NIM during the ZLB period when compared to the pre-crisis period.

To check for robustness, I examine and ascertain that the coefficients that are the focus of this study—the maturities of balance-sheet items—mostly retain the same sign and similar patterns of significance if the NIM and the rates earned versus paid are normalized by a BHC's total financial assets (inclusive of non-interest-bearing financial assets) instead of the average interest-bearing assets (derived using data reported in Schedule RC-K).

In sum, the evidence suggests that a greater maturity mismatch helps slightly more with earning a higher NIM during the ZLB period than during the pre-crisis period, although the change is generally small or not significantly different from zero. A longer asset maturity seems to help more with the interest rates that banks earned after the crisis. On the other hand, maturity mismatch does not appear to be more important (that is, to provide a better goodness of fit) in explaining the NIM after the crisis. A greater maturity mismatch seems to dampen the NIM's asymmetric reaction to yield slope changes in the post-crisis era. Likewise, longer-dated assets are associated with a more symmetric response of the bank rates earned to the market yield changes during the ZLB period.

VI. The Taper Tantrum and Measures to Mitigate Potential Future Losses

It appears that banks have recognized the potential future damage to their capital ratio that may arise from their current elevated asset maturity and, in turn, the resulting maturity mismatch, as they have started to adopt measures to limit the extent of the damage, at least to the extent that this strategic behavior is reflected on their books.

One major risk faced by banks is the potential for future declines in the fair value of their assets as a result of increases in long yields. This decline in FV will directly reduce the regulatory capital held by those BHCs subject to the removal of the AOCI filter, which is an element of the advanced approaches capital rules to implement Basel III that were developed after the crisis. One solution to limit this expected loss of a bank's required regulatory capital is to account for securities as HTM instead of AFS, since the former value is recorded at the amortized cost (that is, the asset's book value) and thus is free from market-value fluctuations. As Figure 8 shows, in recent years the largest BHCs, those subject to the removal of the AOCI filter, and to a lesser extent those BHCs in the two middle size groups, have increased by the largest percentage the share of securities accounted for as HTM.[68] This change in accounting methods contrasts with the historical pattern: the smallest group of BHCs by asset size used to have a greater share of securities, across most categories, classified as HTM.

Increases in the HTM share can be seen across all the categories of securities reported in the Call Reports, but the increase is especially pronounced for Treasuries and pass-through MBS. As discussed above, because of the historically low long yields, the average duration of MBS has risen in recent years so that this asset class now resembles long-term bonds. Since booking securities as HTM to avoid mark-to-market losses is most beneficial to long-dated securities, banks thus should have a greater incentive to book more pass-through MBS as HTM. Moreover, the negative convexity of MBS means that rising yields will have a more negative impact on their value. It is possible that the Treasury securities held by the largest BHCs also tend to be long-dated, and that may be the reason why these BHCs shifted more Treasuries to HTM, but this hypothesis cannot be verified due to the lack of data.

A plausible alternative interpretation for these accounting changes is that the largest BHCs are classifying as HTM those securities that have an active repo market, in order to get the best of both worlds. On the one hand, the HTM classification enables these BHCs to benefit from reduced fluctuations

[68] The denominator for the HTM share is the sum of the book value of the HTM securities and the fair value of the AFS securities, which is the standard definition of a bank's total balance of investment securities. Using the book value of the AFS securities makes virtually no difference in this amount.

in the FV of these securities and the resulting impact on their regulatory capital. On the other hand, the presence of an active repo market means that they can obtain funding through repos collateralized by these securities. By obviating the need to sell securities, which cannot be done on short notice for those securities classified as HTM, these BHCs preserve the liquidity benefit of holding securities while avoiding the traditional cost of using the HTM relative to the AFS classification. Note, however, that the amount of funding obtained through a repo contract is typically the FV of the underlying collateral minus a haircut; thus the amount of funding will fall with the FV when yields rise. The amount of funding that can be obtained may fall more if the haircut rises in anticipation of further yield increases.

The timing of the increase in shares accounted for as HTM is highly suggestive: the largest run-up started immediately after the regulatory agencies published the Final Rule on the AOCI filter in July 2013, as marked by the thin grey line in Figure 8.[69] The other trigger event for this increase in the HTM share may have been the taper tantrum that occurred in May and June 2013: it is probable that the BHCs in the two largest size classes were galvanized into raising the HTM share of their securities portfolios also by the potential prospect of incurring further large losses on their AFS securities beyond the declines experienced during the tantrum.[70] To test this hypothesis, Jordà's (2005) local projection method is used to estimate the impulse response of a bank's securities maturity and the HTM share of Treasuries plus MBS (as shown in Figure 8, the categories of securities that saw the largest increase in the HTM share) since 2013:Q2 to the unrealized losses that occurred in 2013:Q2 during the taper tantrum. That is, a series of h cross-section regressions of the following form are run:

$$\Delta Y_{i,t0\rightarrow t0+h} = \alpha_h + \beta_h Loss_{i,t0} + \varepsilon_{i,t0+h}, \ t0 = \text{2013Q2, and } h = 0, \ldots, 10. \tag{26}$$

In Equation (26), Y = the HTM share or the average maturity of securities. The cumulative change in Y over the quarters since 2013:Q2 is regressed on the unrealized losses on AFS securities that occurred in 2013:Q2; here, the taper tantrum is treated as a shock. Figure 9 plots the impulse responses of these two dependent variables for the largest and the smallest BHCs. It reveals that for both variables, the sign of the changes is as expected: a larger loss in 2013:Q2 leads a BHC to shorten the maturity of its securities and increase its share of securities classified as HTM in subsequent quarters. It is interesting to note that the magnitude of changes in securities maturities are comparable between these two sets of BHCs (and the change is not statistically significant for the largest BHCs because of the small sample size). However, the largest BHCs raised their HTM share by an order of magnitude more than the smallest BHCs, so this

[69] To be more precise, the grey line stands at 2013:Q2 since these are quarterly data.
[70] Unrealized losses on AFS securities suffered by the 11 largest BHCs during 2013:Q2 range from 2.2 to 12.5 percent of their tier-one capital in 2013:Q1. The average loss was 5.0 percent.

change is significant despite the small sample size.

Furthermore, the evidence suggests that the largest BHCs moved more of their long-dated MBS securities into the HTM category after 2012. This timing coincides fairly well with the July 2013 publication of the proposed rule to remove the AOCI filter. To compare the price risk sensitivity of the HTM versus the AFS securities, which is highly correlated with the effective duration as shown in Section III, I estimate the beta of unrealized gains/losses incurred on pass-through MBS on the price returns (equal to difference in log price) of the Barclays Capital U.S. MBS Index. Figure 10 plots the estimated beta of the HTM versus the AFS pass-through MBS for the largest BHCs. The HTM beta used to be lower until around 2012, and then rose clearly relative to the AFS beta.

Using a simple regression, this increase is found to be both large in magnitude and statistically significant. As shown in Table 6, an OLS regression of the asset-weighted-average beta reveals that the HTM beta of the largest BHCs used to be about two-thirds smaller than the AFS beta prior to 2012, but has since risen to become about one-third larger. In contrast, the beta of AFS pass-through MBS has not changed. The magnitude of this relative increase is smaller in the panel regression, suggesting that the largest BHCs are more responsible for this change. By comparison, the two middle-size BHCs show a smaller, albeit significant, relative increase in the beta of HTM pass-through MBS. The smallest BHCs had more similar betas in their HTM and AFS pass-through MBS prior to 2012, and exhibited little relative increase in the HTM beta afterward.

VII. Conclusion

This study finds some evidence that banks reached for yield after the financial crisis by taking on non-credit risk. This behavior was especially prevalent among the smallest BHCs not subject to the spate of new and enhanced regulations introduced to deal with the aftermath of the crisis. These smaller banks invested in assets with longer maturities and thus were more exposed to the interest rate risk, as well as being invested in assets with more exposure to prepayment or illiquidity risk. In particular, the choice of securities with longer maturities or subject to prepayment risk is likely to be largely, if not entirely, driven by a bank's own "supply" factors.

A simple model illustrates a bank's rationale to take on more non-credit risk countercyclically, mainly due to the need to satisfy its capital requirement in the near term during downturns. Some empirical support is found for the model's predictions for the smallest BHCs, those with less than $10 billion in assets: those banks that had lower capital ratios before the crisis or saw their capital ratios decline more during the downturn raised the maturity of their assets and hence their maturity mismatch more after the crisis. A high net interest margin in the past is shown to be a strong factor for the post-crisis increase in maturity. The post-crisis increase in maturity mismatch is found to help a bank more in earning a higher net interest margin, but only slightly. There is also some evidence that the smallest banks holding longer-dated assets received a boost to their NIM during the financial crisis.

After the taper tantrum in May 2013, when some banks suffered nontrivial unrealized losses on their AFS securities, different banks reacted in different ways that are consistent with their disparate regulatory treatment. Yet all BHCs, regardless of size, have acted in an effort to mitigate, at least on paper, the potential future damage to regulatory capital due to mark-to-market losses that will occur when short-term rates eventually rise as the Federal Reserve normalizes monetary policy. The systemically important banks have chosen to increase their share of securities accounted for as HTM, instead of AFS, to reduce the fluctuations in unrealized gains/losses and hence to lower the direct hit to their capital given the removal of the AOCI filter. Moreover, evidence suggests that these largest BHCs have shifted more long-dated securities to their HTM portfolio. The smallest banks, by comparison, seem to have relied more on shortening their securities maturities somewhat.

This kind of selective risk taking over a business cycle can be welfare reducing to the extent that the diminished willingness to take on credit risk during downturns prolongs the feedback loop between weak economic growth and an aversion to credit risk, and thus retards the economic recovery. Furthermore, if the long-dated assets paying lower yields that were taken on during recessions induce banks to lend to more risky borrowers during expansions, when their funding cost rises, it can further exacerbate the cyclical fluctuations. A countercyclical capital requirement should mitigate the increase in the shadow cost of capital attributed to credit risk, and thus encourage more lending during downturns than would otherwise be the case. By the same logic, having the government assume the credit risk at a stable through-the-cycle charge, such as in conforming mortgages guaranteed by the GSEs, should achieve a similar outcome of smoothing credit supply over the cycle.

Going forward, as the Federal Reserve normalizes monetary policy and short-term interest rates rise gradually, those banks that have chosen to hold a higher share of longer-dated assets will face a squeeze on their net interest margin, which may be exacerbated by the negative convexity of mortgages and MBS as fewer borrowers exercise the prepayment option. Moreover, the competition for retail deposits may be more intense owing to the favorable treatment of such funding by the new liquidity requirements enacted after the financial crisis. Those banks with more longer-dated assets thus may choose not to expand their loan portfolios as much as they would otherwise. On the other hand, the aggregate impact of less credit availability may be limited, since the largest BHCs have not extended the maturity of their asset portfolios since the recession, and these institutions account for three quarters of the banking assets in the United States. Future research should assess how the shift toward non-credit risk, such as through maturity extension, during recessions and slow recoveries affects individual bank's lending in boom times, and what the impact is on the aggregate economy's dynamics.

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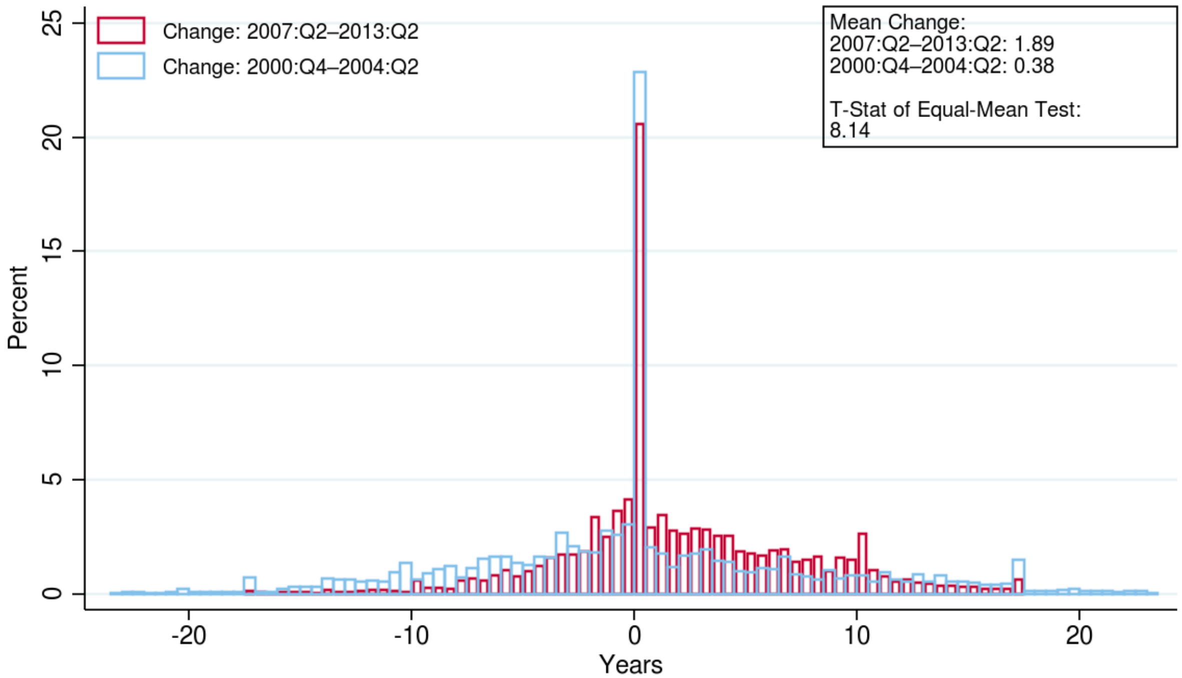
Figure 1. Distribution of Maturity Changes: Comparison between 2007:Q2–2013:Q2 and 2000:Q4–2004:Q2

Panel A. Pass-Through Mortgage-Backed Securities



Panel B. Non-Mortgage-Backed Securities

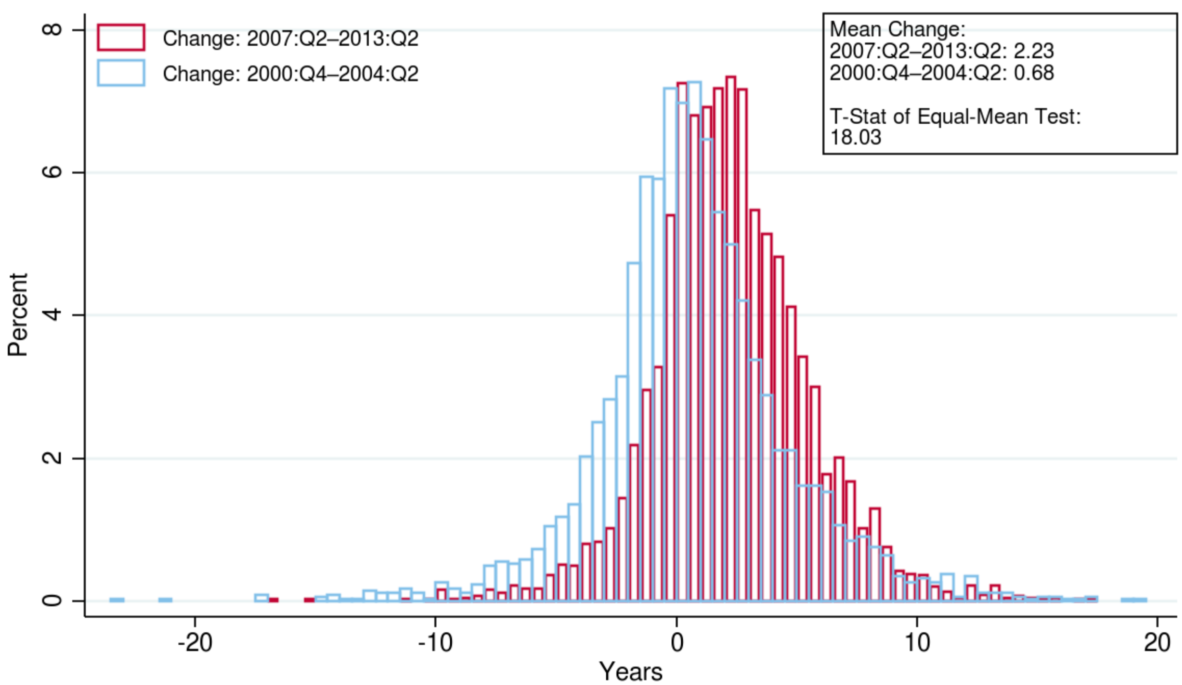
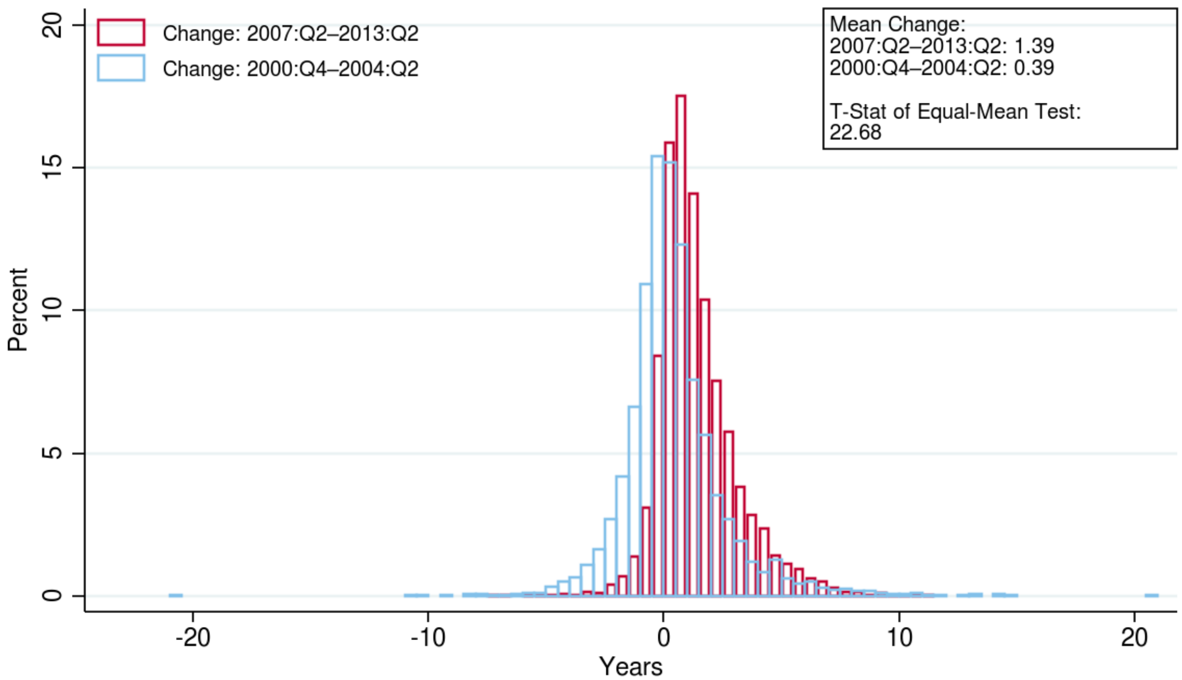
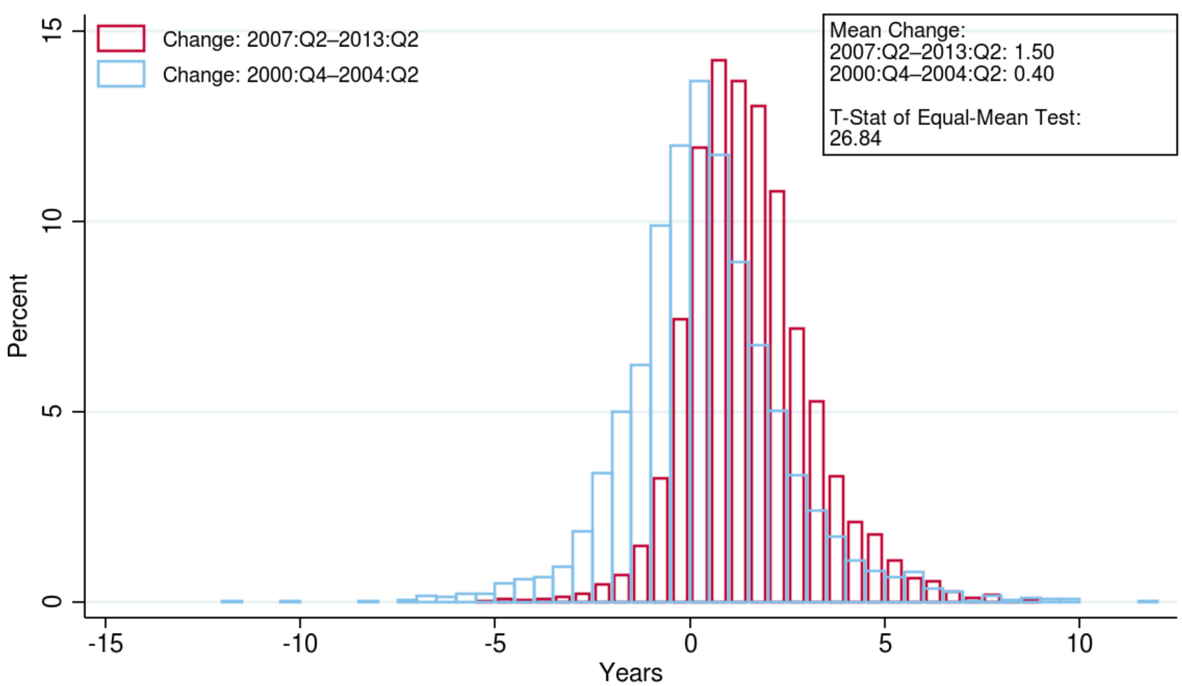


