The Review of Financial Studies

Regulatory Forbearance in the U.S. Insurance Industry: The Effects of Removing Capital Requirements for an Asset Class

Bo Becker
Stockholm School of Economics, CEPR, and ECGI

Marcus M. Opp
Stockholm School of Economics and CEPR

Farzad Saidi
University of Bonn and CEPR

We analyze the effects of a reform of capital regulation for U.S. insurance companies in 2009. The reform eliminates capital buffers against unexpected losses associated with portfolio holdings of MBS, but not for other fixed-income assets. After the reform, insurance companies are much more likely to retain downgraded MBS compared to other downgraded assets. This pattern is more pronounced for financially constrained insurers. Exploiting discontinuities in the reform's implementation, we can identify the relevance of the capital requirements channel. We also document that the insurance industry crowds outs other investors in the new issuance of (high-yield) MBS. (*JEL* G20, G22, G23, G28)

Received April 29, 2020; editorial decision April 24, 2021 by Editor Ralph Koijen. Authors have furnished an Internet Appendix, which is available on the Oxford University Press Web site next to the link to the final published paper online.

The insurance industry is one of the main pillars of the modern U.S. financial system, with a 30% share of all financial intermediation in terms of value added

---

This paper has greatly benefited from comments and suggestions from two anonymous referees and Ralph Koijen (the editor). We also appreciate feedback from Aleksandar Andonov, Jess Cornaggia, Darrell Duffie, Andrew Ellul, Julie Gann, Shan Ge, John Griffin, Dwight Jaffee, Pab Jotikasthira, Anastasia Kartasheva, Eric Kolchinsky, Christian Leuz, Matti Peltonen, Joshua Rauh, Jennifer Rhee, David Scharfstein, Sascha Steffen, Jeremy Stein, Brian Sweeney, Stéphane Verani, Nancy Wallace, and Motohiro Yogo, as well as seminar participants at NYU Stern, Banque de France, the 2020 EFA Annual Meeting, the 2020 NBER Financial Economics of Insurance Meeting, the 2019 SFI "Finance meets Insurance" Conference, and the 2018 UPF-EuroFIT Workshop on "Financial intermediation and risk." We thank Katarina Warg for excellent research assistance. Financial support from the UC Berkeley Fisher Center, Fondation Banque de France, and Riksbankens Jubileumsfond is gratefully acknowledged. Saidi gratefully acknowledges funding by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy [EXC 2126/1 – 390838866]. Supplementary data can be found on *The Review of Financial Studies* web site. Send correspondence to Marcus M. Opp, marcus.opp@hhs.se.

The Review of Financial Studies 00 (2021) 1–45

doi:10.1093/rfs/hhab102 Advance Access publication September 3, 2021

(Greenwood and Scharfstein 2013) and invested assets in excess of $3.6tn in 2015. While it was historically considered safe from a systemic perspective, this began to change in the early 2000s when insurance companies, in particular life insurers, have started to offer riskier products (Koijen and Yogo 2016a), invest in riskier assets (Becker and Ivashina 2015), and exploit state-level law changes permitting captive reinsurance (Koijen and Yogo 2016b). As a result, insurance companies' balance sheets have been heavily hit by the financial crisis, in particular, because of their exposure to downgraded mortgage-backed securities (MBS), pushing several insurers into distress (Ellul et al. 2014; Koijen and Yogo 2015).

We document the effects of an important reform of capital regulation that was instituted in the aftermath of the financial crisis. At a high level, this reform approximately eliminated capital requirements for one asset class, nonagency MBS, whereas capital requirements for all other fixed-income assets (corporate bonds, municipal bonds, asset-backed securities other than MBS, etc.) remain unaffected and tied to credit ratings. Given the unprecedented downgrades of MBS during the financial crisis,[1] the previous regulatory regime would have implied a quadrupling of 2009 capital requirements for MBS compared to 2008 (and further increases in 2010). The reform, thus, both generated massive capital relief for the insurance industry and lowered, going forward, the relative regulatory cost of holding MBS, in particular high-yield MBS, as compared to other asset classes. In addition, for a subset of MBS, the reform introduces quasi-random capital requirements due to discontinuities in their implementation.

Our empirical analysis first examines the differential effect of the reform across asset classes, both in legacy assets and in new issues. After the reform, insurance companies are much less likely to sell downgraded MBS as compared to other downgraded legacy assets. Financially constrained insurers respond more to the reform, pointing to risk-taking as the channel. While the main effect on insurers' portfolios is driven by the (lack of) adjustments to downgraded legacy assets, we also document that the insurance industry crowd outs other investors in the new issuance of (high-yield) MBS. Using a regression discontinuity framework, we can identify the relevance of capital requirements for selling decisions within MBS. This result corroborates the interpretation that capital requirements are a key driver for insurers' differential trading behavior across asset classes.

Figure 1 presents suggestive evidence for our main results. In the 2005 – 2008 period, the high-yield share in the U.S. insurance industry's MBS portfolio increased from 2.6% to 22% in 2009 (see panel A in Figure 1), largely driven by unprecedented downgrades of MBS held by insurance companies. By 2015 this share increases to 34%. In contrast, the high-yield share for non-MBS assets (see panel B in Figure 1) remains remarkably stable at almost exactly

[1] In 2008, S&P downgraded over 30% of structured securities, in 2009 50%, and in 2010 again over 30%. There were virtually no upgrades.

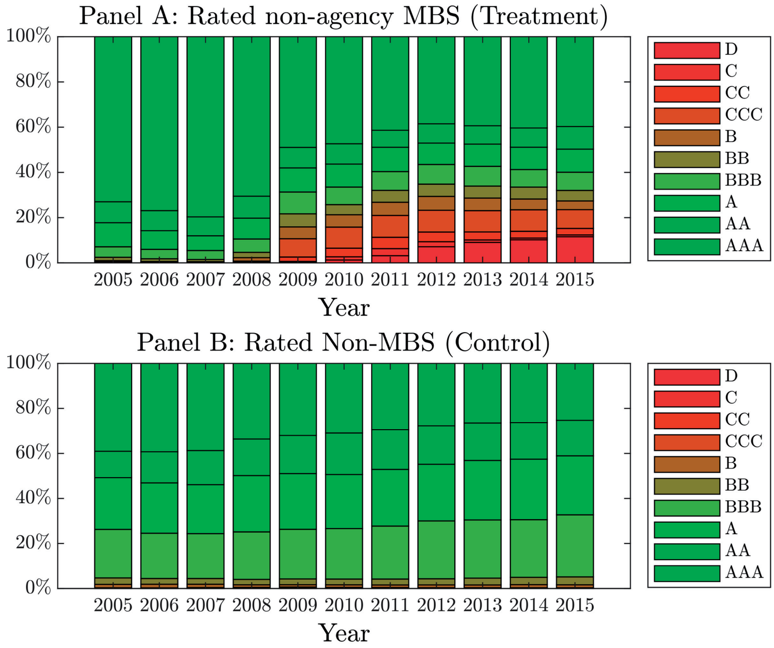

Figure 1
Ratings distribution of MBS and non-MBS holdings of U.S. insurers
For each year-end from 2005 to 2015, this graph plots the ratings distribution of MBS holdings (panel A) and non-MBS holdings (panel B) of all U.S. life and P&C insurers. The respective weights are computed using the book value of aggregate security holdings (BACV) obtained from NAIC Schedule D Part 1. The graph conditions on securities for which at least one rating is available. If multiple ratings are available for a given security, we create a composite rating equal to the lowest rating (for two ratings) or the median (for three ratings).

5% throughout the entire 2005−2015 period, including the Great Financial Crisis. The stability of the high-yield share outside MBS is maintained through selling of downgraded assets (consistent with Ellul, Jotikasthira, and Lundblad 2011) and new purchases of highly rated assets. As a result of these divergent trends, by 2015 40% of all high-yield assets in the overall fixed-income portfolio are MBS investments.

Interpreting these different patterns across asset classes as the effect of the reform would be a leap since the reform also coincides with the 2008/2009 Great Financial Crisis. First, MBS and non-MBS are associated with both different baseline liquidity and creditworthiness. Second, a particular challenge for identification is that while the financial crisis caused a major deterioration of credit quality and drop in liquidity for all asset classes, MBS were disproportionately affected. To control for these confounding factors, we posit that credit ratings capture changes in credit quality and liquidity during the financial crisis. That is, while the distribution of downgrades substantially differs across asset classes, we assume that conditional on a credit-rating downgrade, the deterioration of liquidity and credit quality is similar for MBS as for other asset classes, so that differential trading patterns can be interpreted as the effect of the regulatory reform.