Figure 1. (continued)

Panel C. Loans

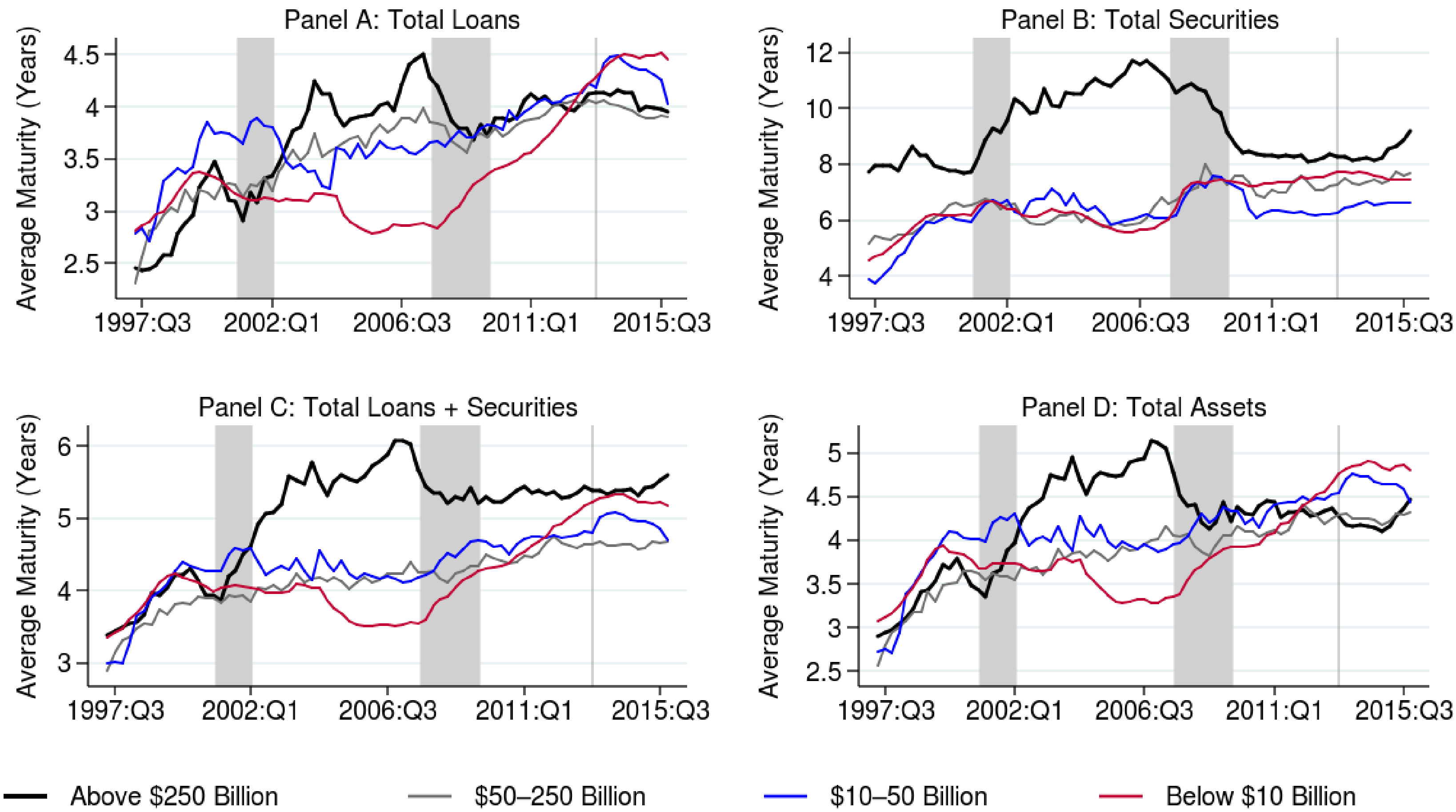


Panel D. Maturity Mismatch between Total Assets and Total Liabilities



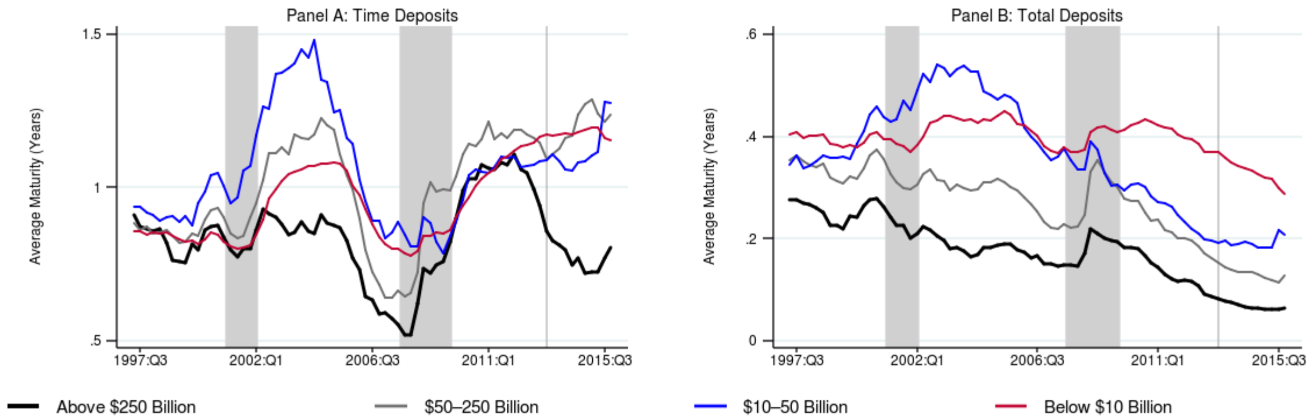
Source: Bank Reports of Income and Condition Data. Author's calculations.

Figure 2. Weighted-average Maturity of Total Loans, Total Securities, and Total Assets



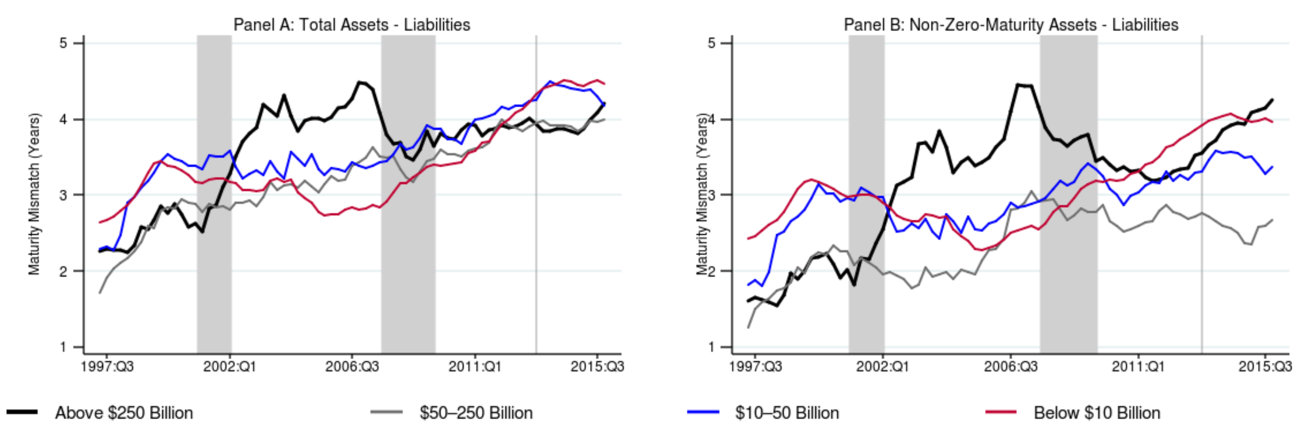
Notes: 1) Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets. 2) The grey vertical line in these figures marks 2013:Q2, the quarter ending immediately after the taper tantrum, to highlight the change in maturity movements, if any. 3) In Panel B, the line for the largest (Above $250 Billion) BHCs is adjusted to smooth out outsized swings in Bank of America's securities holdings in 2004:Q2–2004:Q3 and to a lesser extent swings in J.P. Morgan Chase's holdings in 2004:Q3. See the data appendix (Appendix B) for more details. These adjustments are then carried over to the line for the largest BHCs in Panels C and D.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Figure 3. Weighted-average Maturity of Time Deposits and Total Deposits



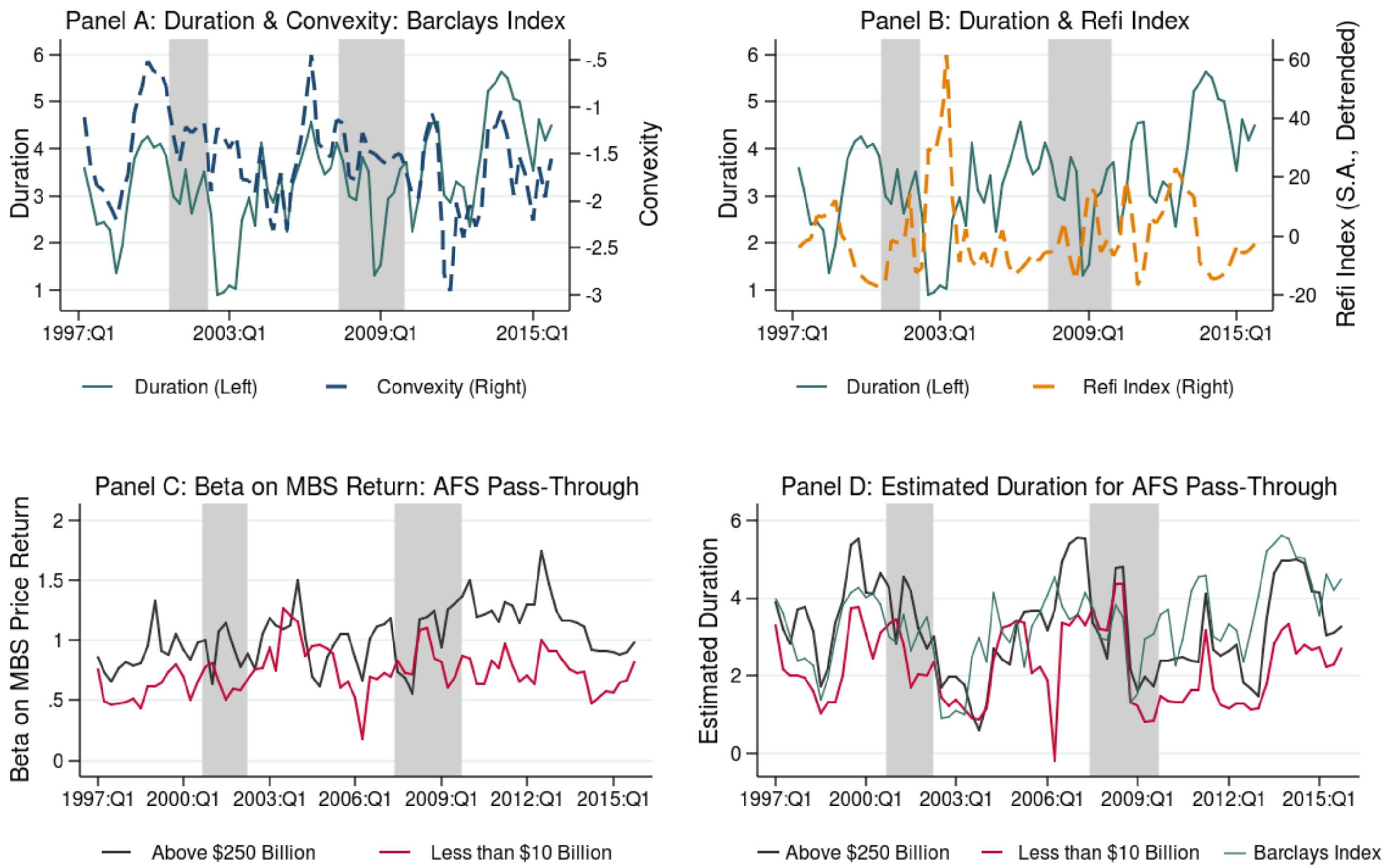
Notes: 1) Non-zero-maturity assets: loans plus securities while non-zero-maturity liabilities exclude transaction and savings deposits. 2) Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets. 3) The grey vertical line marks 2013:Q2, the quarter end immediately after the taper tantrum, to highlight the change in maturity movements, if any.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Figure 4. Maturity Mismatch between Assets and Liabilities



Notes: 1) Non-zero-maturity assets: loans plus securities while non-zero-maturity liabilities exclude transaction and savings deposits. 2) Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets. 3) The grey vertical line in these figures marks 2013:Q2, the quarter end immediately after the taper tantrum, to highlight the change in maturity movements, if any.
Source: Bank Reports of Income and Condition Data. Author's calculations.

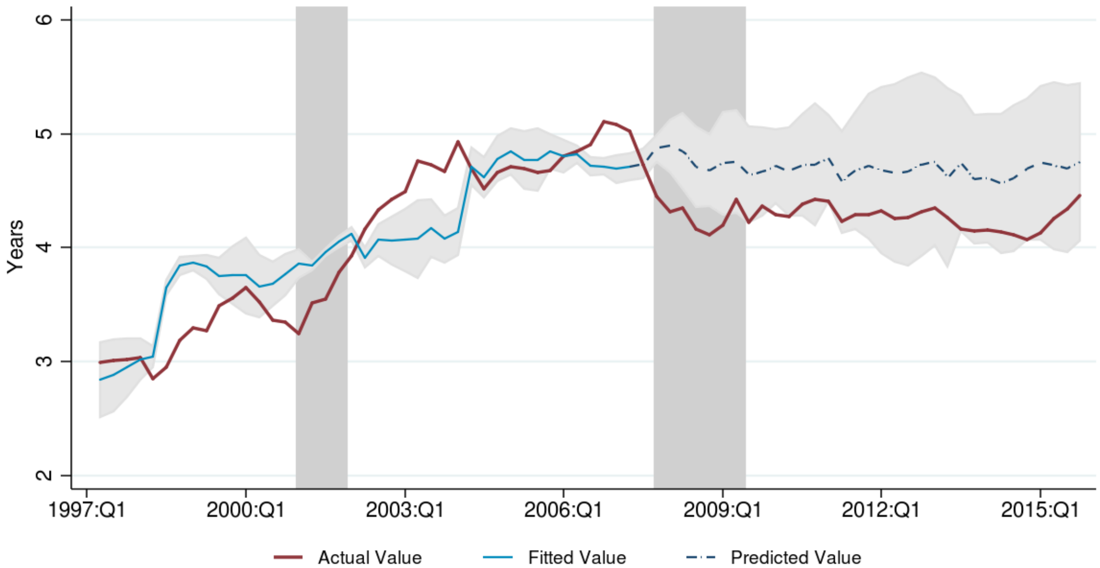
Figure 5. Duration and Convexity of Barclays Mortgage-Backed Security Index, Price Beta of Banks' Pass-Through and Other Mortgage-Backed Securities



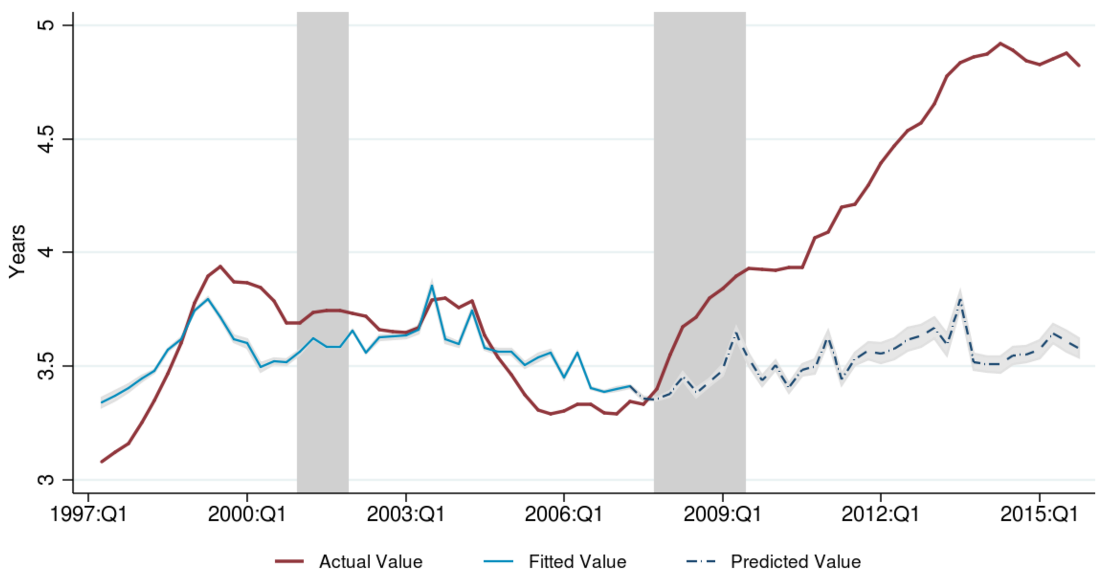
Notes: Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.
Sources: Bank Reports of Income and Condition Data. Bloomberg Barclays U.S. Aggregate Bond Index. MBA/Haver Analytics. Author's calculations.

Figure 6. Total Asset Maturity: Prediction Versus Actual Since the Onset of the Financial Crisis (2007:Q2)

Panel A. Bank Holding Companies Subject to the Advanced Approaches (Above $250 Billion in Assets)



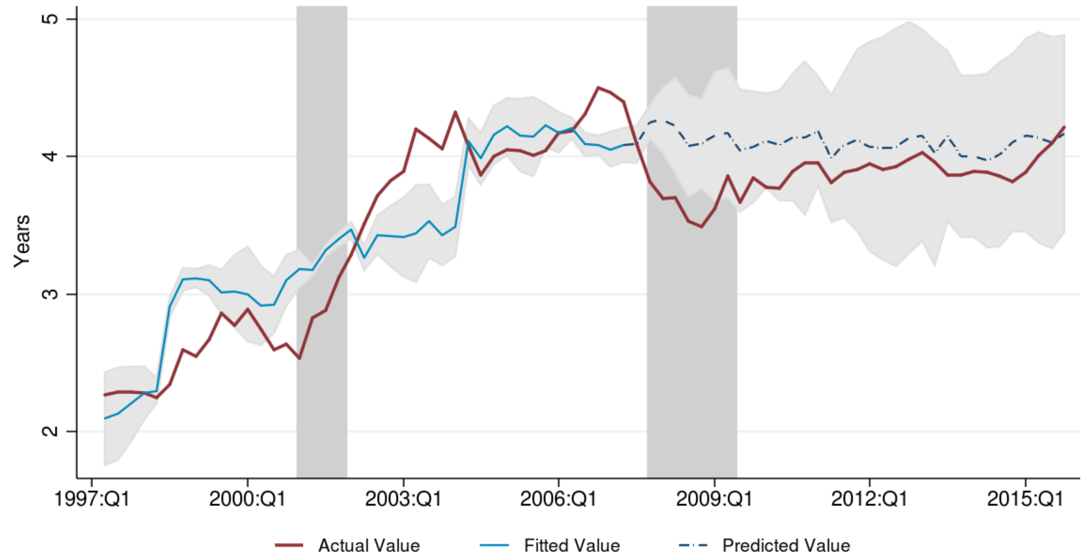
Panel B. Bank Holding Companies with Less than $10 Billion in Assets



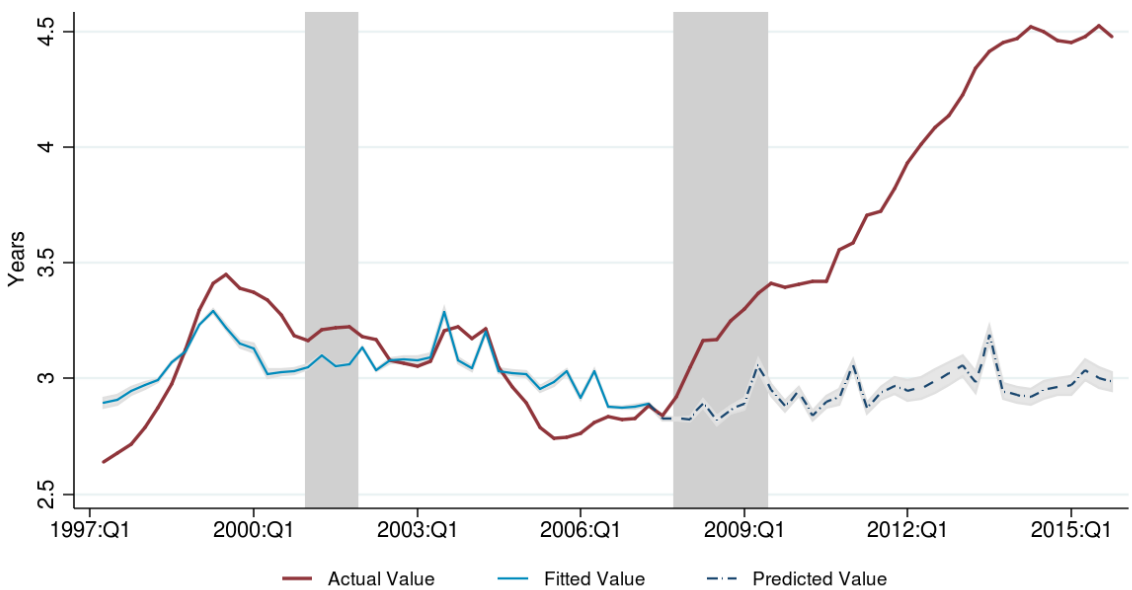
Notes: The maroon line depicts the actual values, the light blue dashed line the in-sample fitted value through 2007:Q2 while the blue dash-dot line the out-of-sample predicted value from 2007:Q3 to 2015:Q4. The light grey shaded band around the fitted and predicted values measures two standard errors. Panel A covers bank holding companies (BHCs) subject to the advanced approaches capital framework, which have $250 billion in total assets or $10 billion in total foreign exposure, along with their merger targets with above $10 billion in assets.
Source: Bank Reports of Income and Condition Data. Board of Governors of the Federal Reserve/Haver Analytics. Author's calculations.

Figure 7. Maturity Mismatch: Prediction versus Actual Since the Onset of the Financial Crisis (2007:Q2)

Panel A. Bank Holding Companies Subject to the Advanced Approaches (Above $250 Billion in Assets)



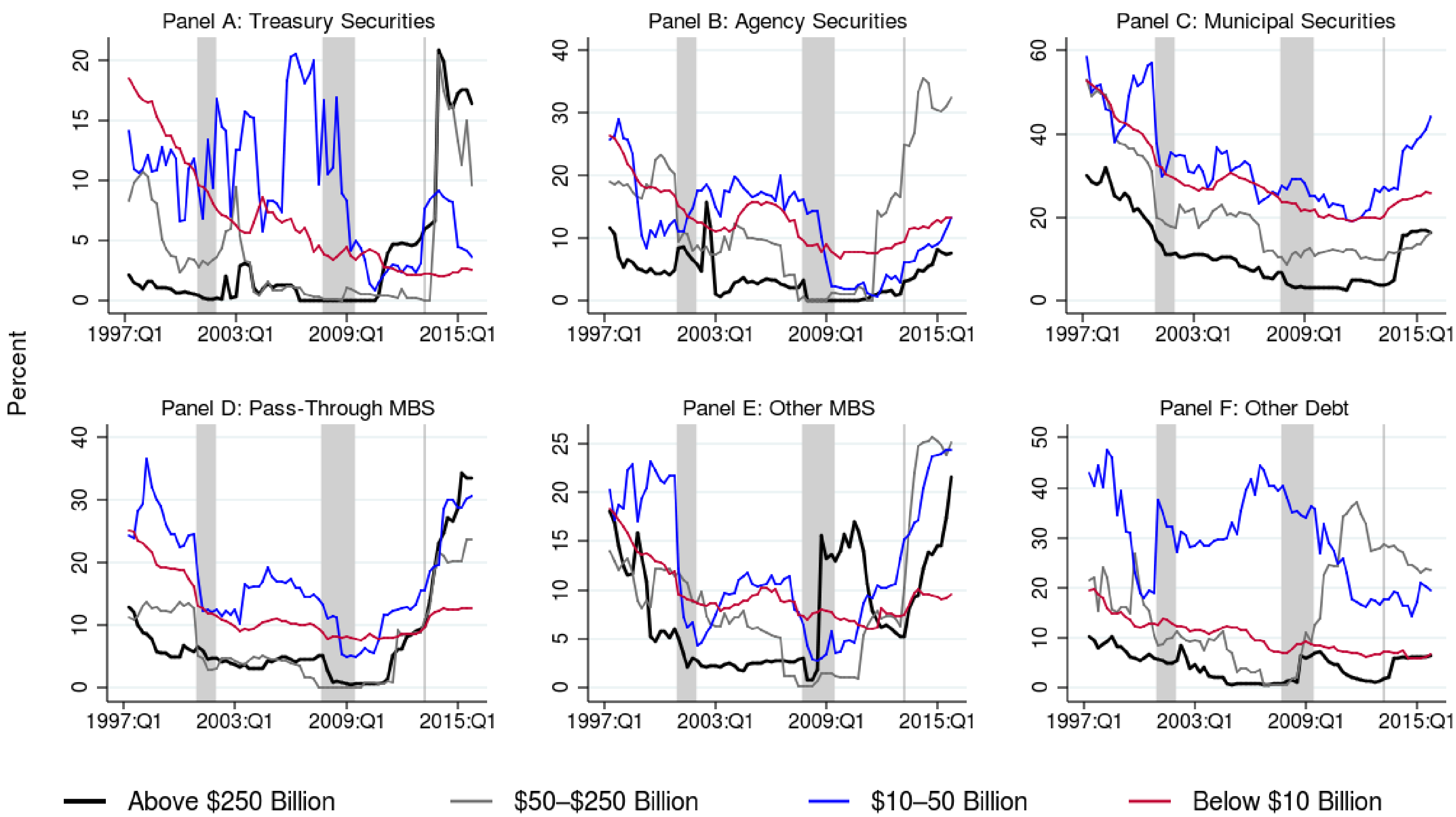
Panel B. Bank Holding Companies with Less than $10 Billion in Assets



Notes: The maroon line depicts the actual values, the light blue dashed line the in-sample fitted value through 2007:Q2 while the blue dash-dot line the out-of-sample predicted value from 2007:Q3 to 2015:Q4. The light grey shaded band around the fitted and predicted values measures two standard errors. Panel A covers bank holding companies (BHCs) subject to the advanced approaches capital framework, which have $250 billion in total assets or $10 billion in total foreign exposure, along with their merger targets with above $10 billion in assets.

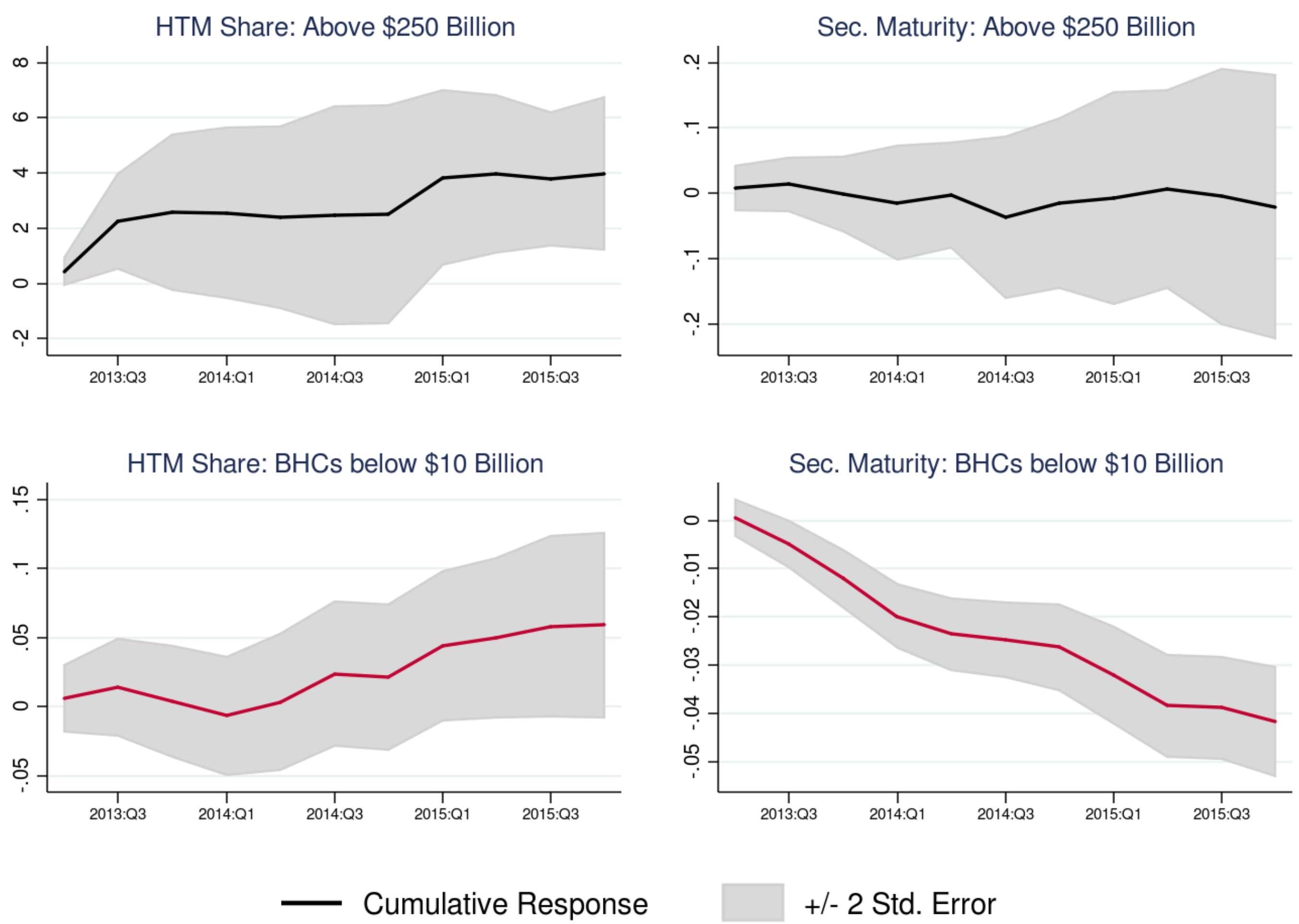
Source: Bank Reports of Income and Condition Data. Board of Governors of the Federal Reserve/Haver Analytics.. Author's calculations.

Figure 8. Share of Securities Classified as Held-to-Maturity by Category



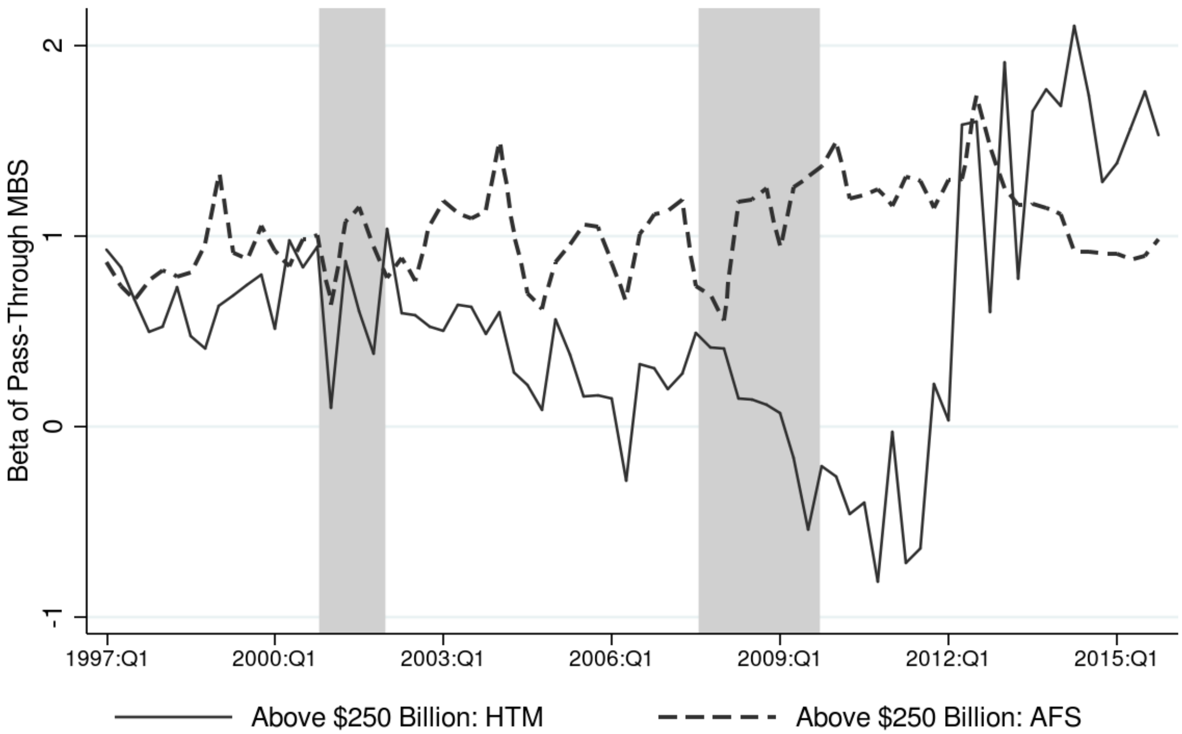
Notes: 1) These figures depict the share (in percent) of held-to-maturity within each category of securities. The hump in the held-to-maturity share of Other MBS in 2009 to 2011 is due to Citi Group reclassifying available-for-sale to held-to-maturity by arguing that markets were too illiquid during the crisis (http://www.citigroup.com/citi/fin/data/ar08c_en.pdf, p. 160) and later reverting the securities back to available-for-sale in order to sell and raise capital (*Wall Street Journal*, March 23rd, 2015). The grey vertical line marks 2013:Q2. 2) Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Figure 9. Impulse Responses of Securities Maturity and the Held-To-Maturity Share to Unrealized Losses from the Taper Tantrum in 2013:Q2



Notes: 1) These figures depict cumulative responses starting from the taper tantrum in 2013:Q2 of securities (Sec.) maturity (in year) and the share (in percent) of held-to-maturity (HTM) within Treasury plus mortgage-backed securities to unrealized losses on available-for-sale (AFS) securities holdings suffered in 2013:Q2. 2) Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Figure 10. Beta of Pass-Through Mortgage-Backed Securities for Bank Holding Companies Subject to the Advanced Approaches Capital Rule (Generally Above $250 Billion in Assets)
Comparison between Held-To-Maturity and Available-For-Sale



Notes: Bank holding companies (BHCs) subject to the advanced approaches capital framework have $250 billion in total assets, or $10 billion in total foreign exposure. To be consistent with the other figures and tables, these calculations also include merger targets with assets above $10 billion of the advanced approaches BHCs.
HTM stands for held-to-maturity, and AFS stands for available-for-sale.
Sources: Bank Reports of Income and Condition Data. Bloomberg Barclays U.S. Aggregate Bond Index. Author's calculations.

Table 1. Summary of Maturity Change of Bank Assets and Liabilities

Panel A. Bank Holding Companies Subject to the Advanced Approaches Capital Framework (Generally with Above $250 Billion in assets)

	Weighted Average Maturity (Years)					Share in Assets or Liabilities (%)				
	2007:Q2	2013:Q2	2015:Q4	Change 2007–2013	Change 2013–2015	2007:Q2	2013:Q2	2015:Q4	Change 2007–2013	Change 2013–2015
ASSETS	5.02	4.27	4.45	**-0.75**	**0.19**					
Securities	11.52	8.28	9.20	**-3.24**	**0.91**	14.45	19.96	21.50	**5.50**	**1.55**
Pass-Through MBS	16.13	15.40	15.86	**-0.73**	**0.46**	8.00	7.33	8.21	**-0.67**	**0.88**
Other MBS	4.44	3.65	4.04	**-0.79**	**0.39**	2.66	4.11	3.38	**1.44**	**-0.73**
All Other Debt Securities	6.74	4.39	5.43	**-2.35**	**1.04**	3.78	8.51	9.91	**4.73**	**1.40**
Loans	4.51	4.13	3.96	**-0.38**	**-0.17**	51.95	45.74	47.29	**-6.21**	**1.54**
1–4 Family Mortgages	10.40	11.27	11.99	**0.87**	**0.72**	12.12	10.93	10.25	**-1.19**	**-0.67**
All Other Loans	2.72	1.89	1.73	**-0.83**	**-0.16**	39.84	34.82	37.03	**-5.02**	**2.22**
Cash						5.37	12.43	13.52	**7.06**	**1.09**
Fed Funds Sold & RRP						7.39	4.56	3.71	**-2.83**	**-0.85**
Trading Assets						11.33	7.78	6.02	**-3.55**	**-1.76**
Nonfinancial Assets						1.06	1.09	0.92	**0.03**	**-0.17**
LIABILITIES	0.57	0.30	0.23	**-0.27**	**-0.07**					
Deposits	0.14	0.08	0.06	**-0.06**	**-0.02**	46.48	63.89	68.36	**17.41**	**4.47**
Transaction						5.38	10.48	12.41	**5.09**	**1.94**
Savings						29.29	47.32	50.59	**18.04**	**3.27**
Time, < $100K	0.74	1.16	1.45	**0.42**	**0.29**	5.52	2.60	1.59	**-2.92**	**-1.01**
Time, >= $100K	0.42	0.63	0.53	**0.21**	**-0.10**	6.29	3.49	3.76	**-2.80**	**0.28**
Other Borrowing	0.84	0.83	0.87	**-0.01**	**0.04**	10.25	5.73	7.18	**-4.52**	**1.45**
Fed Funds Purchased & Repos						8.95	4.29	2.28	**-4.66**	**-2.01**
Trading Liabilities						5.42	3.32	3.01	**-2.10**	**-0.31**
Subordinated Debt						2.33	1.24	0.78	**-1.09**	**-0.47**
All Other Liabilities						26.56	21.53	18.40	**-5.03**	**-3.13**

Notes: MBS stands for mortgage backed securities. These statistics also include merger targets with assets above $10 billion of the advanced approaches bank holding companies.