Using rich data on credit ratings and insurer holdings and trades in the period from 2005 to 2015, we find that insurance companies are significantly less likely to sell downgraded MBS after the reform, both in absolute terms and relative to other asset classes. This result holds at the industry, the insurance conglomerate (group), and the individual company level. Life insurers have a higher propensity to hold on to downgraded assets as compared to property & casualty (P&C) insurers. Within the set of life insurance companies, we find that this pattern is even more pronounced for those with riskier liabilities, as measured by a higher share of variable annuities (Koijen and Yogo 2018). Moreover, financially constrained insurers, with low risk-based capital (RBC) ratios and A.M. Best Capital Adequacy Ratios, are more prone to retaining downgraded MBS. The cross-sectional heterogeneity of our findings is, thus, consistent with the basic theoretical prediction that more constrained companies have greater risk-taking incentives.

Since the reform for MBS capital requirements applies not only to legacy assets but also to any MBS issued after the reform, we predict similar insurer behavior in the primary market. Apart from the relevance of the primary market in itself, this analysis has the additional advantage that we can rule out secondary-market illiquidity as a driver of insurer behavior. While the issuance of private residential mortgage-backed securities (RMBS) has not recovered after the financial crisis, the market for commercial mortgage-backed securities (CMBS) started to revive in 2012.

Based on a comprehensive data set of over 1.5 million newly issued securities between 2005 and 2015, we show that following the reform the insurance industry crowds out other investors (such as pension funds, bond funds) in the issuance of MBS and, in particular, high-yield MBS. This response is primarily driven by (large) life insurers, consistent with the idea that the business model of these insurers is under greater reaching-for-yield pressure in times of low interest rates (see Koijen and Yogo 2016a). In sum, our results suggest that the response to the reform extends above and beyond legacy assets, although the contribution of new (high-yield) MBS to the overall riskiness of the insurance industry is modest due to the low total volume of new MBS issues.

This part of our analysis is motivated by the approximation that capital requirements for MBS holdings are effectively zero regardless of risk; that is, they fall into the most preferential NAIC-1 bucket. However, even after the reform, a subset of MBS positions obtains designations ranging from NAIC-2 to the least attractive NAIC-6 bucket. This subset is inconsequential for overall capital relief and the documented patterns across asset classes, but it offers a unique opportunity for causal evidence: discontinuities in the assignments of capital requirements introduce quasi-random capital requirements around thresholds, thereby allowing us to cleanly identify the effects of capital requirements on insurers' selling behavior.

To exploit this variation, additional institutional details of the reform are relevant. As part of the reform, the coordinating body of insurance regulators (NAIC) removed references to credit ratings in the calculation of capital requirements for MBS.[2] Instead of ratings, capital requirements for individual securities are now based on "intrinsic prices" that reflect the *expected loss* of principal. These intrinsic prices are provided by PIMCO (for RMBS) and BlackRock (for CMBS), and are highly correlated with the market price.[3] Apart from the new inputs, the second key change is that the reform recalibrates capital requirements, so that the implied capital buffers against *unexpected losses* in adverse scenarios are zero. In practice, this is achieved by assigning the "risk-free" NAIC-1 category as long as an asset is carried on the books at its intrinsic price (or below). For the vast majority of MBS positions, accounting rules governing marking-to-market and impairments (see Appendix B) imply that risky MBS are indeed held at close to their intrinsic price, giving rise to our approximation that the reform "eliminates capital requirements."

However, for a subset of MBS, assets are recorded on the books above intrinsic prices, for example, because price quotes for assets that are marked to market are only imperfectly correlated with the intrinsic price provided by PIMCO. Since the book price markup—the markup of the book value relative to the valuation based on intrinsic prices—maps discontinuously ointo capital requirements, we can exploit quasi-random capital requirements around thresholds. For example, for any MBS with a book price markup between 0.85% and 2.95%, a life insurer would face a capital requirement of 1.3% (NAIC-2), jumping to 4.6% (NAIC-3) as soon as the book price markup exceeds 2.95%.

Using a regression discontinuity design with five cutoffs, we estimate the sales elasticity at these cutoffs separately for life and P&C insurers. We find that insurance companies react strongly in their decision to sell a mortgage-backed security if it is assigned a higher capital requirement bucket, but with different intensities at the five cutoffs. We estimate an easily interpretable elasticity estimate across cutoffs that suggests that for every percentage-point increase in capital requirements, life (P&C) insurers are 0.34 (0.25) percentage points more likely to sell any fraction of their legacy MBS in the subsequent year. These results confirm the relevance of capital requirements for selling decisions even within an asset class that is not highly liquid.

The reform we study addresses a commonly voiced concern of hardwiring institutional capital requirements to credit ratings.[4] However, it also introduces new flaws. First of all, by construction, the new risk measures focus on expected

---

2 Concerns about the accuracy of credit ratings motivated the reform (see Internet Appendix A).

3 In 2016, BlackRock replaced PIMCO as the provider of intrinsic prices for RMBS.

4 The optimistic ratings issued in the precrisis period were perceived to reflect long-term weaknesses within the business model of rating agencies (Bolton, Freixas, and Shapiro 2012; Griffin and Tang 2012; He, Qian, and Strahan 2012; Benmelech and Dlugosz, 2009b; Becker and Milbourn 2011; Baghai and Becker, 2018). These could be exacerbated by the regulatory use of the ratings themselves (Opp, Opp, and Harris 2013).

losses, not tail events, and are, thus, not substantially different from credit ratings. Second, the mapping of these new metrics to capital requirements is calibrated in such a way that the implied capital buffers cover expected losses, thereby providing no protection against unexpected losses, the very losses capital requirements ought to protect against (Brunnermeier et al. 2009). Moreover, by selectively targeting MBS, the reform introduces cross-sectional asset distortions in that insurers are not discouraged from investing in high-risk MBS, while the penalty for other types of high-risk fixed-income assets remains in place.

What was the motivation for this reform? One potential explanation is the political-economy channel behind regulation going back to Olson (1965), Stigler (1971), and Peltzman (1976). Consistent with this view, we show that large life insurance companies are the biggest beneficiaries of this reform, that is, companies that are presumably more influential in the regulatory process. This interpretation also would be consistent with prior experience: Kroszner and Strahan (1999) argue that industry interests were important to U.S. financial regulation in the 1970s and 1980s.

Another, not necessarily mutually exclusive, motivation is that insurance regulators may have wanted to relieve pressure on the industry so as to mitigate fire-sale discounts caused by industry-wide sales (see Shleifer and Vishny 1992, or, within the insurance setting, Ellul et al. 2018), or to protect insurance clients from price movements (Chodorow-Reich, Ghent, and Haddad 2020). Indeed, the increase in capital requirements under the previous system would have occurred at a difficult time: many insurance companies simultaneously experienced market-value losses in their asset portfolios and faced tight conditions for raising new equity. However, to avoid fire sales of legacy assets, it does not seem necessary to extend capital relief to newly purchased securities.

Our paper is most closely related to two papers covering this reform. First, it subsumes (and significantly extends) Becker and Opp (2013), the first paper in the literature on this reform. Second, it is related to Hanley and Nikolova (2021), who show that insurers with a larger MBS exposure in the precrisis period (and, hence, greater capital relief) are more likely to retain MBS. A unique feature of our paper is that we have access to intrinsic prices from the NAIC. This proprietary data set enables us to estimate the effect of capital requirements on selling decisions by exploiting the discontinuous assignment of capital requirements. Our paper also differs from that of Hanley and Nikolova (2021) in our understanding of the reform and the hypotheses that we test in the reduced-form empirical analysis. Hanley and Nikolova (2021) argue that the reform grants insurers additional flexibility to strategically choose their book values, which in turn generates capital relief. Instead, we show that the very design of the reform generates capital relief, without any need for strategically choosing book values. Second, they hypothesize that insurers with greater capital relief would engage in greater risk-taking within MBS. However, we show that insurer-level capital relief does not yield robust predictions about trading in any particular security class.

More broadly, our paper is related to recent work on the insurance industry, on capital requirements, and on the design and implementation of financial regulation in general. Insurance companies are prominent institutional investors, and their demand is important for the pricing of traded assets (e.g., Koijen and Yogo 2019; Harris, Opp, and Opp 2021; Becker and Ivashina 2015; Ellul, Jotikasthira, and Lundblad 2011; Ellul et al. 2015). We contribute to this literature by documenting a permanent asset-portfolio impact of capital regulation. To the best of our knowledge, ours is the first paper in the literature to use a framework based on a regression discontinuity design to identify the effects of capital requirements. The rapid, large, and less foreseeable reduction in capital requirements generated by the reform that we study enables us to better tease out the effects of capital requirements on institutional investors, as compared to the more gradual and predictable changes of capital requirements for banks. Yet, our results chime with recent work showing that banks respond to higher capital requirements by aggregate risk reduction and less lending (Behn, Haselmann, and Vig 2021; Chen, Hanson, and Stein 2017; Gropp et al. 2019).

1. The 2009 Regulatory Reform

Since 1994, the NAIC has used a risk-based capital system to regulate insurance companies. This system imposes capital requirements and computes a solvency metric, the risk-based capital (RBC) ratio, for each insurer at the end of each year (see Appendix A for details). It aims to protect policyholders and taxpayers from losses that may result from the insurer's investment decisions (assets) or underwriting business (liabilities).