Source: Bank Reports of Income and Condition Data. Author’s calculations.

Table 1. Summary of Maturity Change of Bank Assets and Liabilities

Panel B. Bank Holding Companies with Assets Less Than $10 Billion

	Weighted Average Maturity (Years)					Share in Assets or Liabilities (%)				
	2007:Q2	2013:Q2	2015:Q4	Change 2007–2013	Change 2013–2015	2007:Q2	2013:Q2	2015:Q4	Change 2007–2013	Change 2013–2015
ASSETS	3.35	4.78	4.82	**1.43**	**0.04**					
Securities	5.89	7.71	7.44	**1.82**	**-0.27**	19.89	23.29	20.86	**3.40**	**-2.43**
Pass-Through MBS	9.90	11.25	11.29	**1.35**	**0.04**	4.34	6.24	5.52	**1.90**	**-0.72**
Other MBS	3.67	3.49	4.05	**-0.18**	**0.56**	3.28	4.22	3.60	**0.94**	**-0.62**
All Other Debt Securities	5.07	7.38	6.67	**2.31**	**-0.71**	12.26	12.82	11.74	**0.56**	**-1.09**
Loans	2.88	4.28	4.46	**1.40**	**0.18**	68.22	61.83	66.70	**-6.39**	**4.87**
1–4 Family Mortgages	5.66	7.03	7.52	**1.37**	**0.49**	11.76	12.24	12.81	**0.48**	**0.57**
All Other Loans	2.30	3.61	3.73	**1.30**	**0.13**	56.46	49.60	53.90	**-6.86**	**4.30**
Cash						3.26	7.34	6.02	**4.07**	**-1.31**
Fed Funds Sold & RRP						2.69	0.70	0.45	**-1.99**	**-0.25**
Trading Assets						0.13	0.03	0.04	**-0.10**	**0.01**
Nonfinancial Assets						1.93	2.45	1.89	**0.52**	**-0.56**
LIABILITIES	0.46	0.43	0.34	**-0.03**	**-0.09**					
Deposits	0.37	0.37	0.29	**0.00**	**-0.08**	88.18	92.58	92.16	**4.40**	**-0.41**
Transaction						14.46	19.01	20.51	**4.55**	**1.50**
Savings						33.19	44.48	48.64	**11.29**	**4.16**
Time, < $100K	0.86	1.23	1.23	**0.37**	**0.00**	22.86	14.36	10.35	**-8.50**	**-4.02**
Time, >= $100K	0.72	1.12	1.10	**0.40**	**-0.03**	17.66	14.72	12.66	**-2.94**	**-2.06**
Other Borrowing	1.92	2.10	1.40	**0.18**	**-0.70**	6.10	3.86	4.84	**-2.25**	**0.99**
Fed Funds Purchased & Repos						4.12	2.28	1.95	**-1.83**	**-0.34**
Trading Liabilities						0.02	0.01	0.02	**0.00**	**0.01**
Subordinated Debt						0.11	0.06	0.06	**-0.05**	**0.00**
All Other Liabilities						1.47	1.21	0.97	**-0.26**	**-0.25**

Notes: MBS stands for mortgage-backed securities.

Source: Bank Reports of Income and Condition Data. Author's calculations.

Table 2. Impact of Fair Value Adjustments to Maturity Estimates

Panel A: Bank Holding Companies Subject to the Advanced Approaches Capital Framework (Generally with Above $250 Billion in assets)

	Based on Fair Value of AFS Securities					**Based on Book Value of AFS Securities**				
	2007:Q2	**2013:Q2**	**2015:Q4**	**Change 2007–2013**	**Change 2013–2015**	**2007:Q2**	**2013:Q2**	**2015:Q4**	**Change 2007–2013**	**Change 2013–2015**
ASSETS	5.02	4.27	4.45	**-0.75**	**0.19**	**5.04**	**4.31**	**4.46**	**-0.73**	**0.15**
Securities	11.52	8.28	9.20	**-3.24**	**0.91**	11.57	8.39	9.21	**-3.18**	**0.82**
Pass-Through MBS	16.13	15.40	15.86	**-0.73**	**0.46**	16.15	15.44	15.87	**-0.70**	**0.43**
Other MBS	4.44	3.65	4.04	**-0.79**	**0.39**	4.44	3.65	4.04	**-0.79**	**0.39**
All Other Debt Securities	6.74	4.39	5.43	**-2.35**	**1.04**	6.80	4.50	5.45	**-2.30**	**0.95**

Panel B: Bank Holding Companies with Assets Below $10 Billion

	Based on Fair Value of AFS Securities					**Based on Book Value of AFS Securities**				
	2007:Q2	**2013:Q2**	**2015:Q4**	**Change 2007–2013**	**Change 2013–2015**	**2007:Q2**	**2013:Q2**	**2015:Q4**	**Change 2007–2013**	**Change 2013–2015**
ASSETS	3.35	4.78	4.82	**1.43**	**0.04**	**3.36**	**4.80**	**4.82**	**1.44**	**0.03**
Securities	5.89	7.71	7.44	**1.82**	**-0.27**	5.93	7.79	7.45	**1.86**	**-0.34**
Pass-Through MBS	9.90	11.25	11.29	**1.35**	**0.04**	9.93	11.30	11.30	**1.37**	**-0.01**
Other MBS	3.67	3.49	4.05	**-0.18**	**0.56**	3.68	3.50	4.05	**-0.18**	**0.55**
All Other Debt Securities	5.07	7.38	6.67	**2.31**	**-0.71**	5.11	7.48	6.68	**2.37**	**-0.80**

Notes: MBS stands for mortgage-backed securities and AFS refers to available-for-sale securities.

Source: Bank Reports of Income and Condition Data. Author's calculations.

Table 3. Change in Asset Maturity and Maturity Mismatch between 2007:Q2 and 2013:Q2

Panel A. Change in Maturity Mismatch

	(1)	(2)	(3)
VARIABLES	Δ Average Maturity Mismatch 2007:Q2–2013:Q2		
Δ Maturity Mismatch 2000:Q4–2004:Q2	0.0858***	0.0874***	0.0864***
	(0.0264)	(0.0261)	(0.0257)
Log assets 2007:Q2	-0.0338	-0.0264	-0.0149
	(0.0470)	(0.0489)	(0.0474)
Liquid Assets Ratio, Avg. 2005–2006	0.0162**	0.0182**	0.0105*
	(0.00697)	(0.00774)	(0.00572)
Share of MBS in Assets, Avg. 2005–2006	-0.00331	-0.00236	-0.0109
	(0.00897)	(0.00918)	(0.00756)
Share of CRE in assets, Avg. 2005–2006	0.00652	0.00547	
	(0.00589)	(0.00595)	
Share of RRE in Assets, Avg. 2005–06	0.00597	0.00631	
	(0.00683)	(0.00686)	
NIM, Avg. 2005–2006	0.173**		0.202***
	(0.0745)		(0.0673)
Tier-One Leverage Ratio, Avg. 2005–2006	-0.0205	-0.0177	-0.0208
	(0.0159)	(0.0175)	(0.0162)
CRE NPL Ratio, Avg. 2005–2006	0.149	0.149	0.264*
	(0.163)	(0.163)	(0.154)
Δ CRE NPL Ratio, 2007:Q2–2009:Q4	-0.0138	-0.0164	0.0242
	(0.0612)	(0.0620)	(0.0627)
RRE NPL Ratio, Avg. 2005–2006	-0.886**	-0.911***	-1.008***
	(0.347)	(0.350)	(0.352)
Δ RRE NPL Ratio, 2007:Q2–2009:Q4	-0.0871	-0.0891	-0.0496
	(0.192)	(0.192)	(0.184)
C&I NPL Ratio, Avg. 2005–2006	-0.0942	-0.103	-0.175
	(0.143)	(0.142)	(0.138)
Δ C&I NPL Ratio, 2007:Q2–2009:Q4	-0.0107	-0.0143	-0.144
	(0.256)	(0.254)	(0.239)
Consumer Loan NPL Ratio, Avg. 2005-2006	0.619	0.544	0.324
	(0.498)	(0.527)	(0.499)
Δ Consumer NPL Ratio, 2007:Q2–2009:Q4	-0.780	-0.807	-0.871
	(1.101)	(1.109)	(1.136)
Asset Growth Rate, 2007:Q2-2009:Q4	2.010	2.062*	1.762
	(1.231)	(1.230)	(1.199)
Tier-1 Capital Growth Rate, 2007:Q2–2009:Q4	-1.454	-1.496*	-1.431
	(0.885)	(0.882)	(0.884)
Rate Paid (Over Earning Assets), Avg. 2005–2006		-0.110	
		(0.127)	
Rate Received on Earning Assets, Avg. 2005-2006		0.209**	
		(0.0947)	
CRE Loan Growth, 2002:Q1–2006:Q4			1.562**
			(0.650)
RRE Loan Growth, 2002:Q1–2006:Q4			-1.907**
			(0.937)
C&I Loan Growth, 2002:Q1–2006:Q4			0.826*
			(0.490)
Constant	0.803	0.265	0.980
	(0.758)	(1.233)	(0.748)
Observations	3,649	3,649	3,637
R-squared	0.089	0.090	0.092
Adjusted R2-squared	0.0843	0.0847	0.0870

Notes: Cross-section average-asset weighted OLS regressions include only BHCs below $10 billion that have data over 1997:Q2 to 2013:Q2. Robust standard errors are in parentheses. The symbols ***, ** and *, respectively, denote significant at 1, 5 and 10 percent level.

Source: Bank Reports of Income and Condition Data. Author's calculations.

Table 3. Change in Asset Maturity and Maturity Mismatch between 2007:Q2 and 2013:Q2
Panel B. Change in Maturity of Securities other than Mortgage-Backed Securities

	(1)	(2)	(3)
VARIABLES	∆ Avg. Non–MBS Sec. Maturity 2007:Q2–2013:Q2		
∆ Non-MBS Securities Maturity 2000:Q4–2004:Q2	0.0230	0.0239	0.0171
	(0.0300)	(0.0300)	(0.0296)
Log Assets 2007:Q2	-0.199*	-0.214*	-0.216*
	(0.112)	(0.118)	(0.114)
Liquid Assets Ratio, Avg. 2005–2006	0.0420***	0.0373**	0.0351***
	(0.0144)	(0.0159)	(0.0130)
Share of MBS in Assets, Avg. 2005–2006	0.0133	0.0110	0.00263
	(0.0153)	(0.0158)	(0.0134)
Share of CRE in Assets, Avg. 2005–2006	-0.00304	-0.000675	
	(0.0136)	(0.0134)	
Share of RRE in Assets, Avg. 2005–2006	0.0137	0.0128	
	(0.0147)	(0.0147)	
NIM, Avg. 2005–2006	0.186		0.161
	(0.150)		(0.145)
Tier-One Leverage Ratio, Avg. 2005–2006	-0.0662*	-0.0729*	-0.0629*
	(0.0364)	(0.0396)	(0.0358)
CRE NPL Ratio, Avg. 2005–2006	0.190	0.192	0.253
	(0.258)	(0.256)	(0.233)
∆ CRE NPL Ratio, 2007:Q2–2009:Q4	-0.0625	-0.0567	-0.0767
	(0.0906)	(0.0916)	(0.0903)
RRE NPL Ratio, Avg. 2005–2006	-1.828**	-1.767**	-1.589**
	(0.746)	(0.721)	(0.670)
∆ RRE NPL Ratio, 2007:Q2–2009:Q4	0.349	0.353	0.379
	(0.393)	(0.392)	(0.386)
C&I NPL Ratio, Avg. 2005–2006	0.488	0.507	0.382
	(0.327)	(0.329)	(0.323)
∆ C&I NPL Ratio, 2007:Q2–2009:Q4	0.373	0.388	0.330
	(0.443)	(0.442)	(0.431)
Asset Growth Rate, 2007:Q2–2009:Q4	6.930***	6.791***	7.019***
	(2.627)	(2.585)	(2.604)
Tier-1 Capital Growth Rate, 2007:Q2–2009:Q4	-5.124**	-5.019**	-5.357***
	(1.999)	(1.951)	(1.974)
∆ Time Deposit Maturity, 2007:Q2–2013:Q2	-0.0392	-0.0414	0.00128
	(0.375)	(0.376)	(0.377)
Rate Paid (Over Earning Assets), Avg. 2005–2006		-0.334	
		(0.281)	
Rate Received on Earning Assets, Avg. 2005–2006		0.111	
		(0.178)	
CRE Loan Growth, 2002:Q1–2006:Q4			-1.338
			(1.252)
RRE Loan Growth, 2002:Q1–2006:Q4			3.894*
			(2.352)
C&I Loan Growth, 2002:Q1–2006:Q4			-0.608
			(0.903)
Constant	3.458*	4.648	4.327**
	(2.032)	(2.958)	(1.782)
Observations	3,650	3,650	3,639
R-squared	0.053	0.053	0.055
Adjusted R2-squared	0.0473	0.0478	0.0497

Notes: Cross-section average-asset weighted OLS regressions include only BHCs below $10 billion that have data over 1997:Q2 to 2013:Q2. Robust standard errors are in parentheses. The symbols ***, ** and *, respectively, denote significant at 1, 5 and 10 percent level.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Table 3. Change in Asset Maturity and Maturity Mismatch between 2007:Q2 and 2013:Q2
Panel C. Change in Maturity of Loans

	(1)	(2)	(3)
VARIABLES	Δ Average Loan Maturity 2007:Q2–2013:Q2		
Δ Loan Maturity 2000:Q4–2004:Q2	0.0835***	0.0840***	0.0837***
	(0.0283)	(0.0282)	(0.0267)
Log Assets 2007:Q2	-0.0708	-0.0642	-0.0525
	(0.0546)	(0.0550)	(0.0540)
Liquid Assets Ratio, Avg. 2005–2006	0.0118	0.0136	0.00550
	(0.00782)	(0.00973)	(0.00785)
Share of MBS in Assets, Avg. 2005–2006	0.00558	0.00640	-0.00251
	(0.0122)	(0.0130)	(0.0111)
Share of CRE in Assets, Avg. 2005–2006	0.00381	0.00286	
	(0.00848)	(0.00831)	
Share of RRE in Assets, Avg. 2005–06	0.00832	0.00860	
	(0.00828)	(0.00835)	
NIM, Avg. 2005–2006	0.315***		0.340***
	(0.0747)		(0.0709)
Tier-One Leverage Ratio, Avg. 2005–2006	-0.0333	-0.0309	-0.0351*
	(0.0207)	(0.0216)	(0.0206)
CRE NPL Ratio, Avg. 2005–2006	0.344	0.344	0.432**
	(0.221)	(0.223)	(0.199)
Δ CRE NPL Ratio, 2007:Q2–2009:Q4	0.0559	0.0536	0.0815
	(0.0583)	(0.0598)	(0.0525)
RRE NPL Ratio, Avg. 2005–2006	-1.430**	-1.454**	-1.476**
	(0.709)	(0.706)	(0.661)
Δ RRE NPL Ratio, 2007:Q2–2009:Q4	-0.280	-0.282	-0.240
	(0.225)	(0.226)	(0.211)
C&I NPL Ratio, Avg. 2005–2006	-0.330*	-0.338**	-0.415**
	(0.169)	(0.165)	(0.162)
Δ C&I NPL Ratio, 2007:Q2–2009:Q4	-0.421**	-0.424**	-0.505**
	(0.201)	(0.200)	(0.197)
Consumer Loan NPL Ratio, Avg. 2005–2006	0.509	0.445	0.224
	(0.630)	(0.658)	(0.634)
Δ Consumer NPL Ratio, 2007:Q2–2009:Q4	-0.211	-0.237	-0.239
	(1.046)	(1.051)	(1.074)
Asset Growth Rate, 2007:Q2-2009:Q4	-0.0227	0.0192	-0.159
	(1.253)	(1.241)	(1.239)
Tier-1 Capital Growth Rate, 2007:Q2–2009:Q4	-0.0638	-0.0996	-0.0702
	(0.950)	(0.935)	(0.937)
Δ Time Deposit Maturity, 2007:Q2–2013:Q2	-0.248	-0.247	-0.226
	(0.162)	(0.163)	(0.160)
Rate Paid (Over Earning Assets), Avg. 2005–2006		-0.259*	
		(0.151)	
Rate Received on Earning Assets, Avg. 2005–2006		0.346***	
		(0.0984)	
CRE Loan Growth, 2002:Q1–2006:Q4			1.401
			(0.994)
RRE Loan Growth, 2002:Q1–2006:Q4			-1.142
			(1.325)
C&I Loan Growth, 2002:Q1–2006:Q4			0.123
			(0.493)
Constant	0.964	1.291	1.198
	(0.897)	(2.021)	(0.934)
Observations	3,650	1,830	3,639
R-squared	0.128	0.210	0.128
Adjusted R2-squared	0.123	0.201	0.123

Notes: Cross-section average-asset weighted OLS regressions. They include only BHCs below $10 billion that have data over 1997:Q2 to 2013:Q2. Robust standard errors are in parentheses. The symbols ***, ** and *, respectively denote significant at 1, 5 and 10 percent level.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Table 4. Relationship between Interest Rates, Margins, and Maturity Mismatch

Panel A. Net Interest Margin (NIM) and Maturity Mismatch

	(1)	(2)	(3)	(4)
VARIABLES	**Above $250 Billion**	**$50–250 Billion**	**$10–50 Billion**	**Less than $10 Billion**
NIM over Interest-Earning Assets (t–1)	0.457***	0.234***	0.490***	0.810***
	(0.0685)	(0.0517)	(0.107)	(0.00605)
Maturity Mismatch of Int-Earning Assets (t–1)	-0.0274	0.0474	0.0268	-0.0164***
	(0.0320)	(0.0473)	(0.0181)	(0.00278)
Yield Curve Slope (10-Year – 3-Month)	-0.0674	-0.0668*	-0.0336	0.00521*
	(0.0356)	(0.0290)	(0.0365)	(0.00253)
∆ Slope (t–1 to t) when (+)	0.00498	0.0132	0.0131	-0.176***
	(0.0821)	(0.120)	(0.0993)	(0.00841)
∆ Slope (t–1 to t) when (–)	0.120	-0.0684	-0.180	-0.0187*
	(0.0962)	(0.112)	(0.0963)	(0.00762)
Maturity Mismatch (t–1) X Slope	0.00631	0.00897	0.00339	0.00430***
	(0.00914)	(0.0138)	(0.0100)	(0.000575)
Maturity Mismatch (t–1) X (+) ∆ Slope	0.0192	-0.00415	-0.00677	0.00218
	(0.0210)	(0.0541)	(0.0212)	(0.00293)
Maturity Mismatch (t–1) X (-) ∆ Slope	-0.0283	0.0377	0.0646	0.0197***
	(0.0225)	(0.0540)	(0.0380)	(0.00250)
NIM (t–1) X Crisis Dummy	-0.117*	-0.101	0.0357	-0.0166***
	(0.0552)	(0.0932)	(0.0372)	(0.00219)
Maturity Mismatch (t–1) X Crisis	0.0647	0.105	-0.0656*	0.0239***
	(0.0700)	(0.151)	(0.0300)	(0.00298)
Yield Curve Slope X Crisis	-0.0215	0.0116	-0.150*	-0.00871
	(0.0687)	(0.152)	(0.0605)	(0.00471)
∆ Slope (t–1 to t) when (–) X Crisis	-0.647	0.976**	0.763**	0.288***
	(0.572)	(0.295)	(0.282)	(0.0273)
Maturity Mismatch (t–1) X Slope X Crisis	-0.0232	-0.0713	0.0205	-0.00259
	(0.0271)	(0.0682)	(0.0108)	(0.00134)
Maturity Mismatch (t–1) X (–) ∆ Slope X Crisis	0.0812	-0.110	-0.0668	-0.0294***
	(0.177)	(0.101)	(0.0761)	(0.00767)
NIM (t–1) X ZLB Dummy	0.00211	0.134	0.109	-0.0424***
	(0.0639)	(0.0834)	(0.0780)	(0.00474)
Maturity Mismatch (t–1) X ZLB	-0.0641	-0.185	-0.0987	-0.0319***
	(0.0728)	(0.0941)	(0.0542)	(0.00371)
Yield Curve Slope X ZLB	-0.0753	-0.205*	-0.150	0.00355
	(0.0655)	(0.0837)	(0.0854)	(0.00617)
∆ Slope (t–1 to t) when (+) X ZLB	0.163	0.219	0.145	0.249***
	(0.133)	(0.156)	(0.125)	(0.0141)
∆ Slope (t–1 to t) when (–) X ZLB	-0.189	-0.0932	0.225	0.00557
	(0.263)	(0.161)	(0.123)	(0.0132)
Maturity Mismatch (t–1) X Slope X ZLB	0.0247	0.0368	0.0240	0.00917***
	(0.0176)	(0.0266)	(0.0132)	(0.00130)
Maturity Mismatch (t–1) X (+) ∆ Slope X ZLB	-0.0530	0.00251	0.00735	-0.00265
	(0.0425)	(0.0563)	(0.0278)	(0.00378)
Maturity Mismatch (t–1) X (–) ∆ Slope X ZLB	-0.0246	-0.0615	-0.0946*	-0.0260***
	(0.0749)	(0.0632)	(0.0362)	(0.00348)
Constant	1.432***	2.449***	2.267***	0.865***
	(0.374)	(0.296)	(0.460)	(0.0201)
Observations	1,224	1,406	1,714	420,915
R-squared	0.398	0.199	0.520	0.789
Number of merger adjusted BHCs	83	88	85	11,331
Adjusted R-squared	0.383	0.182	0.512	0.789

Notes: Fixed-effects panel regressions, standard errors (in parentheses) clustered at the merger-adjusted BHC level. The symbols ***, ** and *, respectively, denote significant at 1, 5 and 10 percent level. Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.

Source: Bank Reports of Income and Condition Data. Board of Governors of the Federal Reserve/Haver Analytics. Author's calculations.

Table 4. Relationship between Interest Rates, Margins, and Maturity Mismatch
Panel B. Interest Rate Earned on Interest-Earning Assets and Asset Maturity

	(1)	(2)	(3)	(4)
VARIABLES	**Above $250 Billion**	**$50–250 Billion**	**$10–50 Billion**	**Less than $10 Billion**
Rate Received on Int-Earning Assets (t–1)	0.387***	0.251***	0.324*	0.791***
	(0.0525)	(0.0567)	(0.134)	(0.00433)
Maturity of Non-Zero-Maturity Assets (t–1)	-0.0713	0.176	0.0423	-0.0988***
	(0.0683)	(0.163)	(0.0570)	(0.00657)
10-Year T-bond Yield	0.785***	0.984***	0.956***	0.324***
	(0.0967)	(0.0889)	(0.174)	(0.00740)
Δ10-Year Yield (t–1 to t) when (+)	-1.284***	-0.676*	-0.679**	0.00933
	(0.259)	(0.277)	(0.217)	(0.0156)
Δ10-Year Yield (t–1 to t) when (–)	-0.166	-0.829**	-0.329	0.176***
	(0.260)	(0.268)	(0.442)	(0.0301)
Asset Maturity (t–1) X 10-Year Yield	-0.00564	-0.0324	-0.0178	0.0127***
	(0.0154)	(0.0373)	(0.00894)	(0.00160)
Asset Maturity (t–1) X (+) Δ10-Year Yield	0.118*	-0.0236	0.0135	-0.00894*
	(0.0464)	(0.0737)	(0.0288)	(0.00418)
Asset Maturity (t–1) X (–) Δ10-Year Yield	-0.0461	0.0705	-0.0706	-0.0125
	(0.0430)	(0.0678)	(0.0864)	(0.00735)
Rate Received (t–1) X Crisis Dummy	-0.114	-0.0157	0.0148	-0.0581***
	(0.0754)	(0.114)	(0.141)	(0.00688)
Asset Maturity (t–1) X Crisis	0.290*	0.346**	0.342***	0.300***
	(0.118)	(0.121)	(0.0620)	(0.00791)
10-Year T-Bond Yield X Crisis	0.277	0.103	0.0218	0.0750***
	(0.145)	(0.119)	(0.190)	(0.0113)
Δ10-Year Yield (t–1 to t) when (–) X Crisis	0.327	0.0292	-0.0291	-0.795***
	(0.466)	(0.692)	(0.478)	(0.0397)
Asset Maturity (t–1) X 10-Year Yield X Crisis	-0.0786*	-0.0747	-0.0768***	-0.0659***
	(0.0313)	(0.0453)	(0.0161)	(0.00202)
Asset Maturity (t–1) X (–) Δ10-Year Yield X Crisis	-0.0254	0.0867	0.126	0.0396***
	(0.0999)	(0.132)	(0.0905)	(0.00939)
Rate Received (t–1) X ZLB Dummy	0.153*	0.495***	0.420**	0.0307***
	(0.0667)	(0.0799)	(0.127)	(0.00495)
Asset Maturity (t–1) X ZLB	0.0218	-0.229	0.00696	0.106***
	(0.0593)	(0.124)	(0.0469)	(0.00634)
10-Year T-Bond Yield X ZLB	-0.347**	-0.575***	-0.624**	-0.0578***
	(0.107)	(0.150)	(0.187)	(0.00751)
Δ10-Year Yield (t–1 to t) when (+) X ZLB	1.252***	0.273	0.298	0.0835***
	(0.291)	(0.325)	(0.235)	(0.0223)
Δ10-Year Yield (t–1 to t) when (–) X ZLB	-0.655	0.397	0.311	-0.218***
	(0.411)	(0.335)	(0.445)	(0.0325)
Asset Maturity (t–1) X 10-Year Yield X ZLB	0.00708	0.0377	0.00194	-0.0232***
	(0.0205)	(0.0257)	(0.0130)	(0.00160)
Asset Maturity (t–1) X (+) Δ10-Year Yield X ZLB	-0.168**	0.0528	0.0384	0.0175***
	(0.0534)	(0.0788)	(0.0332)	(0.00497)
Asset Maturity (t–1) X (–) Δ10-Year Yield X ZLB	0.134*	-0.0470	0.0324	0.00760
	(0.0662)	(0.0752)	(0.0881)	(0.00781)
Constant	1.769***	1.558***	1.039**	0.444***
	(0.445)	(0.367)	(0.349)	(0.0208)
Observations	1,224	1,406	1,714	421,548
R-squared	0.784	0.728	0.870	0.920
Number of merger adjusted BHCs	83	88	85	11,338
Adjusted R-squared	0.779	0.722	0.868	0.920

Notes: Fixed-effects panel regressions, standard errors (in parentheses) clustered at the merger-adjusted BHC level. The symbols ***, ** and *, respectively, denote significant at 1, 5 and 10 percent level. Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.
Source: Bank Reports of Income and Condition Data. Board of Governors of the Federal Reserve/Haver Analytics. Author's calculations.

Table 4. Relationship between Interest Rates, Margins, and Maturity Mismatch
Panel C. Interest Rate Paid (Normalized by Interest-Earning Assets) and Liability Maturity

VARIABLES	(1) Above $250 Billion	(2) $50–250 Billion	(3) $10–50 Billion	(4) Below $10 Billion
Rate Paid on Int-Earning Assets (t–1)	0.366***	0.423**	0.399*	0.880***
	(0.0557)	(0.134)	(0.152)	(0.00243)
Ratio of Transac. Deposits to Int.-Earning Assets (t–1)	-0.652	-1.575**	-1.231***	-0.134***
	(0.389)	(0.495)	(0.242)	(0.0206)
Ratio of Savings Deposits to Int.-Earning Assets (t–1)	-0.521	-0.943	-1.307***	-0.0729**
	(0.328)	(0.684)	(0.326)	(0.0278)
Bank Holding Company Deposit HHI	-0.227	-1.813	0.335	-0.0288*
	(0.272)	(1.010)	(0.640)	(0.0133)
6 Month Int. Rate Swaption Volatility	0.356**	0.211	0.192	0.0300***
	(0.113)	(0.160)	(0.103)	(0.00500)
Δ 6 Month Int. Rate Swaption Volatility (t–1 to t)	-0.226	0.00394	0.0484	-0.0577***
	(0.132)	(0.184)	(0.0826)	(0.00464)
Maturity of Non-Zero-Maturity Liabilities (t–1)	-0.0489	0.0205	-0.0581	-0.00505*
	(0.0651)	(0.0470)	(0.0608)	(0.00254)
3-Month T-Bill Yield	0.353***	0.272***	0.329***	0.104***
	(0.0407)	(0.0701)	(0.0908)	(0.00211)
Δ3-Mon. Yield (t–1 to t) when (+)	-0.138	-0.237	-0.0948	0.0333**
	(0.202)	(0.401)	(0.177)	(0.0110)
Δ3-Mon. Yield (t–1 to t) when (–)	-0.269**	-0.213	-0.176	0.489***
	(0.101)	(0.177)	(0.155)	(0.0143)
Liability Maturity (t–1) X 3-Mon. Yield	0.0404*	0.0578**	0.00498	-0.00111
	(0.0161)	(0.0206)	(0.0243)	(0.000977)
Liability Maturity (t–1) X (+) Δ3-Mon. Yield	-0.0706	-0.124	-0.123	0.0143
	(0.102)	(0.154)	(0.0669)	(0.00786)
Liability Maturity (t–1) X (–) Δ3-Mon. Yield	0.0933	0.0987	0.0129	-0.179***
	(0.0628)	(0.110)	(0.0333)	(0.0140)
Rate Paid (t–1) X Crisis Dummy	-0.0198	-0.0170	0.171	-0.0401***
	(0.0768)	(0.0885)	(0.0959)	(0.00281)
Liability Maturity (t–1) X Crisis	0.0519	0.135	0.0483	0.104***
	(0.0858)	(0.0771)	(0.0494)	(0.00487)
3-Month T-Bill Yield X Crisis	0.109	0.0445	-0.100	-0.0210***
	(0.0904)	(0.0890)	(0.0741)	(0.00233)
Δ3-Mon. Yield (t–1 to t) when (–) X Crisis	-0.115	-0.117	0.171	-0.535***
	(0.198)	(0.239)	(0.164)	(0.0149)
Liability Maturity (t–1) X 3-Mon. Yield X Crisis	-0.0413	-0.0544	-0.0304	-0.0100***
	(0.0416)	(0.0343)	(0.0335)	(0.00171)
Liability Maturity (t–1) X (–) Δ3-Mon. Yield X Crisis	-0.0175	0.00594	-0.0408	0.174***
	(0.126)	(0.120)	(0.0568)	(0.0143)
Rate Paid (t–1) X ZLB Dummy	0.0101	0.0905	0.139	-0.0160***
	(0.0964)	(0.0969)	(0.102)	(0.00260)
Liability Maturity (t–1) X ZLB	0.0186	0.0561	0.0798	0.0511***
	(0.0561)	(0.0734)	(0.0560)	(0.00394)
Constant	0.407	1.049**	0.908**	0.0617***
	(0.264)	(0.330)	(0.272)	(0.0132)
Observations	1,224	1,406	1,714	420,924
R-squared	0.929	0.892	0.957	0.966
Number of merger adjusted BHCs	83	88	85	11,323
Adjusted R-squared	0.928	0.890	0.956	0.966

Notes: These are fixed-effects panel regressions, with standard errors (in parentheses) clustered at the merger-adjusted BHC level. The symbols ***, ** and *, respectively, denote significant at 1, 5 and 10 percent level. Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.
Source: Bank Reports of Income and Condition Data. Board of Governors of the Federal Reserve/Haver Analytics. Summary of Deposits. Author's calculations.

Table 5. Explanatory Power of Maturity Mismatch for Net Interest Margin (NIM)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Above $250 Billion				Below $10 Billion			
VARIABLES	1997:Q2–2008:Q2		2008:Q3–2015:Q4		1997:Q2–2008:Q2		2008:Q3–2015:Q4	
NIM over interest-earning assets (t–1)	0.184*	0.187*	0.443***	0.462***	0.797***	0.798***	0.626***	0.629***
	(0.0907)	(0.0911)	(0.100)	(0.0955)	(0.0113)	(0.0114)	(0.00947)	(0.00944)
Share of Securities in Int.-Earning Assets (t–1)	-1.460*	-1.482*	0.0211	-0.0491	0.144***	0.115***	-0.283***	-0.299***
	(0.627)	(0.614)	(0.962)	(0.897)	(0.0276)	(0.0284)	(0.0336)	(0.0329)
BHC Deposit HHI	-1.747	-1.685	1.492***	1.441***	0.0372	0.0334	-0.0691	-0.0705
	(2.170)	(2.200)	(0.277)	(0.322)	(0.0437)	(0.0438)	(0.0590)	(0.0595)
6 Month Int. Rate Swaption Volatility	0.163	0.151	0.138	0.108	-0.145***	-0.153***	-0.0927***	-0.0992***
	(0.222)	(0.215)	(0.204)	(0.206)	(0.0144)	(0.0152)	(0.00873)	(0.00867)
∆ 6 Month Int. Rate Swaption Volatility (t–1 to t)	-0.140	-0.132	0.723*	0.735*	-0.244***	-0.251***	0.120***	0.127***
	(0.269)	(0.271)	(0.308)	(0.302)	(0.0130)	(0.0131)	(0.00842)	(0.00835)
Maturity mismatch of int-earning assets (t–1)	-0.00819		-0.210		0.00368		0.00150	
	(0.0359)		(0.210)		(0.00432)		(0.00816)	
Level Factor	-0.0795	0.0169	-0.229	-0.286	0.158***	0.158***	0.0999***	0.00767
	(0.0569)	(0.0383)	(0.271)	(0.264)	(0.00619)	(0.00352)	(0.0157)	(0.00911)
Level factor (t–1)	0.295***	0.194***	0.181	0.101	-0.0363***	-0.0204***	-0.0631***	0.0321***
	(0.0733)	(0.0473)	(0.181)	(0.160)	(0.00476)	(0.00467)	(0.0103)	(0.00608)
Slope Factor	0.361*	0.331**	0.220	0.0502	-0.175***	-0.0871***	-0.178***	-0.0166
	(0.153)	(0.0998)	(0.453)	(0.421)	(0.0145)	(0.00685)	(0.0228)	(0.0126)
Slope Factor (t–1)	0.197	0.267**	-0.336	0.0285	0.481***	0.462***	0.152***	0.0633***
	(0.123)	(0.0916)	(0.350)	(0.306)	(0.0143)	(0.00746)	(0.0164)	(0.00896)
Maturity mismatch (t–1) X Level factor	0.0335		-0.0108		-1.84e-05		-0.0281***	
	(0.0169)		(0.0935)		(0.00202)		(0.00354)	
Maturity mismatch (t–1) X Level factor (t–1)	-0.0346		-0.0275		0.00664***		0.0301***	
	(0.0199)		(0.0485)		(0.00168)		(0.00248)	
Maturity mismatch (t–1) X Slope Factor	-0.00926		-0.0700		0.0345***		0.0471***	
	(0.0468)		(0.198)		(0.00472)		(0.00496)	
Maturity mismatch (t–1) X Slope Factor (t–1)	0.0253		0.120		-0.00831		-0.0282***	
	(0.0351)		(0.133)		(0.00480)		(0.00376)	
Constant	3.856***	3.817***	0.511	-0.192	1.482***	1.513***	1.616***	1.599***
	(0.582)	(0.584)	(0.858)	(0.749)	(0.0438)	(0.0471)	(0.0538)	(0.0450)
Observations	875	875	322	322	258,458	258,458	152,988	152,988
R-squared	0.281	0.277	0.540	0.531	0.767	0.767	0.471	0.469
Number of merger adjusted BHCs	79	79	16	16	10,172	10,172	6,632	6,632
Adjusted R-squared	0.267	0.267	0.515	0.513	0.767	0.767	0.471	0.469

Notes: Fixed-effects panel regressions, standard errors (in parentheses) clustered at the merger-adjusted BHC level. The symbols ***, ** and *, respectively denote significant at 1, 5 and 10 percent level. The above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.

Source: Bank Reports of Income and Condition Data. Summary of Deposits. Board of Governors of the Federal Reserve/Haver Analytics. Author's calculations

Table 6. Change in Duration of Held-To-Maturity Pass-Through Mortgage-Backed Securities Held by the Bank Holding Companies After 2011

	(1)	(2)	(3)	(4)	(5)	(6)
	Above $250 Billion		Below $10 Billion		$50–250 Billion	$10–50 Billion
VARIABLES	Panel	Time series	Panel	Time series	Time series	Time series
HTM Dummy	-0.374***	-0.660***	-0.191***	-0.167***	0.0405	-0.488***
	(0.0447)	(0.0649)	(0.00455)	(0.0340)	(0.0829)	(0.0465)
Post 2011 Dummy	0.0426	0.0978	-0.0455***	-0.0165	0.0978	0.0978
	(0.0725)	(0.0999)	(0.00416)	(0.0524)	(0.128)	(0.0716)
HTM X Post-2011	0.734***	1.016***	0.0460***	0.145	0.454*	0.384***
	(0.0966)	(0.141)	(0.0102)	(0.0741)	(0.181)	(0.101)
Constant	0.968***	0.981***	0.661***	0.736***	0.981***	0.981***
	(0.0251)	(0.0459)	(0.00186)	(0.0240)	(0.0586)	(0.0328)
Observations	1,901	152	384,865	152	152	152
R-squared	0.062	0.556	0.005	0.153	0.133	0.494
Merger-adjusted BHCs	81	--	9,996	--	--	--
R2-adjusted	0.0195	0.547	-0.0215	0.135	0.115	0.484

Notes: Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets. The estimated duration of available-for-sale and held-to-maturity pass-through mortgage-backed securities is regressed on the held-to-maturity dummy, post-2011 dummy and their interaction. The coefficient on the last term measures the change in the beta of held-to-maturity after 2011. For the panel regressions, each observation is at the bank holding company-quarter level. For the time series regressions, the dependent variable is the weighted-average duration for the relevant size group in each quarter.

Source: Bank Reports of Income and Condition Data. Bloomberg Barclays U.S. Aggregate Bond Index. Author's calculations.

Appendix A. Data and Sample Construction

This appendix details how the dataset used for analysis is constructed, focusing on the adjustments made to the raw data to ensure consistency and minimize the influence of outliers.

B.1 Bank Data—Call Reports

The primary data used in this study come from the Call Reports—regulatory financial statements filed by all FDIC-insured banks and some other specialty banking organizations each quarter. The following selection mechanism is applied to the raw Call Reports data.

First, only data for commercial banks (all of which file forms FFIEC 031 and 041) are retained; this criterion eliminates 80,316 observations between 1997:Q2 and 2015:Q4, corresponding to 2,297 banks and 2,449 holding companies, respectively. Chief among the entities removed are state-chartered savings banks—a total of 1,036 banks and 1,234 holding companies. Compared to commercial banks, these institutions generally have a different business model—typically a much higher concentration of residential mortgage lending—that renders the issues analyzed in this study irrelevant.[71] For the same reason of a different business model, among commercial banks, I omit 15 custodial banks (such as State Street and Bank of New York Mellon) and 85 banks that specialize in credit card lending (such as Bank One). Similarly, the first eight quarters of a de novo bank's existence are omitted because such banks tend to have a rather different balance-sheet structure: significantly higher capital ratios and higher shares of securities in the asset portfolio. This restriction eliminates 17,129 quarterly observations.