In this paper, we focus on a change in capital regulation for a subcategory of fixed-income assets, namely, nonagency mortgage-backed securities, which we will, henceforth, simply refer to as MBS (without the "nonagency" qualifier). Fixed-income securities represent the most important asset class for insurance companies, and their regulatory treatment is conceptually similar to bank capital requirements under the standardized model of Basel II. Precisely, the dollar capital requirement for a particular fixed-income security s (CR_s) is the product of the book value of the asset (BV_s) and its capital ratio requirement (c_s).[5] The capital ratio requirement depends on the NAIC risk designation, which takes on discrete values from 1 to 6 (see Table 1). NAIC-1 refers to the lowest risk category, and NAIC-6 represents the highest risk category.[6]

[5] Formally, the book value corresponds to the book-adjusted carrying value (BACV) and the capital ratio requirement refers to the risk-based charge.

[6] Holdings of U.S. government debt (including agency MBS) are exempt from capital requirements.

Table 1
NAIC risk classification and capital ratio requirements

	c			Threshold for $(BP-IP)/BP$	
NAIC	Life	P&C	Rating threshold	Life	P&C
1	0.4%	0.3%	A	0.85%	0.65%
2	1.3%	1%	BBB	2.95%	1.5%
3	4.6%	2%	BB	7.3%	3.25%
4	10%	4.5%	B	16.5%	7.25%
5	23%	10%	CCC	26.5%	20%
6	30%	30%	D		

This table shows the capital ratio requirements (c) for fixed-income securities as a function of the NAIC risk category ($1-6$) for life and P&C insurers (columns 2 and 3). Column 4 illustrates the minimum rating that guarantees the respective risk category and is applicable for all non-MBS fixed-income securities, for nonagency RMBS until 2009, and for CMBS until 2010. The cutoffs for (nonagency) MBS under the new system based on $\frac{BP_{si}-IP_s}{BP_{si}}$ are listed in columns 5 and 6 for life and P&C insurers, respectively.

Table 1 illustrates that if a life insurance company holds a NAIC-4 bond with a book value of \$100, it faces a capital requirement of \$10. The capital requirement (in \$) for the insurer's entire fixed-income portfolio (CR) with N bonds is given by:

$$CR=\sum_{s=1}^{N} CR_s=\sum_{s=1}^{N} c_s \times BV_s. \tag{1}$$

Prior to year-end 2009, the NAIC designations for all fixed-income securities were tied to credit ratings, as illustrated in the fourth column of Table 1.[7] That is, all AA-rated bonds received a NAIC-1 designation, whereas all B-rated bonds were considered NAIC-4. The capital ratio requirements for corporate bonds, asset-backed securities, and municipal bonds still follow this ratings-based classification scheme.

Starting year-end 2009 for RMBS and year-end 2010 for CMBS, the NAIC made fundamental changes in how to classify MBS. This reform instituted changes in terms of both the input dimension of capital regulation and its calibration of capital buffers.

1.1 New input to regulation

The goal of the reform is to replace credit ratings as inputs to capital regulation.[8] To this end, the NAIC obtains annual expected-loss assessments from PIMCO (for RMBS) and BlackRock (for CMBS).[9] For each security (CUSIP), these

---

7 Only credit ratings by acceptable ratings organizations (AROs) qualify. AROs roughly correspond to credit rating agencies designated as nationally recognized statistical ratings organizations (NRSROs) by the SEC.

8 The official rationale is stated as follows by NAIC (2021): "The huge impact that the NRSRO ratings-based regulatory process for determining RBC had on insurance companies, along with the recognition of the data and methodological shortcomings that rendered NRSRO credit ratings inaccurate, necessitated the development for an alternative rating methodology."

9 Starting 2016, BlackRock became responsible for assessing both RMBS and CMBS. We investigate potential conflicts of interest on the side of BlackRock and PIMCO by examining whether their risk assessments are related to their holdings/trading behavior, but we could not detect any such pattern.

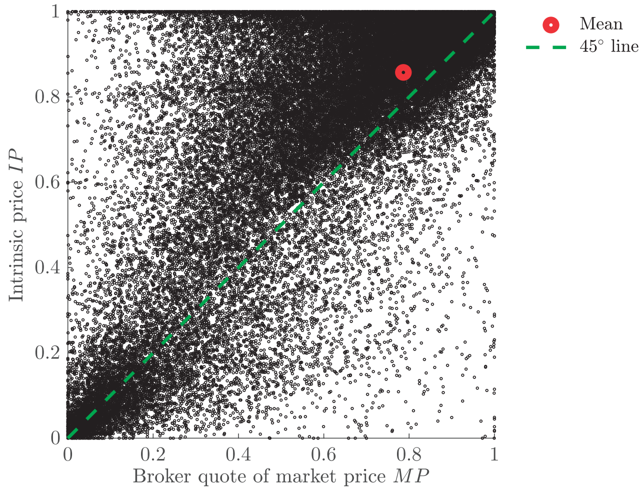

Figure 2
Intrinsic price versus market price
This graph plots IP (i.e., $1-ELOSS$) against *MP*. In particular, we plot intrinsic prices for all modeled MBS tranches from 2009 to 2015 against brokerage quotes of year-end market prices. Brokerage quotes are obtained from NAIC Schedule D Part 1 by computing the ratio of "fair value" and "par value."

providers estimate discounted expected losses of principal payments, which we refer to as *ELOSS*. While it measures, in principle, the same object as credit ratings, $ELOSS \in [0,1]$ is different in that it is a continuous estimate of expected loss in contrast to a letter-grade rating. In particular, *ELOSS* determines the regulator's notion of an "intrinsic price" (IP) for a security:

$$IP := 1 - ELOSS. \tag{2}$$

For example, the intrinsic price of a bond with 30% expected loss is given by 70% of par. The intrinsic prices provided by PIMCO and BlackRock are highly correlated with brokerage quotes of the market price (see Figure 2): the respective correlation coefficients are 0.82 and 0.81. Moreover, Figure 2 reveals that the intrinsic price, with a mean of 0.86, is close to, but on average slightly above, the market price (*MP*), with a mean of 0.81.[10]

1.2 New calibration of capital buffers

Zero-loss securities are always assigned to the NAIC-1 category. For securities with positive loss, the determination of a security's capital ratio requirement held by insurer i, c_{si}, depends on the new metric *ELOSS* and on its book value.

---

10 In Appendix C, we highlight two channels that imply $IP > MP$ for the typical structured security. First, *ELOSS* disregards losses to coupons. Second, the discount rate used to estimate *ELOSS*, that is, the coupon rate of the respective security, is inappropriate. Since losses tend to be higher in bad aggregate states of the world (negative beta), standard insights from consumption-based asset pricing imply that the discounted market expectation of losses must be greater than the losses using a state-independent discount rate equal to the coupon rate. See Almeida and Philippon (2007), who make a similar point in the context of estimating distress cost.

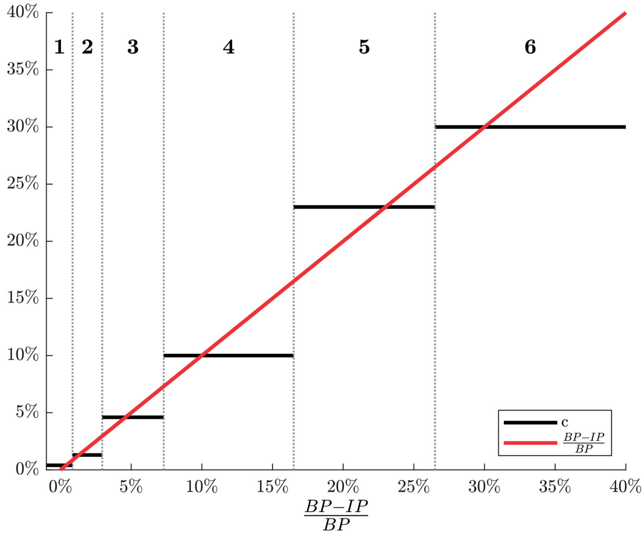

Figure 3
Discontinuous implementation of MBS RBC charges
This graph plots the capital charges c for life insurers as a function of $\frac{BP_{si}-IP_s}{BP_{si}}$. The dotted lines refer to the cutoffs for the respective NAIC $1-6$ risk classification (as determined by column 5 in Table 1). The red line visualizes the approximation implied by (4).

The requirement is an increasing step function of $\frac{BP_{si}-IP_s}{BP_{si}}$, where the book price $BP_{si} := \frac{BV_{si}}{PV_{si}}$ refers to the book value of the bond per unit of par. $\frac{BP_{si}-IP_s}{BP_{si}}$ measures the *book price markup* relative to the intrinsic price IP. The book price markup is lower the more of the expected loss is reflected in the book price, that is, the lower BP. As the black line in Figure 3 illustrates, the five cutoffs for the step function are designed to approximate the identity function:[11]

$$c_{si} = f\left(\frac{BP_{si}-IP_s}{BP_{si}}\right) \approx \frac{BP_{si}-IP_s}{BP_{si}}. \tag{3}$$

Example 1 contrasts the old and new system for capital ratio requirements.