Banks with the following unusual attributes are also omitted: those banks without FDIC insurance (six observations), or institutions identified as a specialty bank (defined as having a non-zero value for the variable RSSD9425, such as being a bankers' bank, an Edge and agreement corporation, and so on, corresponding to 5,512 observations). Likewise, I leave out bank subsidiaries of Goldman Sachs (holding company ID RSSD9348 = 2380443) and Morgan Stanley (RSSD9348 = 2162966), both of which were formerly investment banks and converted to financial holding companies during the financial crisis. A few other banks that would otherwise satisfy the selection criteria are removed for the following reasons: 1) Ally Bank is classified as an Internet-only bank (RSSD9425 = 6) except for one quarter, 2) Countrywide converted its charter from commercial bank to thrift in 2007:Q1 and thus dropped out of the

[71] The other major institutional category removed is federal savings banks. Compared to other banks and thrift institutions, federal savings banks have an even more specialized business model, as they concentrate almost exclusively in making residential mortgage loans. After the Office of Thrift Supervision (OTS) was abolished, as stipulated in the Dodd-Frank Act, savings and loans institutions also started filing the Call Reports in 2012:Q1. Naturally, they are not included in the sample.

Call Reports data until it was acquired by Bank of America and became embedded in Bank of America's numbers starting from 2008:Q2, and 3) UFJ Trust Company was misclassified as a commercial bank.

Naturally, the sample drops any observations that have unreasonable values: negative assets or capital, negative interest income or interest expenses, or a negative noninterest expense such as employee salaries and benefits. These requirements eliminate a total of 136 observations.

The application of these criteria leads to a bank-level sample of 527,359 observations corresponding to 11,167 unique bank identification numbers (IDs) over the 1997:Q2–2015:Q4 sample period. Once aggregated up to the BHC level, I end up with a sample of 448,802 observations corresponding to 10,787 unique BHC IDs over the same sample period.

To minimize or remove any undue influence on the analysis stemming from activity related to mergers and acquisitions, the merger and acquisition records maintained by the Federal Reserve are used to make cross-BHC merger adjustments (note that no adjustment is needed for within-BHC mergers of bank subsidiaries because all the analysis is performed at the BHC level). The first post-merger quarter for each survivor is left out when computing growth rates in order to avoid erroneous large jumps in growth rates. On the other hand, when it comes to ratios or shares, the merger quarters are generally retained, a choice which has noticeable impact only on the sample of BHCs greater than $10 billion in assets. If the merger quarters were removed, the sample composition would change sufficiently in quite a few quarters so that the weighted-average maturity of many asset categories for the BHCs in the top three size groups would become rather volatile.

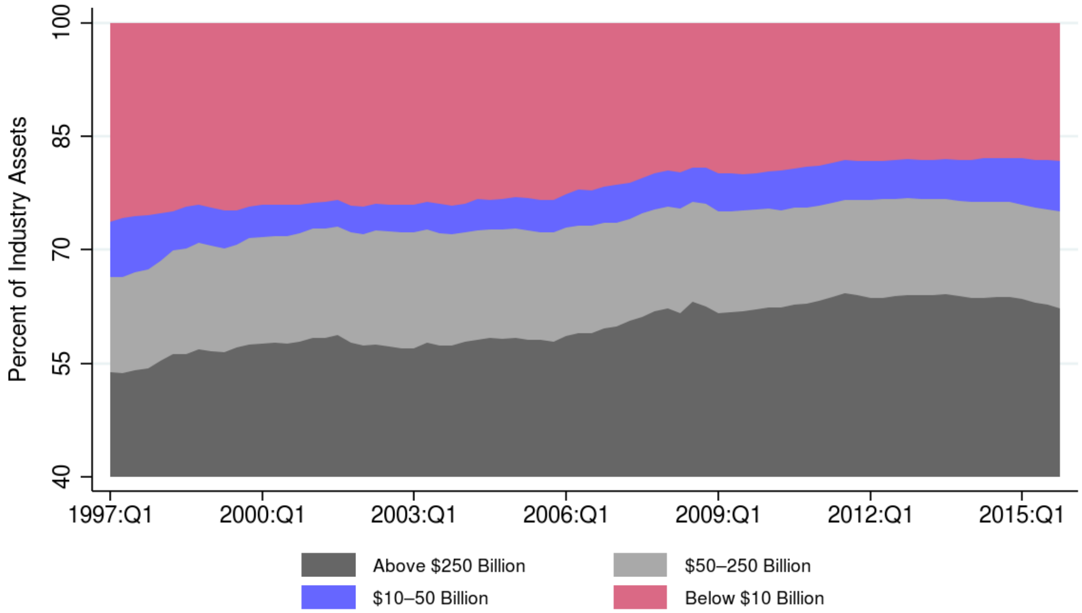
Since most of the analysis is conducted at the BHC level, there is a need to manually adjust the high holder IDs for a few banks in order to consistently aggregate bank-level balance or flow values to the BHC level. The following is the list of banks whose BHC high holder IDs are adjusted: Banco Santander Puerto Rico (from blank high holder to Banco Santander), M&I Bank (from RSSD9348 = 1199497 to RSSD9348 = 3594612 during 1997:Q1 to 2001:Q1), Citizens (from RSSD9348 = 1132449 to 3833526 in just one quarter, 2015:Q4), the latter being the ID of the Royal Bank of Scotland, which divested Citizens in 2015:Q4), and ABN AMRO (from RSSD9348 = 1718245 to RSSD9348 = 1718227 during 2001:Q1 to 2003:Q4 as the new BHC ID 1718245 was created merely to implement an internal governance reform). In the cases where a bank reports no high holder, I set the RSSD9348 ID to match its bank ID.

Furthermore, a number of observations have to be specifically adjusted in order to avoid nontrivial swings in maturity values at the BHC size group or even at the industry level. The first adjustment addresses a spike in Bank of Montreal's (BMO's) transaction deposit balance in 2008:Q4, which is replaced with the average of the two neighboring quarters. The other addresses significant drops in the weighted-average of Bank of America's pass-through MBS collateralized with 1-4 family mortgages in 2004:Q2 to 2004:Q4 because a high fraction of balances in the longest maturity bin (above 15 years) appear to have fallen to the next maturity bin. These observations may be correct if some MBS had maturity of 15 years in 2004:Q2, the threshold between two maturity bins. Without more detailed data, however, the shares of the two top maturity bins in 2004:Q2 and 2004:Q3 are linearly extrapolated using the reported values for 2004:Q1 and 2004:Q4. A similar problem exists for Bank One in 2004:Q3, its single quarter of Call Reports after being acquired by J.P. Morgan Chase; this issue is solved by linearly extrapolating the relative share across maturity bins from the two previous quarters. For robustness, I also tried simply dropping this observation from the sample, and doing so makes no difference to any of the results.

B.1 Consolidated BHC Data from Form FR Y-9C

For certain variables, such as the balance of assets that mature or reprice within a year, it is more accurate to use the consolidated BHC data directly reported in the form FR Y-9C. I keep only those BHCs that match to the banks in the Call Reports sample. The Y-9C sample is in fact a smaller set because BHCs below a size threshold are not required to file the form. This cutoff was $150 million until 2005:Q4. Starting from the March 2006 filing, the threshold was raised to $500 million. It is further increased to $1 billion starting from March 2015. For this reason, 25,598 observations in the dataset that combines the Call Reports and Y-9C data are eliminated; this omission corresponds to 10,788 BHC IDs.

Figure A1. Asset Share of BHCs Bank Holding Companies in Each of the Four Size Classes



Notes: Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Appendix B. Dynamic of Amortized Cost and Fair Value of Portfolios of Debt Securities

This appendix derives the formula used to approximate the book value (BV, used interchangeably with amortized cost) of available-for-sale (AFS) debt securities in each maturity bin to minimize the impact of yield changes on the fair value (FV) of such securities. The goal is to minimize the impact of yield changes on the reported value of securities by maturity bin, which is the sum of the BV of held-to-maturity (HTM) and the FV of AFS securities, and in turn the weighted-average maturity of each category of securities. The derivation is built upon formulae describing how the BV and the FV evolve differently in response to yield changes.

B.1 Dynamics of Book Value and Fair Value of Portfolios of a Single Maturity

I start with a portfolio of AFS securities (denoted with the superscript *A*) of a single maturity.[72] Denote the portfolio's BV on day τ of quarter t $BV^A_{t,\tau}$, and denote the end of a quarter day *T* (to be precise, *T* should also have a subscript *t*, but it is ignored here). Then the quarter-end BV, denoted $BV^A_{t,T}$, evolves as follows (with continuous compounding of daily rates):

$$BV^A_{t,T} = BV^A_{t,0}\prod\nolimits_{\tau=1}^{T}(1-\delta_{t,\tau})\exp\left(y^0_{t,\tau}-c^0_{t,\tau}\right)+\sum\nolimits_{\tau=1}^{T}\left(FV^A_{t,\tau}\prod\nolimits_{s=\tau+1}^{T}(1-\delta_{t,s})\exp\left(y^\tau_{t,s}-c^\tau_{t,s}\right)\right). \quad \text{(A1)}$$

In the formula, the first term describes the BV evolution of securities inherited from last quarter over the course of quarter *t*: on each day τ the BV shrinks by a fraction $\delta_{t,\tau}$ (because securities were redeemed or sold, or matured), and the remaining securities' BV grows by the average amortization rate $y^0_{t,\tau}-c^0_{t,\tau}$.[73] $y^0_{t,\tau}$ is the (value-weighted) average market yield while $c^0_{t,\tau}$ is the average coupon rate, with the superscript "0" denoting the first date within the quarter the securities are included in the portfolio while τ in the subscript denoting the date when the average yield and coupon rates are computed. Both $y^0_{t,\tau}$ and $c^0_{t,\tau}$ are determined prior to quarter *t*.[74] The average rate changes from day to day within quarter *t* only because the subset of debt remaining the portfolio on a given day may differ, although the variation is likely small. I use $y^0_t-c^0_t$ to denote the mean rate, that is, $T\left(y^0_t-c^0_t\right)=\ln\prod\nolimits_{\tau=1}^{T}\exp\left(y^0_{t,\tau}-c^0_{t,\tau}\right)$.

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[72] For derivations in this section, it is assumed that the same maturity corresponds to the same duration, which is not necessarily the case for coupon bonds as will be explained further below when we discuss the portfolio FV.

[73] We will refer to $\delta_{t,\tau}$ as the "depreciation" rate and 1 – $\delta_{t,\tau}$ as the retention rate. Here, $\delta_{t,\tau}$ is defined based on the beginning BV on a given day, so it is specific to each day. Multiplying by $\exp\left(y^0_{t,\tau}-c^0_{t,\tau}\right)$ yields the equivalent depreciation rate based on the end-of-day balance.

[74] To be fully precise, a third subscript is needed to denote the quarter when the coupon rate was set.

The first term in (A1) can be further decomposed into two parts: the quarter-end BV of the initial portfolio (denoted $BV_{t,T}^{A0}$) if intact and the "depreciation" of this BV that takes place within the quarter: $BV_{t,0}^{A}\exp\left(T\left(y_t^0 - c_t^0\right)\right)\left(1-\bar{\delta}_t\right) \equiv BV_{t,T}^{A0}\left(1-\bar{\delta}_t\right)$, where $\bar{\delta}_t \equiv 1-\prod_{\tau=1}^{T}(1-\delta_{t,\tau})$ is the average depreciation rate of the initial portfolio. The quarterly growth rate of this initial portfolio's BV thus can be expressed as:

$$\left[BV_{t,T}^{A0}\left(1-\bar{\delta}_t\right)-BV_{t,0}^{A}\right]\Big/BV_{t,0}^{A} \approx \ln\left[BV_{t,T}^{A0}\left(1-\bar{\delta}_t\right)\right]-\ln\left(BV_{t,0}^{A}\right)=T\left(y_t^0-c_t^0\right)+\ln\left(1-\bar{\delta}_t\right)\approx T\left(y_t^0-c_t^0\right)-\bar{\delta}_t. \quad \text{(A1')}$$

Note that this relationship holds approximately only if the change is small, meaning that the amortization rate and the fraction maturing or being sold must both be small. It can be inferred that the amortization rate $T\left(y_t^0 - c_t^0\right)$, equivalent to the initial portfolio's BV growth rate absent depreciation, tends to be small. Recall that y and c represent interest rates (in percent) at the daily frequency and T is the number of days in a quarter. Equation (A1') thus means that the quarterly growth rate in portfolio BV is about one-fourth of the difference between current yield (y) and historical coupon rate (c), with both expressed as annual rate. If I assume that all securities purchased by banks were issued no more than five years ago, then the value of (y – c) should follow the distribution of yield changes over all horizons within every five-year interval. This distribution falls between –3.36 and 1.80 percentage points for 10-year Treasuries over the sample period starting 1997Q2, with an inter-quartile range of –1.71 to 0.21. This means that the quarterly change in BV is generally small, less than 1percent and mostly no more than one-half of a percent. If banks tend to purchase securities newly issued in the last quarter, then over our sample the quarterly BV growth is likely within 1/4 percent since the absolute quarterly yield change never exceeded 1.5 and the average change is only 21 basis points. This then implies that any large quarterly change in BV is almost surely due to portfolio adjustment—new purchases net of depreciation of the initial portfolio.

The second term in Equation (A1) tallies up the BV of securities purchased and kept during the quarter, with $y_{t,s}^{\tau}$ and $c_{t,s}^{\tau}$ being defined analogously. A debt security is recorded at its market value (i.e., fair value) at the time of purchase. The difference between its (par) value at maturity and its purchase price is amortized (or accreted) over its life. In fact, in the Call Reports, the rate at which interest on a bond is earned is the coupon rate adjusted by the amortization (or accretion) so that the bond's value at maturity will equal the redemption value (typically par value). For example, if a bond was purchased at a premium to par because market yield at that time fell below its coupon rate, then interest on the income statement is earned at the market yield and its book value would decline over time so that its value at maturity equals par value, and vice versa. This implies that the book value of new purchases following a period of falling rates is more likely to be falling over time if the purchases contain bonds whose coupons were set in earlier periods, and vice versa. The former scenario is likely applicable to long bonds purchased during the ZLB period.

Equation (A1) makes clear that the BV does not depend on an asset's duration. In fact, since the portfolio's BV changes at a rate equal to the difference between current and past yields, the BV of long-term debt tends to move by a smaller percentage than that of short-term debt because, before short-term rates hit theZLB, long yields tended to fluctuate less than short yields. This dynamic contrasts with the relative fluctuation in FV: the FV of long-term debt tends to fluctuate more than that of short-term debt for the given shift in yield curve. Moreover, the BV depends explicitly on yields within the quarter ($y^{\tau}_{t,s}$), but only to the extent that new purchases include securities whose coupon rates ($c^{\tau}_{t,s}$) were set before quarter *t*.

By comparison, the FV of the same portfolio (of bonds of a single maturity) evolves as follows:

$$FV^{A}_{t,T} = FV^{A}_{t,0}\prod\nolimits_{\tau=1}^{T}(1-\delta_{t,\tau})\exp\left(-D_{t,\tau}\Delta y_{t,\tau}\right)+\sum\nolimits_{\tau=1}^{T}\left(FV^{A}_{t,\tau}\prod\nolimits_{s=\tau+1}^{T}(1-\delta_{t,s})\exp\left(-D_{t,s}\Delta y_{t,s}\right)\right). \qquad \text{(A2)}$$

$D_{t,\tau}$ is the duration (corresponding to the given maturity) of securities outstanding on day τ. It is assumed to be sufficiently long so that it is treated as constant within a quarter, that is $D_{t,\tau} = D_t$ for all τ. Note that the duration of coupon bonds is invariably shorter than the stated maturity; for any given maturity, the higher the coupon rate or yield, the lower the duration. The "depreciation" rate based on FV may differ from that defined on book value, but the difference is likely small and thus ignored here. Equation (A2) makes clear the intuition that, given any portfolio "depreciation" and new purchases, FV would change more (inversely to yield changes) within a quarter the longer the portfolio duration. This contrasts against the evolution of BV laid out in (A1) above.

I can gauge the magnitude of the growth rate in FV for the initial portfolio, the first term in (A2), as follows:

$$\begin{aligned}&\left[FV^{A0}_{t,T}\left(1-\bar{\delta}_t\right)-FV^{A}_{t,0}\right]\Big/FV^{A}_{t,0}\approx\ln\left[FV^{A0}_{t,T}\left(1-\bar{\delta}_t\right)\right]-\ln\left(FV^{A}_{t,0}\right)\\&\equiv\ln\left[FV^{A}_{t,0}\exp\left(-D_t\sum\nolimits_{\tau=1}^{T}\Delta y_{t,\tau}\right)\left(1-\bar{\delta}_t\right)\right]-\ln\left(FV^{A}_{t,0}\right)\approx -D_t\sum\nolimits_{\tau=1}^{T}\Delta y_{t,\tau}-\bar{\delta}_t\ .\end{aligned} \qquad \text{(A2')}$$

Here, $\bar{\delta}_t$ is defined as for Equation (A1) above. So, absent depreciation, the FV grows at a rate in proportion to duration. Note that, as in Equation (A1'), Equation (A2') also holds approximately only for small changes. As an example, for a portfolio with a long duration of 10 years and absent depreciation, its value will rise by about 2.5 percent over a quarter if the annual yield falls by just 25 basis points (about the median quarterly change). This clearly exceeds the typical change in BV due to amortization over a quarter. For any given yield change, portfolios with shorter durations will experience proportionally smaller (absolute) FV growth.

If I further assume that $T\left(y_t^0 - c_t^0\right)$ is sufficiently small to be ignored, as argued above, then the growth rate difference between the FV and the BV of a given portfolio (net of depreciations) is the product between its duration and the cumulative change in yield over the quarter:

$$\left(1-\bar{\delta}_t\right)FV_{t,T}^{A0}\Big/FV_{t,0}^{A} - \left(1-\bar{\delta}_t\right)BV_{t,T}^{A0}\Big/BV_{t,0}^{A} \approx -D_t\sum\nolimits_{\tau=1}^{T}\Delta y_{t,\tau} - T\left(y_t^0 - c_t^0\right) \approx -D_t\sum\nolimits_{\tau=1}^{T}\Delta y_{t,\tau}\ . \qquad \text{(A3)}$$

It is clear from Equation (A3) that the longer the duration, the greater the FV-BV growth differential of the initial portfolio for a given quarterly change in yield. It is obvious that an analogous relationship applies to any securities of a given duration newly purchased on any day τ within the quarter:

$$\left(1-\bar{\delta}_t\right)FV_{t,T}^{A\tau}\Big/FV_{t,\tau}^{A} - \left(1-\bar{\delta}_t\right)BV_{t,T}^{A\tau}\Big/FV_{t,\tau}^{A} \approx -D_t\sum\nolimits_{s=\tau+1}^{T}\Delta y_{t,s} - T\left(y_{t,\tau}^{\tau} - c_{t,\tau}^{\tau}\right) \approx -D_t\sum\nolimits_{s=\tau+1}^{T}\Delta y_{t,s}\ . \qquad \text{(A3')}$$

Note here that the denominator is the initial FV of the purchase made on day τ.

Combining Equations (A3) and (A3') then leads to the result that the difference in the growth of a portfolio's FV and the growth of its BV is a weighted-average of yield changes over the quarter scaled by the portfolio's duration, with the relative size of the portfolio purchased on day τ as the weight:

$$FV_{t,T}^{A}\Big/FV_{t,0}^{A} - BV_{t,T}^{A}\Big/BV_{t,0}^{A} \approx -D_t\sum\nolimits_{\tau=1}^{T}\left[\Delta y_{t,\tau} + \left(FV_{t,\tau}^{A}\Big/FV_{t,0}^{A}\right)\sum\nolimits_{s=\tau+1}^{T}\Delta y_{t,s}\right]. \qquad \text{(A4)}$$

Equation (A4) implies that, assuming monotonic changes in yield within a quarter, if the fraction of new purchases is high, especially if toward the end of a quarter, then the difference between the FV and BV change for a long-duration portfolio may not exceed that of a shorter-duration portfolio even given the same overall quarterly yield movement. Nevertheless, it is likely more important to adjust the FV of long-dated AFS securities to minimize the influence of valuation changes.

B.2 Dynamic of BV and FV of Portfolios of Multiple Maturities

As noted, the above derivations apply to a portfolio of securities with the same maturity. In the actual Call Reports data, a separate BV and FV are reported only for each category of securities (such as Treasuries and agency MBS), which comprise a range of maturities. Hence, simplifying assumptions are needed for a relationship analogous to (A1') to exist for the BV of a portfolio of assets with different amortization and depreciation rates and, likewise, for the FV of such a portfolio of mixed maturities.

As an example, if it is assumed that assets in a portfolio amortize at about the same rate (that is, $y_{t,i}^0 - c_{t,i}^0 \approx y_t^0 - c_t^0$ for all i = 1, …, N assets), then the quarterly growth of the initial portfolio's BV (that is, absent new purchases) approximately equals the amortization rate net of depreciation:

$$\left[\sum_{i=1}^{N} BV_{t,0,i}^{A}\left(1-\bar{\delta}_{t,i}\right) e^{T\left(y_t^0-c_t^0\right)} \Big/ \sum_{i=1}^{N} BV_{t,0,i}^{A}\right]-1 \approx T\left(y_t^0-c_t^0\right)+\ln\left(1-\sum_{i=1}^{N} w_{t,i}^{BV}\bar{\delta}_{t,i}\right) \approx T\left(y_t^0-c_t^0\right)-\sum_{i=1}^{N} w_{t,i}^{BV}\bar{\delta}_{t,i} \,. \tag{A5}$$

where $w_{t,i}^{BV} \equiv BV_{t,0,i}^{A} \Big/ \sum_{i=1}^{N} BV_{t,0,i}^{A}$ is the weight (that is, share) of asset group i in the initial portfolio's BV. $\sum_{i=1}^{N} w_{t,i}^{BV}\bar{\delta}_{t,i}$ can be regarded as the weighted-average depreciation rate for the initial portfolio.

An analogous equation holds for new purchases made on day τ within a quarter:

$$\left[\sum_{i=1}^{N} BV_{t,\tau,i}^{A}\left(1-\bar{\delta}_{t,\tau,i}\right) e^{(T-\tau)\left(y_t^\tau-c_t^\tau\right)} \Big/ \sum_{i=1}^{N} BV_{t,\tau,i}^{A}\right]-1 \approx (T-\tau)\left(y_t^\tau-c_t^\tau\right)-\sum_{i=1}^{N} w_{t,\tau,i}^{BV}\bar{\delta}_{t,\tau,i} \,. \tag{A5'}$$

Multiplying (A5') by $w_{t,\tau}^{BV} \equiv \sum_{i=1}^{N} BV_{t,\tau,i}^{A} \Big/ \sum_{i=1}^{N} BV_{t,0,i}^{A}$, day-$\tau$ purchases relative to the initial balance, I obtain the result that the growth of a portfolio's BV is a weighted-average of amortization rates and depreciation rates:

$$\left[\sum_{i=1}^{N} BV_{t,T}^{A} \Big/ \sum_{i=1}^{N} BV_{t,0,i}^{A}\right]-1 \approx \sum_{\tau=0}^{T} w_{t,\tau}^{BV}\left[(T-\tau)\left(y_t^\tau-c_t^\tau\right)-\sum_{i=1}^{N} w_{t,\tau,i}^{BV}\bar{\delta}_{t,\tau,i}\right]. \tag{A6}$$

Note that Equation (A6) requires assuming that amortization rates are basically the same across debt of different durations and assuming low depreciation rates for all debt in the portfolio. Violating an assumption analogous to the first assumption explains why such an approximation does not hold for the FV of a mixed-duration portfolio.

In a portfolio consisting of multiple durations, since the FV growth is about proportional to the duration of each subset of securities, the FV growth of the initial portfolio over a quarter is:[75]

$$\left[\sum_{i=1}^{N} FV_{t,0,i}^{A0}\left(1-\bar{\delta}_{t,i}\right) \Big/ \sum_{i=1}^{N} FV_{t,0,i}^{A}\right]-1 \approx \ln\left[\sum_{i=1}^{N} w_{t,i}^{FV} \exp\left(-D_{t,i}\sum_{\tau=1}^{T}\Delta y_{t,\tau,i}\right)\left(1-\bar{\delta}_{t,i}\right)\right]. \tag{A7}$$

Here $w_{t,i}^{FV} \equiv FV_{t,0,i}^{A} \Big/ \sum_{i=1}^{N} FV_{t,0,i}^{A}$ is the FV weight of asset group i; it is the FV counterpart to $w_{t,i}^{BV}$ in Equation (A6). Equation (A7) implies that the two factors that can diminish the influence of long-dated assets on the entire portfolio's FV are: 1) a smaller share, or 2) a higher depreciation rate. Recall that $\partial FV_{t,i} \big/ \partial D_{t,i} < 0$, and this implies the following result:

$$\frac{\partial\left\{\ln\left[\sum_{i=1}^{N} FV_{t,0,i}^{A0}\left(1-\bar{\delta}_{t,i}\right)\right]-\ln\left(\sum_{i=1}^{N} FV_{t,0,i}^{A}\right)\right\}}{\left(\partial D_{t,i}\right)\left(\partial w_{t,i}^{FV}\right)} = \frac{e^{\Delta(t,i)}\left(1-\bar{\delta}_{t,i}\right)\sum_{\tau=1}^{T}\Delta y_{t,\tau,i}\left[w_{t,i}^{FV}e^{\Delta(t,i)}\left(1-\bar{\delta}_{t,i}\right)-\sum_{i=1}^{N} w_{t,i}^{FV}e^{\Delta(t,i)}\left(1-\bar{\delta}_{t,i}\right)\right]}{\left[\sum_{i=1}^{N} w_{t,i}^{FV}e^{\Delta(t,i)}\left(1-\bar{\delta}_{t,i}\right)\right]^2} < 0,$$

and
$$\frac{\partial\left\{\ln\left[\sum_{i=1}^{N} FV_{t,0,i}^{A0}\left(1-\bar{\delta}_{t,i}\right)\right]-\ln\left(\sum_{i=1}^{N} FV_{t,0,i}^{A}\right)\right\}}{\left(\partial D_{t,i}\right)\left(\partial \bar{\delta}_{t,i}\right)} = \frac{w_{t,i}^{FV}e^{\Delta(t,i)}\sum_{\tau=1}^{T}\Delta y_{t,\tau,i}\left[\sum_{i=1}^{N} w_{t,i}^{FV}e^{\Delta(t,i)}\left(1-\bar{\delta}_{t,i}\right)-w_{t,i}^{FV}e^{\Delta(t,i)}\left(1-\bar{\delta}_{t,i}\right)\right]}{\left[\sum_{i=1}^{N} w_{t,i}^{FV}e^{\Delta(t,i)}\left(1-\bar{\delta}_{t,i}\right)\right]^2} > 0 \,.$$

[75] This equation also reveals that the BV growth of a portfolio in Equation (A6) has a similar expression without the assumption of similar amortization rates across assets of different maturities.

Here $e^{\Delta(t,i)} \equiv \exp\left(-D_{t,i}\sum_{\tau=1}^{T}\Delta y_{t,\tau,i}\right)$.

Equations (A6) and (A7) then imply the growth rate differential between the FV and the BV of this portfolio of mixed maturities, which is not nearly as neat as Equation (A3). Nevertheless, a similar conclusion can be inferred: debt with longer durations tends to exert a greater influence on the FV-BV growth differential of the initial portfolio, unless one of three conditions is present: 1) their share in the portfolio is much lower, 2) their depreciation rate much higher than those of debt of shorter durations, or 3) if the quarterly change in long yields are especially small relative to that of short yields.

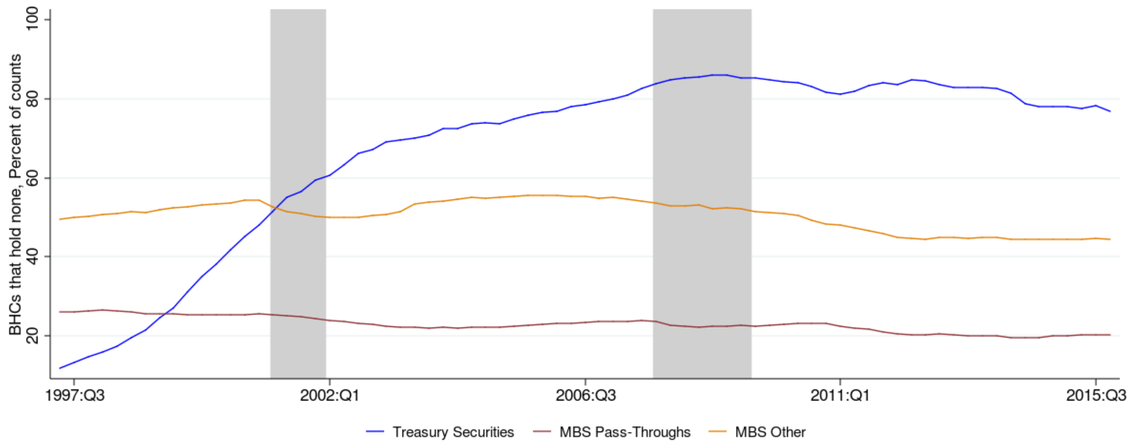
This relationship can also break down because of new purchases in a quarter, just as in the case of Equation (A3). That is, if some long-dated securities contain a sufficiently high fraction of new purchases, especially if toward the end of a quarter, then there may be little difference between a portfolio's FV and BV growth, possibly even less than the FV-BV growth difference of shorter-dated debt.

B.3 Dynamic of BV and FV of MBS—Securities with Embedded Options

As explained in the main text, the sizable and time-varying negative convexity on MBS must be accounted for in understanding the dynamic of unrealized gains/losses of MBS, that is, the difference between the BV and FV changes, in response to yield movements. By comparison, the overall change in the BV and the FV in the Call Reports data also include changes in the principal amount of the MBS pool because some of the underlying mortgages are prepaid (in addition to normal amortization). Since the prices of MBS and the speed of prepayment both move in the opposite direction to yields, the reported FV likely changes less than would be implied by the valuation change alone because it is partially offsets by the concurrent change in the prepayment rate. In the notation of derivations in the last subsection, this means that the depreciation rate also varies systematically with long yields. Specifically, when yields rise, the MBS valuation falls but the outstanding balance does not decline as fast because prepayments also slow. Conversely, for a period when yields by and large trend downward, such as since/after the financial crisis, the outstanding amount of a given MBS pool on a bank's balance sheet is likely to shrink faster than usual because borrowers prepay at a faster rate, even while the FV of the given MBS pool rises owing to the price appreciation. In short, the valuation change should still be solely respective for the difference between the BV and the FV changes.

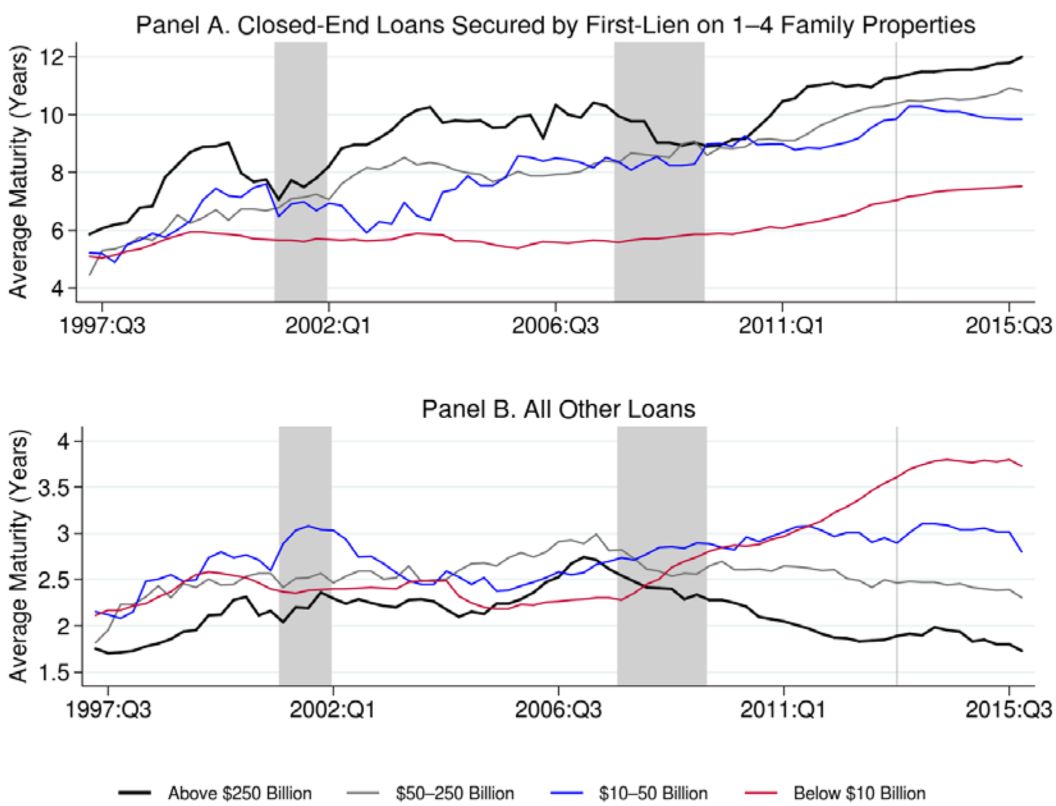
Appendix C. Additional Details of Bank Portfolio Composition and Maturity

Figure C1. Share of BHCs Bank Holding Companies Below $10 Billion (Size Bin 4) with Zero Holdings of Treasuries and Mortgage-Backed Securities (MBS)



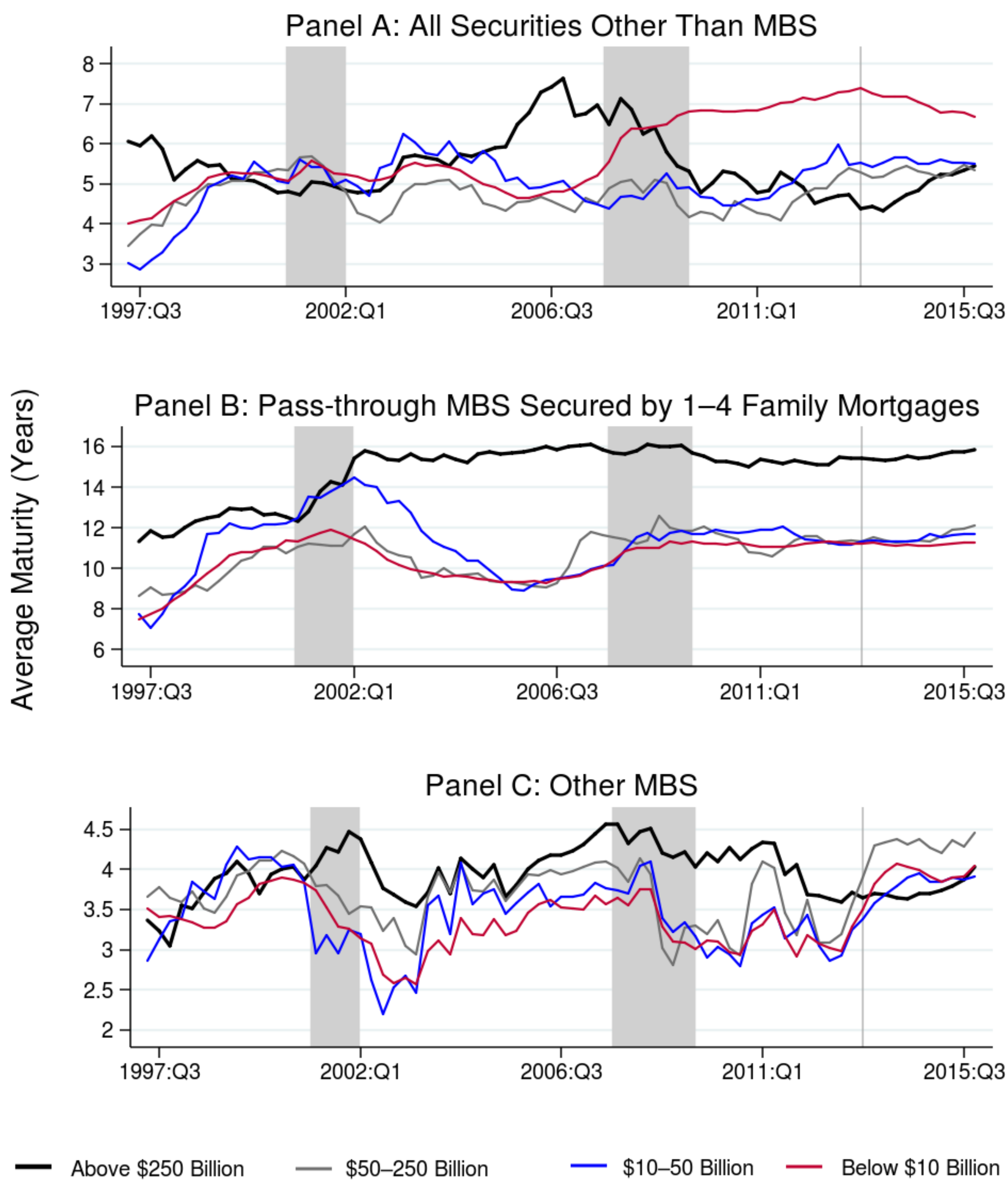
Source: Bank Reports of Income and Condition Data. Author's calculations.