Example 1. In 2003, life insurer i purchased a Aaa-rated mortgage-backed security s at par, so that $BP_{si}^{OLD}=1$. By 2010, the bond features substantial credit risk as reflected by $ELOSS_s=40.6\%$, a D credit rating, and a market price well below par, $MP=0.6$. As marking-to-market rules force the insurer to mark the asset to market (see Appendix B for details), we obtain that $BP_{si}^{NEW} =$

[11] To understand the magnitudes of the capital ratio requirements, observe that the cutoffs (in columns 5 and 6 of Table 1) are simply the average of the respective adjacent NAIC capital ratio requirements: for life insurers, the NAIC-1 cutoff is thus given by (0.4%+1.3%)/2 = 0.85%. The respective cutoffs for life and P&C insurers ensure that the approximation in (3) holds.

$MP_s = 0.6$. Here, $BP_{si}^{NEW} - IP_s = 0.6\%$ captures the difference between the expected loss of the security and the 40% write-down due to marking-to-market. Table 1 now implies:

1) Old system: Based on the credit rating, the bond would be **NAIC-6** with $c_s = 30\%$.

2) New system: Using $\frac{BP_{si}^{NEW} - IP_s}{BP_{si}^{NEW}} = 1\%$, the bond is **NAIC-2** with $c_{si} = 1.3\% \approx 1\%$.

2. Reform Assessment and Hypotheses

In this section, we evaluate the implications of the capital reform. We focus on three types of implications: the impact on how capital buffers protect against adverse scenarios (Section 2.1), the interaction of the new system with accounting rules (Section 2.2), and, finally, the empirical implications for insurer behavior (Section 2.3). Throughout this section we ignore nonlinearities (Figure 3) in the relationship between IP and capital requirements. These are not important to understanding the overall impact of the reform (they are important for a few individual securities). We focus on the case where IP is close to MP, which describes the majority of asset positions in practice (see Figure 2).

2.1 Economic capital buffers

We aim to evaluate the reform regarding the economic purpose of capital requirements, namely to ensure capital buffers that protect against adverse future shocks (relative to what is currently expected). In the language of banking regulation, these losses are *unexpected* (see Brunnermeier et al. 2009).

Now, abstracting from discontinuities, (1) and (3) jointly imply that the \$ capital requirements for any MBS (per unit of par holding) satisfy:

$$\frac{CR_{si}}{Par_{si}} = BP_{si} \times f\left(\frac{BP_{si} - IP_s}{BP_{si}}\right) \approx BP_{si} - IP_s. \tag{4}$$

To understand the capital buffer that these capital requirements provide against *unexpected* losses, first consider the scenario in which the book price of the asset already reflects *expected losses*, that is, $BP_{si} = 1 - ELOSS = IP_s$. Then, it is immediate from (4) that the capital buffer against unexpected losses is zero. Now consider the case where expected losses are not already reflected in book prices, ($BP_{si} > IP_s$). In this case, the asset's book value is inflated relative to the fundamental intrinsic price by an amount of $BP_{si} - IP_s$. (4) now implies that the resultant inflation of book equity is one-for-one compensated with higher capital requirements on book equity, so that the true economic capital buffer against unexpected losses is still zero. Thus, regardless of the accounting practice (marking-to-market or historical cost), we obtain:

Result 1. After the reform, capital requirements for MBS are set such that the implied capital buffer against unexpected losses is (approximately) zero.

The reform can, thus, be understood as effectively removing capital requirements for MBS. The following numerical example illustrates this fundamental design flaw.[12]

Example 2. Consider a risk-neutral economy in which the discount rate is normalized to zero. Over the next year, three macro states occur with respective probabilities of $(95\%, 3\%, 2\%)$. The state-contingent payoffs of a bond carried at par value of \$100 are $\left(\$100, \$78, \$33\right)$. Then, the intrinsic price of the bond satisfies

$$IP_s = 95\% \times 1 + 3\% \times 0.78 + 2\% \times 0.33 = 0.98.$$

If the regulator aimed to calibrate capital buffers to protect up to the worst 2% of outcomes, the financial institution would need to have a capital buffer against unexpected losses of $\$98 - \$78 = \$20$. In contrast, by Result 1, the 2009 regulatory reform for MBS ensures a buffer against unexpected losses of \$0.

From a solvency point of view, it is equivalent if the bond in the example is carried on the books at \$98 (fundamental value) with \$0 capital requirements, or at \$100 (par), thereby inflating assets and equity by \$2, and capital requirements are increased by the "expected loss" of \$2. However, since insurance companies, much like banks, are concerned about book equity (and, relatedly, book-based RBC ratios), the two treatments may have different implications for the behavior of insurance companies. Next, we investigate the implications of the reform for formal capital requirements levied on book values as determined by the NAIC designation.

2.2 Book capital requirements

The dependence of the NAIC designation on book prices (see (1) and Table 1) makes it necessary to understand the two relevant accounting rules governing write-downs, *marking-to-market requirements* and *other-than-temporary impairments (OTTI)*. In either case, the associated write-downs ensure that book values account for the expected loss, that is,

$$BP_{si}^{NEW} \approx IP_s, \tag{5}$$

which, using (4), implies that book capital requirements are also approximately zero. Write-downs are triggered if at least one of the following two conditions is satisfied:

[12] We thank an anonymous referee for suggesting this example. The example is not meant to suggest that setting appropriate capital requirements against unexpected losses is an easy task. Even if one agrees on an objective (here, 2% default probability), the appropriate calibration of capital requirements against unexpected losses requires access to accurate measures of infrequently observed tail events and the correlation structure of assets in the down state.

1. **Marking-to-market requirements:** Marking-to-market requirements apply for sufficiently distressed assets. For MBS, an insurer is required to mark to market if the amortized-cost value exceeds the intrinsic price with some margin.[13] For life (P&C) insurers, marking-to-market is required if IP is 26.5% (1.5%) below amortized cost. Upon marking-to-market, the book value satisfies $BP_{si}^{NEW} = MP_s \approx IP_s$, where the approximate equality follows from the empirical relationship documented in Figure 2. Thus, (5) applies again.
2. **Other-than-temporary impairments (OTTI):** The NAIC mandates that any nontemporary credit loss leads to loss recognition (see SSAP No. 43R).[14] Then, the asset should be impaired to the present value of cash flows expected to be collected (for which IP is an appropriate proxy), so that (5) applies.

Because of the large credit deterioration of many MBS (as illustrated by the time trend of credit ratings plotted in Figure 1), these conditions apply for the vast majority of assets. Zooming in on the relevant subset of MBS with $ELOSS > 0$,[15] after the reform 67.3% of all life-insurer positions and 84.3% of all P&C-insurer positions are carried at or below the NAIC-1 cutoff based on the intrinsic price, despite the significant credit risk shown in Figure 1.

The interaction of accounting rules and the reform of capital requirements, thus, implies the following high-level approximation for capital requirements across asset classes under the new system (the previous regime, described above, is included for reference).

Table 2
High-level summary of reform

	Previous regime	New regime
MBS	NAIC 1 to 6 as function of rating	$\approx$ NAIC 1
non-MBS	NAIC 1 to 6 as function of rating	NAIC 1 to 6 as function of rating

Table 2 reveals that the reform introduces both *low* and *risk-insensitive* capital requirements for MBS in the post-reform period. The capital savings compared to the previous system are, thus, greatest for assets with poor ratings.

2.3 Predictions and hypotheses

To derive predictions of how the regime change for capital requirements affects the allocation across asset classes, we consider the following parsimonious

13 Marking-to-market requirements for other asset classes and under the previous regime are a function of credit ratings (see Appendix B for more details).

14 "For MBS, OTTI is considered to have occurred when there has been a delinquency or other credit event in the referenced pool of mortgages such that the entity does not expect to recover the entire amortized cost basis of the security" (paragraphs 30 – 37 of SSAP No. 43R).

15 Recall book prices are irrelevant for the set of securities with $ELOSS = 0$ since these securities are always considered to be NAIC-1.

framework.[16] Let $v(\mathbf{A})$ denote the objective function of the insurance company as a function of the investment in n different asset/risk classes $\mathbf{A}=(A_{MBS}, A_2, ..., A_n)$, where $A_1 = A_{MBS}$ is, for example, \$ investment in high-risk MBS. This objective function could be driven by incentives to engage in risk-taking (as in Harris, Opp, and Opp 2021) or to manage risks (as in Froot, Scharfstein, and Stein 1993). Then, given an equity amount E, the insurer's problem is to maximize $v(\mathbf{A})$ subject to the RBC ratio constraint, taking as given the capital ratio requirements c_j associated with asset class j:

$$V(\mathbf{c}, E) := \max_{\mathbf{A}} v(\mathbf{A}) \qquad \text{s.t.}$$

$$E \geq \sum_{j=1}^{n} c_j A_j.^{17} \tag{RBC}$$

This formulation suggests a useful parallel to standard consumer theory. Just like goods prices affect the quantity of goods that can be purchased for a given income budget, capital requirements affect how many assets can be purchased for a given amount of equity. Drawing on this parallel, the 2009 reform effectively altered the "price" for high-yield MBS, c_{MBS}. Now, as standard consumer theory implies, even though the reform only changed capital requirements for MBS, the allocation to all asset classes is potentially affected since an optimizing insurer may reshuffle the entire allocation in response to the price change.

Counterfactual behavior under previous reform. Taking the observed equilibrium asset allocation A_j^* under the post-reform capital requirements as the benchmark, we conceptually analyze the effect of reverting to the previous regime on asset allocation. The total effect for any given asset class j can be decomposed into a substitution effect, that is, high-risk MBS would have been relatively more expensive ($\Delta c_{MBS} > 0$), and an income effect, that is, an insurer-level capital shock of size $A_{MBS}^* \Delta c_{MBS}$:

$$\Delta A_j \approx \underbrace{\frac{\partial \tilde{A}_j(\mathbf{c}, V(\mathbf{c}, E))}{\partial c_{MBS}} \Delta c_{MBS}}_{\text{Substitution effect}} - \underbrace{\frac{\partial A_j(\mathbf{c}, E)}{\partial E} A_{MBS}^* \Delta c_{MBS}}_{\text{Income (capital) effect}},^{18} \tag{6}$$

where $\tilde{A}_j(\mathbf{c}, V(\mathbf{c}, E))$ denotes the compensated asset demand holding the insurer's payoff constant at $V(\mathbf{c}, E)$. We now immediately obtain:

[16] For ease of exposition, this framework abstracts from dynamics and liquidity considerations, but these realistic features are irrelevant for the points made in this section.

[18] This textbook Slutsky decomposition can be found in chapter 2 of Mas-Colell, Whinston, and Green (1995), for example.

Result 2. If the shadow value on capital is positive and asset allocation is "normal" for all asset classes, that is, holdings increase in equity, $\frac{\partial A_j(\mathbf{c},E)}{\partial E} > 0$, then
1. (High-yield) MBS asset allocation would have been unambiguously lower under the previous regime, that is, $\Delta A_{MBS} < 0$.
2. The effect on other asset classes is ambiguous, that is, $\Delta A_j \gtrless 0$ for all $j \neq MBS$.

Intuitively, Result 2 requires regulatory constraints to matter, which is empirically the case for more constrained insurers. The reason why the effect on (high-risk) MBS asset allocation is then unambiguously negative follows from standard price theory insights, that is, the (compensated) own price elasticity is unambiguously negative. This effect is reinforced by the negative income effect, that is, the capital shock of size $A^*_{MBS}\Delta c_{MBS}$ that would have occurred.[19] For all other asset classes $j \neq MBS$, this negative income effect is also at play, pushing toward less investment. However, it may be countervailed by the substitution effect as securities from different (high-risk) asset classes are likely net substitutes. As a result, the net effect is unclear and ultimately an empirical question.[20]

A major challenge with estimating the effect of the reform across asset classes is that the timing of the reform is contemporaneous to the Great Financial Crisis. That is, a naïve pre-versus post comparison of observed asset-allocation outcomes captures the effects of both the reform and the financial crisis. In particular, the most relevant confounding effects of the financial crisis affecting asset allocation are the major deterioration of credit quality, the concomitant decrease in liquidity, and resultant capital shocks for insurers. As the credit quality and liquidity of MBS were disproportionately affected by the financial crisis (Benmelech and Dlugosz 2009a), any reasonable identification strategy must control for these direct effects of the financial crisis.

Our analysis of the effects across asset classes in Section 4.1 builds on the identifying assumption that credit ratings capture changes in credit quality and liquidity during the financial crisis. That is, while the distribution of downgrades is substantially different across asset classes, we assume that conditional on a credit-rating downgrade, say from Aa to B, the deterioration of liquidity and credit quality is similar for MBS as for other asset classes. Therefore, downgrades should have similar direct effects on liquidity/credit quality across asset classes, but after the reform no longer trigger increases in capital requirements for MBS, so that differential trading patterns following

19 While formally not captured by our static model, even the regulatory cost of holding highly rated MBS is reduced in a dynamic sense, as possible future deterioriations in ratings will not affect capital ratio requirements.

20 In contrast, if the reform had proportionally lowered capital requirements for all assets, only the income effect would be present, and we would obtain an unambiguous increase for all asset classes (under the conditions stated in Result 2).

downgrades can be interpreted as the effect of the regulatory reform. The second part of our empirical analysis in Section 4.2 does not rely on this identifying assumption, but instead exploits the discontinuous mapping of $\frac{BP_{si}-IP_s}{BP_{si}}$ into capital requirements for MBS in the post-reform period (see Table 1 and Example 1). Using a regression discontinuity framework, we can then estimate the effect of capital requirements within MBS. Building on this conceptual analysis, we now turn to the empirical investigation of the reform.

3. Data

In this section, we first describe all data sources used for our analysis. We then present summary statistics and motivating evidence for the effect of the 2009 regulatory reform on insurance companies' asset allocation.

3.1 Data description

Our main data consist of a panel covering the holdings and trades of fixed-income assets for all insurance companies in the U.S. from 2005 to 2015. This data set is based on NAIC Schedule D Part 1. It contains CUSIP-level end-of-year holdings for all fixed-income securities including treasury bonds, corporate bonds, private MBS, and agency-backed RMBS. It provides the book value and par value for each security and insurer, the NAIC risk classification of each security, and insurer characteristics (such as the state of incorporation and the business type). We limit our analysis to the two most important types of insurers: life and P&C.

We complement the holdings data with data on trades from NAIC Schedule D Part 4. This data set covers transactions for insurers' fixed-income positions from January 1, 2006, to December 31, 2015. Holdings data cannot be used to infer trading activity, since reductions in par value of a fixed-income security can reflect prepayment, calls, or maturity. To identify trades, we use information in the fields "name of purchaser" and "realized gain (loss) on disposal" in Schedule D Part 4. We consider a security actively sold if the "name of purchaser" does not indicate any of the following categories: redemptions, maturity, or default. Moreover, we require that the transaction generate a nonzero realized gain or loss on disposal.[21] For example, if the "name of purchaser" lists a transaction with "Goldman Sachs," it is categorized as an trade, while it would not be a trade if it listed "MBS paydown," "called," or "maturity" (see Appendix D for a detailed description of our classification methodology and keywords). Our analysis indicates that only 25% of all fixed-income transactions listed in NAIC Schedule D Part 4 are due to active sales.

[21] The idea behind this restriction is that transactions in secondary markets will unlikely take place exactly at book values and, thus, generate either realized gains or losses. In contrast, the data indicate that scheduled prepayments (almost) always lead to exactly zero gains or losses. Appendix D provides more details.

We usually aggregate holdings to the insurance group level. Annual financial statements and ratings information, which we retrieve from A.M. Best Company for the fiscal years 2005–2015, are recorded at the individual company level. We aggregate up these data at the group level, but also provide robustness checks of our analyses at the individual company level.

We use extensive credit ratings data. For structured securities, we obtain all ratings directly from the three major credit rating agencies, that is, Moody's, S&P, and Fitch. For all other issues, we rely on the Mergent FISD Corporate-Bond Database, as well as the Mergent FISD Municipal-Bond Database, to obtain ratings from all three rating agencies.[22] If ratings from two rating agencies are available for a given security, we use the lower one. If ratings from all three rating agencies are available, we use the median rating.

In addition, we obtain the year-end NAIC ELOSS metrics calculated by PIMCO and BlackRock for all RMBS (2009 to 2015) and CMBS (2010 to 2015). These proprietary data are used to calculate capital requirements after the reform, and serve as an input to our regression discontinuity analysis.

When we move our analysis from existing securities to newly issued ones, we use data on all newly issued securities from January 1, 2005 to December 31, 2015. We define the issue date as the date of the first rating from any one of our data sources.

Finally, all securities (CUSIPs) are matched with asset categories available from the CUSIP master file, including mortgage-backed securities and private loans. We use this information to build the following seven asset categories: corporate bonds and loans, asset-backed securities (excluding mortgage-backed securities), mortgage-backed securities (excluding agency mortgage-backed securities), agency mortgage-backed securities, government debt, municipal bonds, and other (including equity-like instruments).

3.2 Summary statistics

Figure 4 plots the book values of all fixed-income assets held by life and P&C insurers. (We present book values rather than the quantitatively similar market values to facilitate comparison with official NAIC numbers.) By 2015, life insurers' total fixed-income holdings amounted to \$2,734bn, whereas P&C insurers held in total \$960bn, implying combined holdings of \$3,694bn.