Figure C2. Weighted-average Maturities of Loans by Category



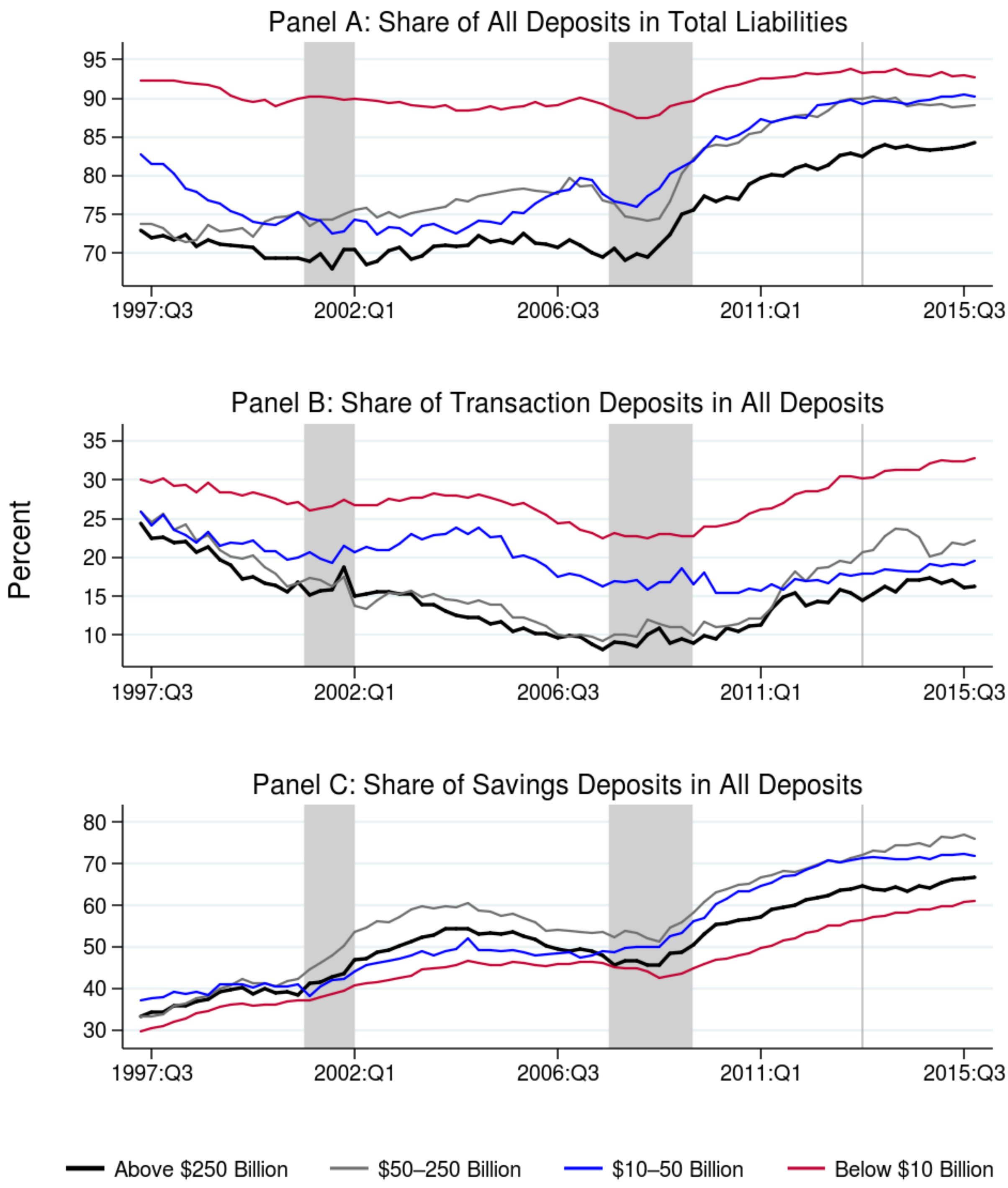
Notes: 1) The grey vertical line marks 2013:Q2, the quarter end immediately after the taper tantrum, to highlight the change in maturity movements, if any. 2) Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Figure C3. Weighted-average Maturities of Securities by Category



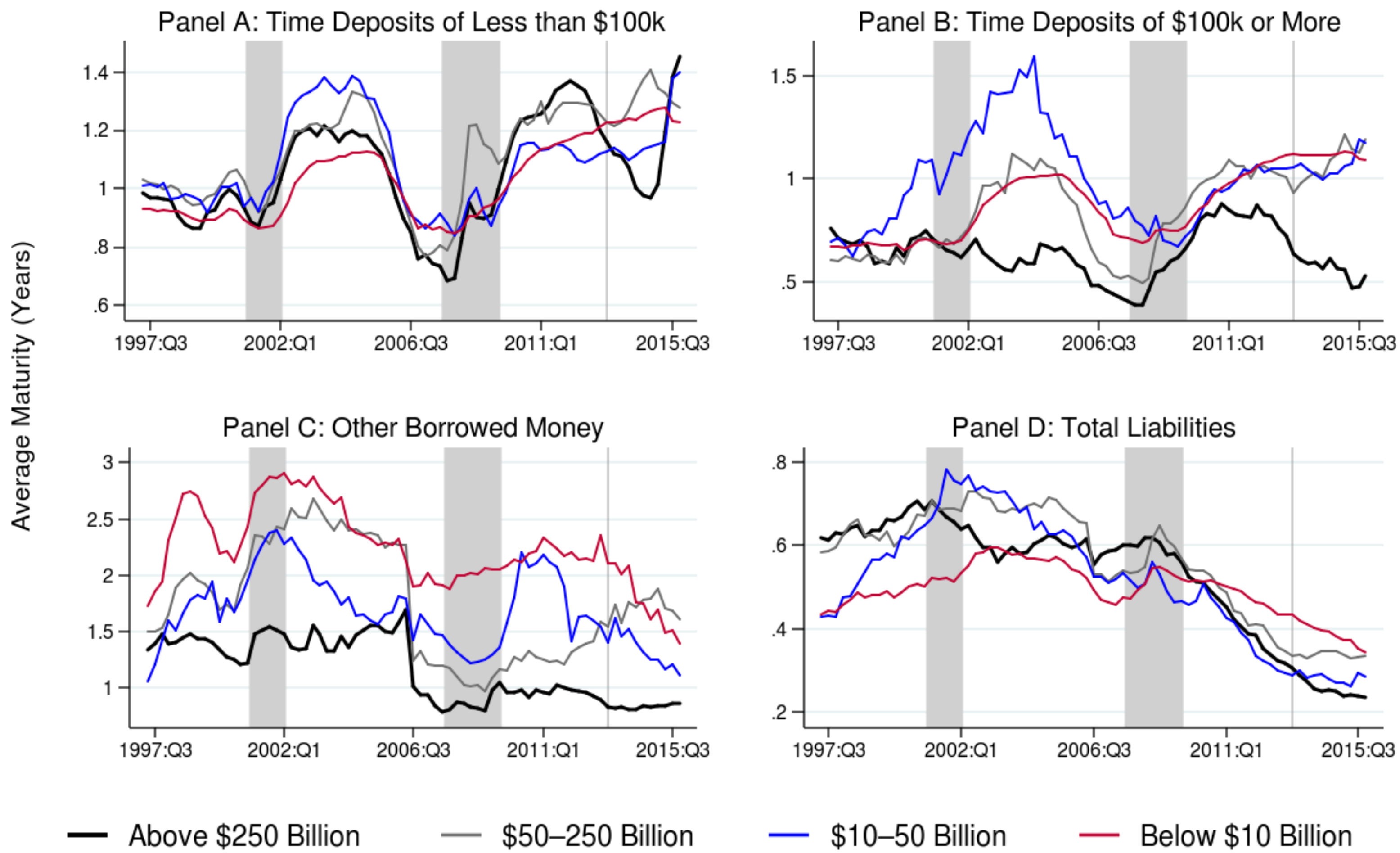
Notes: 1) The grey vertical line marks 2013:Q2, the quarter end immediately after the taper tantrum, to highlight the change in maturity movements, if any. 2) The line for the Above $250 billion BHCs is adjusted to smooth out outsized swings in Bank of America's securities holdings in 2004:Q2–2004:Q3 and to a lesser extent swings in J.P. Morgan Chase's holdings in 2004:Q3. See the data appendix (Appendix B) for more details. 3) Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Figure C4. Liability composition: Shares of All Deposits, and Transactions and Savings Deposits



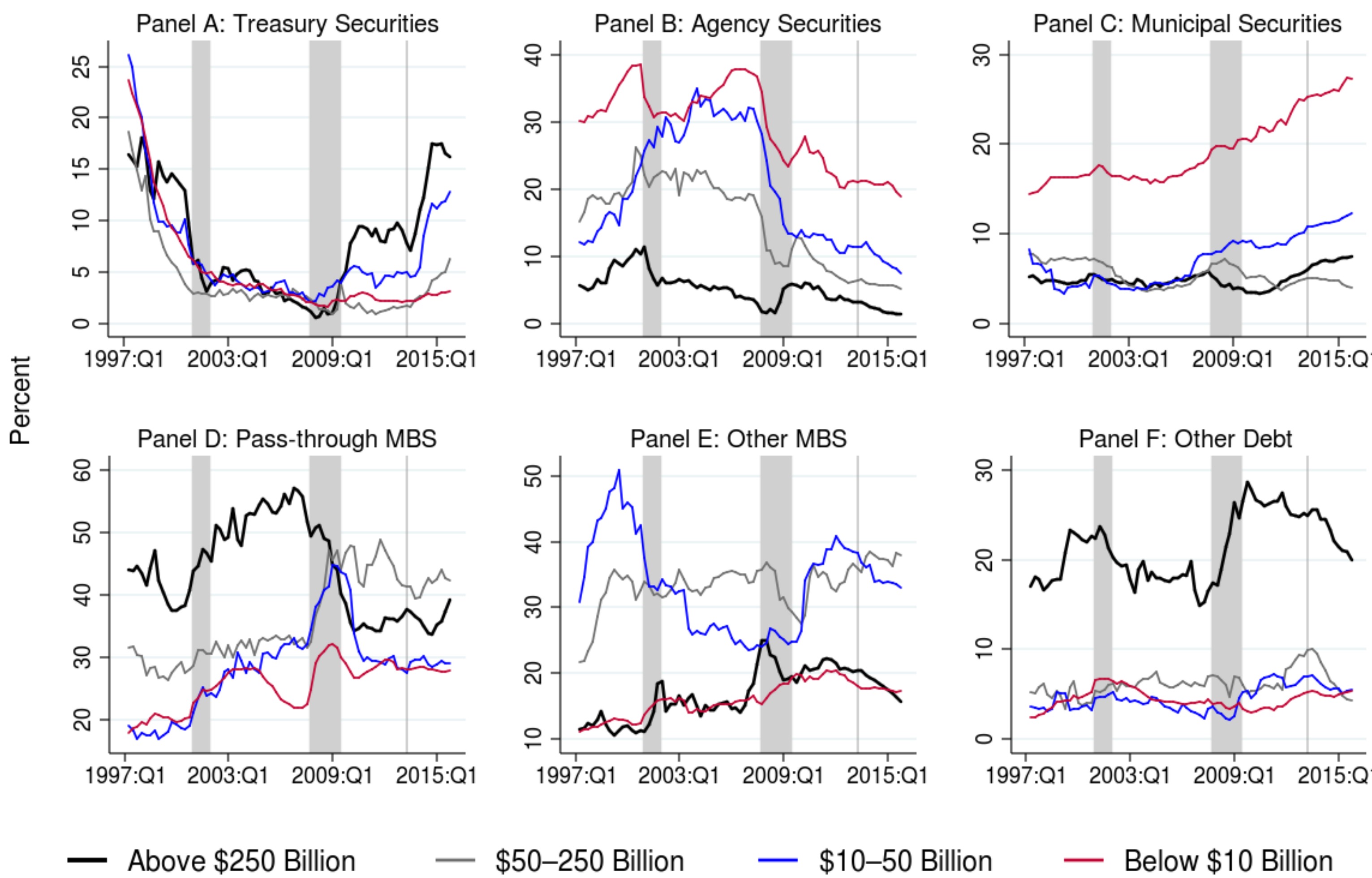
Notes: 1) The grey vertical line marks 2013:Q2, the quarter end immediately after the taper tantrum, to highlight the change in maturity movements, if any. 2) Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Figure C5. Weighted-average Maturities of Time Deposits by Balance, Other Borrowed Money, and Total Liabilities



Notes: 1) The grey vertical line marks 2013:Q2, the quarter ending immediately after the taper tantrum, to highlight the change in maturity movements, if any. 2) The discrete jump down/decrease in the average maturity of other borrowed money (Panel C) in 2006:Q3 is the result of a definitional change—from the maturity for all instruments to the maturity for fixed-rate instruments but next pricing date for floating-rate debt (starting 2006:Q3). 3) Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Figure C6. Composition of Bank Investment Securities Portfolios



Notes: 1) These figures depict the share of each category as percent of total securities. The grey vertical line marks 2013:Q2, the quarter ending immediately after the taper tantrum, to highlight the change in maturity movements, if any. 2) MBS stands for mortgage-backed securities. 3) Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Table C1. Summary of Asset Shares in Each Category by Maturity Bin:
Bank Holding Companies with assets above $250 Billion and Bank Holding Companies with Assets Below $10 Billion

	Bank Holding Companies Above $250 Billion					BHCs with Assets Below $10 Billion				
ASSETS	**2007:Q2**	**2013:Q2**	**2015:Q4**	**Change ('07–13)**	**Change ('13–15)**	**2007:Q2**	**2013:Q2**	**2015:Q4**	**Change ('07–13)**	**Change ('13–15)**
Securities: All Non-Mortgage-Backed Securities										
< 3 Months	0.19	0.29	0.24	**0.10**	**-0.04**	0.13	0.09	0.09	**-0.04**	**0.01**
3 – 12 Months	0.13	0.11	0.05	**-0.02**	**-0.06**	0.15	0.06	0.06	**-0.09**	**0.00**
1 – 3 Years	0.18	0.22	0.14	**0.04**	**-0.08**	0.24	0.14	0.18	**-0.10**	**0.04**
3 – 5 Years	0.09	0.13	0.23	**0.04**	**0.10**	0.14	0.15	0.18	**0.01**	**0.03**
5 – 15 Years	0.16	0.15	0.22	**-0.01**	**0.07**	0.29	0.45	0.40	**0.16**	**-0.05**
> 15 Years	0.25	0.10	0.11	**-0.14**	**0.01**	0.06	0.11	0.09	**0.05**	**-0.02**
Securities: Pass-Through Mortgage-Backed Securities										
< 3 Months	0.03	0.02	0.02	**-0.01**	**0.00**	0.04	0.03	0.03	**-0.01**	**0.00**
3 – 12 Months	0.00	0.00	0.01	**0.00**	**0.00**	0.06	0.03	0.03	**-0.03**	**-0.01**
1 – 3 Years	0.01	0.02	0.01	**0.01**	**0.00**	0.10	0.04	0.02	**-0.06**	**-0.02**
3 – 5 Years	0.01	0.02	0.01	**0.02**	**-0.01**	0.10	0.04	0.03	**-0.06**	**-0.01**
5 – 15 Years	0.07	0.15	0.12	**0.08**	**-0.03**	0.40	0.53	0.60	**0.13**	**0.06**
> 15 Years	0.88	0.79	0.83	**-0.09**	**0.05**	0.30	0.32	0.29	**0.02**	**-0.03**
Securities: Other Mortgage-Backed Securities										
<= 3 Years	0.16	0.39	0.28	**0.23**	**-0.11**	0.38	0.43	0.27	**0.05**	**-0.16**
> 3 Years	0.84	0.61	0.72	**-0.23**	**0.11**	0.62	0.57	0.73	**-0.05**	**0.16**
Loans: First-Lien 1–4 Family Mortgages										
< 3 Months	0.07	0.11	0.07	**0.04**	**-0.04**	0.13	0.10	0.08	**-0.03**	**-0.02**
3 – 12 Months	0.05	0.07	0.06	**0.03**	**-0.01**	0.14	0.13	0.10	**-0.02**	**-0.02**
1 – 3 Years	0.13	0.05	0.05	**-0.08**	**0.00**	0.23	0.17	0.16	**-0.06**	**-0.01**
3 – 5 Years	0.12	0.07	0.07	**-0.05**	**0.00**	0.16	0.16	0.18	**0.00**	**0.02**
5 – 15 Years	0.18	0.18	0.19	**0.00**	**0.02**	0.18	0.23	0.25	**0.05**	**0.02**
> 15 Years	0.45	0.52	0.55	**0.07**	**0.03**	0.15	0.21	0.22	**0.06**	**0.01**
Loans: All Other Loans										
< 3 Months	0.58	0.65	0.68	**0.08**	**0.03**	0.44	0.26	0.29	**-0.18**	**0.03**
3 – 12 Months	0.09	0.06	0.05	**-0.02**	**-0.01**	0.12	0.14	0.11	**0.02**	**-0.04**
1 – 3 Years	0.09	0.10	0.10	**0.01**	**0.00**	0.17	0.18	0.19	**0.01**	**0.00**
3 – 5 Years	0.08	0.08	0.08	**0.00**	**-0.01**	0.15	0.21	0.20	**0.06**	**-0.01**
5 – 15 Years	0.11	0.08	0.07	**-0.03**	**-0.01**	0.09	0.16	0.17	**0.07**	**0.02**
> 15 Years	0.06	0.03	0.02	**-0.03**	**0.00**	0.02	0.04	0.04	**0.02**	**0.00**

Note: Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets.
Source: Bank Reports of Income and Condition Data. Author's calculations.

Table C2. Summary Statistics of Banks' Securities Holdings by Category and Size Class

	Below $10 Billion		$10–50 Billion		$50–250 Billion		Above $250 Billion	
	Freq.	**Percent**	Freq.	**Percent**	Freq.	**Percent**	Freq.	**Percent**
Treasury Securities								
AFS = HTM = 0	291245	**65.60**	443	**23.24**	122	**7.52**	18	**1.32**
AFS = 0 but HTM ≠ 0	23688	**5.34**	108	**5.67**	12	**0.74**		
HTM = 0 but AFS ≠ 0	101661	**22.90**	1006	**52.78**	1188	**73.24**	1092	**79.94**
AFS: BV=FV excluding when both are 0	10746	**2.42**	112	**5.88**	54	**3.33**	35	**2.56**
AFS: ΔBV = ΔFV but BV ≠ FV	866	**0.20**	2	**0.10**	4	**0.25**	3	**0.22**
All other cases	15773	**3.55**	235	**12.33**	242	**14.92**	218	**15.96**
Municipal Securities								
AFS = HTM = 0	74316	**16.74**	153	**8.03**	28	**1.73**	12	**0.88**
AFS = 0 but HTM ≠ 0	83162	**18.73**	146	**7.66**	80	**4.93**	66	**4.83**
HTM = 0 but AFS ≠ 0	192456	**43.35**	718	**37.67**	771	**47.53**	571	**41.80**
AFS: BV=FV excluding when both are 0	9863	**2.22**	100	**5.25**	25	**1.54**	24	**1.76**
AFS: ΔBV = ΔFV but BV ≠ FV	2994	**0.67**	10	**0.52**	3	**0.18**	7	**0.51**
All other cases	81188	**18.29**	779	**40.87**	715	**44.08**	686	**50.22**
Agency Securities								
AFS = HTM = 0	45246	**10.19**	288	**15.11**	141	**8.69**	17	**1.24**
AFS = 0 but HTM ≠ 0	35116	**7.91**	107	**5.61**	40	**2.47**	6	**0.44**
HTM = 0 but AFS ≠ 0	302748	**68.19**	1176	**61.70**	1055	**65.04**	978	**71.60**
AFS: ΔBV = ΔFV but BV ≠ FV	1139	**0.26**			9	**0.55**	3	**0.22**
All other cases	59730	**13.45**	335	**17.58**	377	**23.24**	362	**26.50**
MBS Pass–Through Securities								
AFS = HTM = 0	103470	**23.31**						
AFS = 0 but HTM ≠ 0	30651	**6.90**	80	**4.20**	45	**2.77**	3	**0.22**
HTM = 0 but AFS ≠ 0	240086	**54.08**	1035	**54.30**	1137	**70.10**	626	**45.83**
AFS: BV=FV excluding when both are 0	14264	**3.21**	3	**0.16**	4	**0.25**	7	**0.51**
AFS: ΔBV = ΔFV but BV ≠ FV	2282	**0.51**					1	**0.07**
All other cases	53226	**11.99**	788	**41.34**	436	**26.88**	729	**53.37**
Other MBS Securities								
AFS = HTM = 0	227605	**51.26**	101	**5.30**	57	**3.51**	27	**1.98**
AFS = 0 but HTM ≠ 0	14493	**3.26**	41	**2.15**	30	**1.85**		
HTM = 0 but AFS ≠ 0	166812	**37.57**	1097	**57.56**	1058	**65.23**	728	**53.29**
AFS: BV=FV excluding when both are 0	14697	**3.31**	36	**1.89**	14	**0.86**	17	**1.24**
AFS: ΔBV = ΔFV but BV ≠ FV	686	**0.15**					3	**0.22**
All other cases	19686	**4.43**	631	**33.11**	463	**28.55**	591	**43.27**
All Other Debt Securities								
AFS = HTM = 0	313524	**70.62**	217	**11.39**	39	**2.40**	11	**0.81**
AFS = 0 but HTM ≠ 0	16510	**3.72**	254	**13.33**	120	**7.40**	19	**1.39**
HTM = 0 but AFS ≠ 0	87014	**19.60**	841	**44.12**	876	**54.01**	662	**48.46**
AFS: BV=FV excluding when both are 0	13175	**2.97**	251	**13.17**	126	**7.77**	24	**1.76**
AFS: ΔBV = ΔFV but BV ≠ FV	488	**0.11**	20	**1.05**	1	**0.06**	1	**0.07**
All other cases	13268	**2.99**	323	**16.95**	460	**28.36**	649	**47.51**

Notes: Above $250 Billion refers to bank holding companies (BHCs) subject to the advanced approaches capital framework, along with their merger targets with above $10 billion in assets. HTM stands for held-to-maturity, and AFS is for available-for-sale. Fair value is denoted as FV, book value as BV and mortgage-backed securities as MBS. Source: Bank Reports of Income and Condition Data. Author's calculations.