For our asset categorization, we distinguish between MBS, the treated group of securities, and agency MBS that are not treated. For life and P&C insurers combined, the share allocated to MBS has increased from 12.3% in year-end 2005 up to 14.7% at the onset of the crisis (year-end 2008). It then decreased sharply over the crisis period due to prepayments/redemptions, write-downs and a lack of new issues, and has remained stable at 8% since 2012.

22 If a security's rating shows up in multiple data sources, we rely on the respective credit rating agency as the main source, for example, if for a given CUSIP-year we have both an S&P rating directly from S&P and via Mergent FISD, we use the rating obtained from S&P.

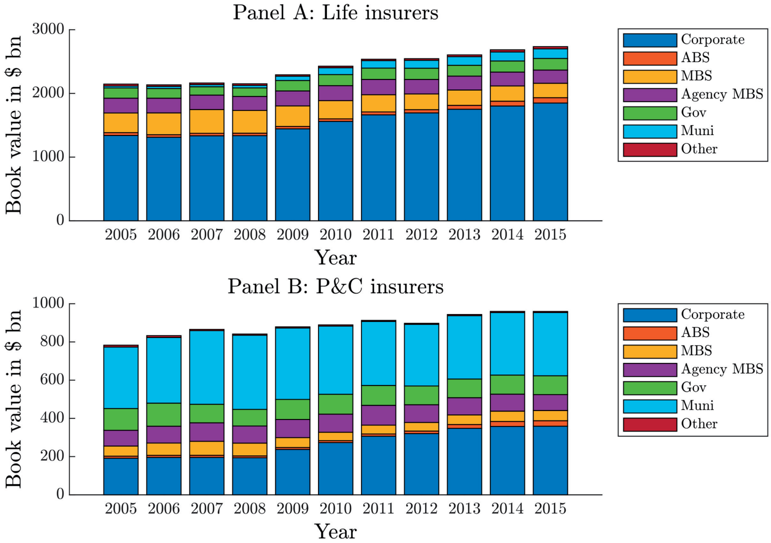

Figure 4
Fixed-income asset allocation by insurance companies
The graphs plot the evolution of book-adjusted carrying values across fixed-income categories from 2005 to 2015 for life insurers (panel A) and P&C insurers (panel B). The asset classification is based on the CUSIP master file.

While corporate bonds are the most important category within the fixed-income portfolio for both life and P&C insurers, only P&C insurers allocate a substantial share toward municipal bonds (of similar magnitude as corporate bonds).

Table 3 presents summary statistics for the main variables used in our analysis. In panel A, we summarize information on our security-insurer(group)-year data set. In panel B, we present summary statistics for our data set of newly issued securities at the security level. While only 1.9% of all new issues are initially rated BB+ or worse, this fraction increases to 12.1% in the subsample of MBS.

In Table 4, we present summary statistics separately for life and P&C insurers, using A.M. Best data on financial statements and ratings for the last year available, 2015.[23] We label an insurance group as life (P&C) if the majority of assets are held by life (P&C) insurers within a given group. This classification does not pose a significant concern as in our data 92% of all groups consist of only life or P&C insurers.

Following Koijen and Yogo (2015) and Koijen and Yogo (2018), we consider their total admitted assets, variable annuity liabilities (measured as the total related account value plus the gross amount of reserves minus the reinsurance reserve credit), the ratio of MBS over total assets, return on equity (ROE), their leverage ratio (calculated as one minus the ratio of equity to total admitted

23 All differences between life and P&C insurers are virtually invariant over our sample period.

Table 3
Summary statistics

A. Security-insurer(group)-year level (2006 − 2015)	Mean	SD	Min	Max	*N*
Sold any fraction	0.128	0.334	0	1	5,806,490
Sold > 50% of position	0.099	0.298	0	1	5,806,490
MBS	0.083	0.276	0.000	1	5,806,490
$\max\left\{\Delta RBC^{ratings}_{sit-1},0\right\}$	0.001	0.014	0	0.297	5,806,490
$\max\left\{\Delta RBC^{ratings}_{sit-1},0\right\}$ if MBS = 1	0.009	0.038	0	0.297	482,888
Life insurer	0.536	0.499	0	1	5,806,490

B. New security issues (security level, 2005 − 2015)	Mean	SD	Min	Max	*N*
Issue volume in 2015 \$m	63.627	2,758.296	0.000	2,199,949	1,552,612
Fraction by insurers	0.047	0.179	0.000	1	1,552,612
Fraction by life insurers	0.018	0.108	0.000	1	1,552,612
Participation by insurers	0.112	0.315	0	1	1,552,612
Participation by life insurers	0.053	0.224	0	1	1,552,612
MBS	0.047	0.212	0	1	1,552,612
High yield (HY)	0.019	0.138	0	1	1,552,612
HY if MBS = 1	0.121	0.326	0	1	73,416

The summary statistics in panel A refer to flow variables from the run-time of year 2006 until the run-time of year 2015, and correspond to the respective descriptions in Table 6. The variables in panel B correspond to the respective descriptions in Table 8.

assets), and RBC ratio (calculated as total adjusted capital over authorized control level risk-based capital). In addition, we include information on A.M. Best Financial Strength Ratings and Capital Adequacy Ratios (ranging from 0 to 999.9), which reflect whether an insurer will be able to meet its policy obligations.

Table 4 reveals several relevant differences between life and P&C insurers. Life insurers are significantly more likely to be held by their shareholders ("stock"), whereas P&C insurers are significantly more likely to be held by their policyholders ("mutual"). Life insurers are significantly larger and are the only type of insurers that relies on variable annuities.[24] Life insurers also hold more mortgage-backed securities on average, 4.7% of their admitted assets as compared to 2.5% for P&C insurers. Life insurers have significantly higher leverage ratios and are worse capitalized, as measured by their RBC ratios and A.M. Best Capital Adequacy Ratios, but their financial strength ratings are similar to those of their P&C counterparts.

3.3 Motivating evidence

In the following, we present evidence that motivates our scrutiny of the role of capital requirements and the 2009 regulatory reform in shaping asset-allocation decisions by U.S. insurers. We use a detailed breakdown of insurers' asset portfolios in conjunction with our comprehensive ratings data to characterize

[24] We record P&C insurance groups with nonzero variable annuities due to (very few) life insurers that are part of P&C insurance groups.

Table 4
Comparison of life and P&C insurers

Life insurers	Min	p25	p50	p75	Max	Mean	SD	*N*	p-value test of group mean equality
Stock share	0.000	1.000	1.000	1.000	1.000	0.873	0.309	303	0.000
Mutual share	0.000	0.000	.000	0.000	1.000	0.119	0.303	303	0.00
Assets in $bn	0.001	0.031	0.363	4.058	595.164	21.641	68.881	303	0.000
Variable annuities/assets	0.000	.000	0.000	0.000	0.914	0.039	0.117	303	0.000
MBS/assets	0.000	0.000	0.024	0.076	0.376	0.047	0.061	303	0.000
ROE	−0.398	0.025	0.070	0.141	0.549	0.082	0.129	297	0.193
Leverage ratio	0.010	0.597	0.817	0.912	0.996	0.735	0.226	303	0.000
RBC ratio	0.594	6.682	9.338	13.240	169.625	13.478	16.472	291	0.017
A.M. Best Financial Strength Rating	D	B++	A-	A	A++	A-	1.8 notches	212	0.691
A.M. Best Capital Adequacy Ratio	0	182	231.5	304	999	276.128	170.198	216	0.000

P&C insurers	Min	p25	p50	p75	Max	Mean	SD	*N*
Stock share	0.000	0.000	0.969	1.000	1.000	0.534	0.482	951
Mutual share	0.000	0.000	0.000	0.969	1.000	0.310	0.449	951
Assets in $bn	0.000	0.020	0.075	0.388	280.218	1.791	13.721	951
Variable annuities/assets	0.000	0.000	0.000	0.000	0.238	0.000	0.009	951
MBS/assets	0.000	0.000	0.000	0.038	0.294	0.025	0.044	951
ROE	−0.466	0.016	0.067	0.126	0.580	0.071	0.122	938
Leverage ratio	0.000	0.399	0.537	0.646	1.000	0.511	0.190	951
RBC ratio	0.189	5.653	8.694	14.130	705.103	17.597	43.253	915
A.M. Best Financial Strength Rating	E	A-	A-	A	A++	A-	1.6 notches	624
A.M. Best Capital Adequacy Ratio	15.6	203.15	280.1	388.5	999.9	329.679	193.571	640

Summary statistics are shown for all insurers (group level), with a leverage ratio (defined as one minus the ratio of equity to total admitted assets) of at most one, that are active in 2015, separately for insurance groups with the majority of their assets held by life insurers (top panel) and P&C insurers (bottom panel). Variable annuity liabilities are measured as the total related account value plus the gross amount of reserves minus the reinsurance reserve credit. A.M. Best Financial Strength Ratings comprise (at most) 15 notches. The last column indicates the p-value of a one-sided difference-in-means test.

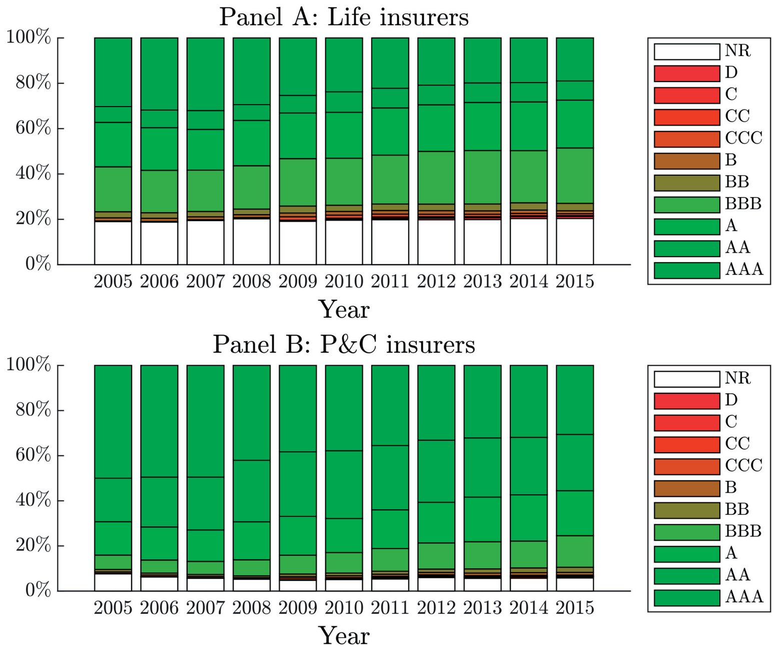

Figure 5
Ratings distribution of all fixed-income assets over time
For each year-end from 2005 to 2015, this graph plots the (book-value weighted) ratings distribution for the fixed income assets held by life insurers (panel A) and P&C insurers (panel B). The category "NR" refers to securities for which we do not observe a rating, either because no rating exists or because those securities are not covered by any of our databases.

the evolution of credit risk in the fixed-income portfolio of the U.S. insurance industry.

Figure 5 plots the year-end ratings distribution of the combined fixed-income asset holdings, separately for life (panel A) and P&C insurers (panel B). Compared to Figure 1, we also include the share of assets without a rating (labeled "NR"). These assets are securities for which no credit rating exists (e.g., a private corporate loan) and (a small number of) securities for which ratings exist, but they are not covered by any of our databases. While the share of assets without a rating is stable over time for both types of insurers, life insurers are much more exposed to unrated assets (20.4% in 2015) as compared to P&C insurers (5.8% in 2015), which largely results from differential exposure to private corporate loans.

We observe two trends in the overall portfolio that are indicative of reaching-for-yield behavior. First, conditional on availability of a rating, the fraction of high-yield investments doubles approximately for both types of insurers, from 5.3% to 8.4% for life insurers and from 2.1% to 5.0% for P&C insurers. Second, even the set of investment-grade securities show a granular trend toward

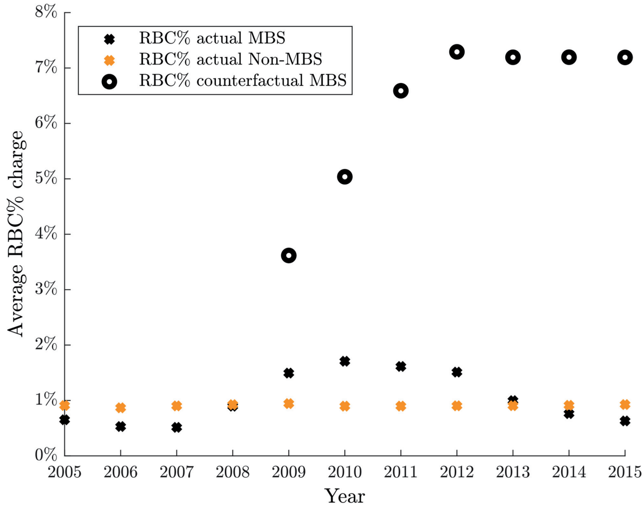

Figure 6
Regulatory-capital charge for MBS and non-MBS held by insurance companies
The graph plots the time series of actual year-end capital requirements (as a fraction of book values) for insurers' non-MBS holdings, MBS holdings, and starting year-end 2009, the counterfactual capital requirements for MBS holdings based on the previous (ratings-based) system. The sample of securities included in this graph requires the availability of at least one rating in the respective year.

lower-rated (but higher-yielding) assets. In particular, the super-safe AAA share (conditional on availability of a rating) dropped from 37.4% to 23.8% between 2005 and 2015 for life insurers, and from 54.1% to 32.5% for P&C insurers. Our introductory Figure 1 indicates that holdings of MBS, the only set of securities treated by the regulation, go a long way of explaining these stylized facts.

Next, we zoom in on the importance of the regulatory reform. To demonstrate the capital relief the reform produced for U.S. insurers, Figure 6 plots the actual average required regulatory-capital charge for MBS holdings (represented by black crosses), the counterfactual average capital requirement for MBS under the previous ratings-based system (starting 2009, indicated by the black circles), and the actual average regulatory-capital charge for non-MBS (indicated by the orange crosses). Compared to the counterfactual capital requirements based on ratings, we observe an extreme capital relief ($\approx$92% in 2015) for insurance companies holding MBS. Moreover, despite the significant deterioration in the credit quality of MBS compared to non-MBS (see Figure 1), capital requirements for MBS drop below those for non-MBS by 2015, consistent with our high-level approximation of the reform in Table 2.

To shed light on the characteristics of insurers that are more affected by the reform, we distinguish between insurers that benefited from the reform, by incurring lower capital requirements than those that would have been implied by the counterfactual ratings-based system, and insurers that did not, in the first year after the reform, 2010.[25] Naturally, these groups differ by the extent to which they were invested in MBS. We present their respective summary statistics in Table 5.

Most notably, insurers that benefited from the reform are much more likely to be life, rather than P&C, insurers: on average, 39.9% of insurers that benefited from the reform are life insurers, in comparison to only 17.7% of insurers that did not (the difference is significant at the 1% level). Consistent with the different correlates of life and P&C insurers (see Table 4), insurers that benefited from the reform are also much larger, have higher leverage ratios, lower RBC ratios, lower A.M. Best Capital Adequacy Ratios, and a higher share of variable annuity liabilities.[26] Other differences, even if statistically significant, are of smaller economic magnitudes, for example, the difference in ROE. While these results should not be interpreted as a test of any particular model of the regulatory process and its political economy, these correlates indicate that the 2009 reform benefited insurers that were more likely to be large and influential.

4. The Impact of the Reform on Asset Portfolios

Based on our evaluation of the reform in Section 2, we first analyze the differential effect of the reform across asset classes by only relying on the high-level summary of the reform in Table 2, that is, low and risk-insensitive capital requirements for MBS after the reform in contrast to all other fixed-income asset classes. As part of this analysis in Section 4.1, we examine the effects on insurers' trading behavior both for legacy assets (Section 4.1.1) and for newly issued securities (Section 4.1.2). In Section 4.2, we then exploit institutional details of the reform, in particular the discontinuous mapping of the book price markup into capital requirements, to identify the effect of capital requirements within MBS.

4.1 The differential effect across asset classes

4.1.1 Insurers' trading behavior for legacy assets. As argued in Section 2.3, different trading behavior around the reform could be driven by higher risk-taking within MBS or lower risk taking for non-MBS, or some combination thereof. Raw data in Figures 1 and 5 suggest, however, that the increase in risk-taking for MBS is the driving force. This would be in line with our conjecture if we assume that the income effects (see (18)) are quantitatively similar across asset classes, while the reform-induced differential effect on MBS trading reflects a potential substitution effect.

25 Results are similar if we use year 2015, the last year of our sample.

26 As variable annuities are only relevant for life insurance companies, one may wonder whether this correlation is also present within the sample of life insurance groups. Indeed, life insurance groups that benefited from the reform have a share of 0.06 in variable annuities, compared to 0.01 for such insurance groups that did not benefit from the reform (the difference is significant at the 1% level).

Table 5
Comparison of insurers based on reform impact

Insurers that benefited from the reform	Min	p25	p50	p75	Max	Mean	SD	N	p-value test of group mean equality
Life share	0.000	0.000	0.000	1.000	1.000	0.399	0.467	349	0.000
Stock share	0.000	0.102	1.000	1.000	1.000	0.664	0.442	349	0.004
Mutual share	0.000	0.000	0.000	0.736	1.000	0.263	0.414	349	0.264
Assets in $bn	0.003	0.167	0.795	4.946	571.354	17.171	56.583	349	0.000
Variable annuities/assets	0.000	0.000	.000	0.000	0.981	0.031	0.113	347	0.000
ROE	−0.469	0.032	0.077	0.148	0.491	0.080	0.131	345	0.004
Leverage ratio	0.001	0.552	0.665	0.844	0.982	0.675	0.196	349	0.000
RBC ratio	0.688	6.018	8.467	11.370	257.845	10.866	15.715	345	0.002
A.M. Best Financial Strength Rating	D	A-	A	A	A++	A-	1.6 notches	301	0.000
A.M. Best Capital Adequacy Ratio	22	178	220.2	291	999.9	254.297	143.484	303	0.000
Insurers that did not benefit from the reform									
	Min	p25	p50	p75	Max	Mean	SD	N	
Life share	0.000	0.000	0.000	0.000	1.000	0.177	0.373	810	
Stock share	0.000	0.000	1.000	1.000	1.000	0.580	0.483	810	
Mutual share	0.000	0.000	0.000	0.983	1.000	0.293	0.446	810	
Assets in $bn	0.000	0.013	0.042	0.193	199.569	0.998	8.903	810	
Variable annuities/assets	0.000	0.000	0.000	0.000	0.643	0.003	0.034	810	
ROE	−0.461	-0.004	0.058	0.119	0.643	0.055	0.135	797	
Leverage ratio	0.000	0.393	0.550	0.665	0.999	0.529	0.213	810	
RBC ratio	−0.139	5.569	9.142	14.302	412.932	15.491	32.801	764	
A.M. Best Financial Strength Rating	D	B++	A-	A	A++	A-	1.8 notches	496	
A.M. Best Capital Adequacy Ratio	35	191	261.65	376.3	999.9	315.679	193.211	490	

Summary statistics are shown for all insurers (group level), with a leverage ratio (defined as one minus the ratio of equity to total admitted assets) of at most one, that are active in 2010, separately for those that saved >0 in terms of risk-based capital thanks to the reform (top panel) and those that saved ≤ 0 (bottom panel). Variable annuity liabilities are measured as the total related account value plus the gross amount of reserves minus the reinsurance reserve credit. A.M. Best Financial Strength Ratings comprise (at most) 15 notches. The last column indicates the p-value of a one-sided difference-in-means test.

Table 6
Effect of regulatory reform on insurers' selling legacy securities

	Sold any fraction of security $\in \{0,1\}$				
Securities	MBS	MBS	MBS	All	All
Variable	(1)	(2)	(3)	(4)	(5)
$\max\left\{\Delta\text{RBC}^{\text{ratings}},0\right\} \times$ MBS $\times$ Post				−0.732***	−0.607***
				(0.138)	(0.140)
$\max\left\{\Delta\text{RBC}^{\text{ratings}},0\right\} \times$ Post	−0.543***	−0.661***	−0.651***	0.005	−0.096
	(0.053)	(0.091)	(0.091)	(0.102)	(0.105)
$\max\left\{\Delta\text{RBC}^{\text{ratings}},0\right\} \times$ MBS				0.581***	0.279**
				(0.122)	(0.124)
$\max\left\{\Delta\text{RBC}^{\text{ratings}},0\right\}$	0.792***	0.676***	0.710***	0.138*	0.481***
	(0.051)	(0.087)	(0.088)	(0.084)	(0.086)
Security FE	N	Y	N	Y	N
Security-insurer FE	N	N	Y	N	Y
Year FE	Y	N	N	N	N
Rating-asset-class-year FE	N	Y	Y	Y	Y
ΔRating-asset-class-year FE	N	Y	Y	Y	Y
Insurer-year FE	N	Y	Y	Y	Y
N	482,888	477,510	454,125	5,677,802	5,264,392

The sample is a panel at the security-insurer-year level sit from 2006 to 2015, that is, nonmaturing security s held by insurer i (group level) in year $t-1$ and traded in year t. In the first three columns, we consider only (nonagency) mortgage-backed securities. The dependent variable is an indicator variable for whether insurer i sold a nonzero fraction of security s in year t. $\max\left\{\Delta RBC_{sit-1}^{ratings},0\right\}$ is the absolute increase in risk-based charges (RBC, from 0 to 0.297) of security s as a function of the NAIC risk category according to credit ratings (also after the regulatory reform) for life and P&C insurers i in year-end $t-1$ (compared to the previous year). MBS_s is an indicator variable for whether security s is a mortgage-backed security, and $Post_t$ is an indicator variable for the year 2010 and onward. Rating-asset-class-year fixed effects are determined by security s's rating in year-end $t-2$, and ΔRating-asset-class-year fixed effects are determined by the change in ratings (in notches) between year-end $t-2$ and $t-1$. All singletons are dropped from the total number of observations N. Robust standard errors (clustered at the security level) are in parentheses. *p <.1; **p <.05; ***p <.01.

To estimate whether the new system increases insurers' willingness to bear risk in structured securities relative to other asset classes, for example, corporate bonds, we exploit downgrades of MBS versus other asset classes before and after the regulatory reform. In particular, we examine insurers' decision to sell legacy assets. Our granular data at the security-insurer(group)-year level sit allow us to exploit the consequences of security downgrades for specific insurer positions.[27]

In Table 6, the dependent variable, $Sold_{sit}$, is an indicator for whether insurer i actively sold any nonzero fraction of security s in year t.[28] As explanatory variable, we use the absolute increase in risk-based charges (RBC, from 0 to 0.297) of security s as implied by credit ratings for life and P&C insurers i in year-end $t-1$ (compared to the previous year), $\max\left\{\Delta RBC_{sit-1}^{ratings},0\right\}$. In the post-reform period, when ratings are replaced as inputs in the calculation of

27 While in Table 6 we focus on the insurance group level, the estimates are very similar in the somewhat larger sample when considering the individual company level (see Table B.1 of the Internet Appendix).

28 We focus on sales, since industry evidence in Table B.3 of the Internet Appendix suggests that selling (rather than buying) decisions are relevant for the risk-taking behavior.

risk-based charges, these risk-based charges are counterfactual.[29] By using implied risk-based charges under the previous regime, we exploit within-security variation across insurers i, as risk-based charges vary by business line, and the fact that not all rating downgrades triggered increases in capital requirements. For example, a rating downgrade by two notches from BBB+ to BBB- would not lead to higher capital requirements under the ratings-based regime, as the NAIC risk designation is the same for both ratings (see Table 1). In contrast, a rating downgrade by two notches from BBB to BB+ would imply an increase in capital requirements from NAIC-2 to NAIC-3.

We first focus on MBS. In column 1, we estimate a raw estimate that does not account for any other source of variation but year fixed effects. Since we consider selling decisions, we expect the sign of the coefficient for $\max\left\{\Delta RBC^{ratings}_{sit-1}, 0\right\} \times Post_t$ to be negative, as capital requirements are no longer sensitive to risk (see Table 2). Indeed, while insurers are more likely to sell MBS that are downgraded and subsequently associated with higher capital requirements (in line with Ellul, Jotikasthira, and Lundblad 2011), they do so with a significantly lower likelihood after the regulatory reform.

This continues to hold in column 2 after adding not only security and insurer by year fixed effects but also rating by year and rating-change (measured in notches) by year fixed effects. The reasoning is that the RBC effect of a rating downgrade is not just a function of the notches (two notches in the above example), but also a function of the previous rating (BBB+ vs. BBB in the example). In this manner, the coefficients for $\max\left\{\Delta RBC^{ratings}_{sit-1}, 0\right\}$ and $\max\left\{\Delta RBC^{ratings}_{sit-1}, 0\right\} \times Post_t$ are estimated off downgrades by any number of notches that were, or would have been, associated with higher capital requirements under the previous regime, as compared to downgrades—by the same number of notches—that were not. Quantitatively, a downgrade from NAIC 2 to 3, that is, a non-investment-grade downgrade, is associated with an absolute increase in RBC of 0.033 for life insurers, from 1.3 to 4.6%. This translates into a $(0.033 \times 0.661 =)$ 2.2-percentage-point lower likelihood of selling MBS after the regulatory reform (column 2), which corresponds to roughly one-sixth of the average value for the dependent variable (see panel A in Table 3).

In column 3, we include security-insurer fixed effects, which capture time-invariant heterogeneity at the security-insurer level, such as the general investment profile of insurance companies according to their business model (life vs. P&C). This implies that we drop (few) observations that are associated with securities held by insurers in only one of the two periods around the regulatory reform. This leaves our estimates virtually unaltered.

[29] All results are robust to using an indicator for an increase in risk-based charges, that is, $\mathbb{1}\left\{\Delta RBC^{ratings} > 0\right\}_{sit-1}$.

In columns 4 and 5 of Table 6, we estimate analogous regression specifications to those in columns 2 and 3 on the sample of all fixed-income securities:

$$\begin{aligned} Sold_{sit} = &\beta_1 \max\left\{\Delta RBC_{sit-1}^{ratings}, 0\right\} \times MBS_s \times Post_t \\ &+ \beta_2 \max\left\{\Delta RBC_{sit-1}^{ratings}, 0\right\} \times Post_t + \beta_3 \max\left\{\Delta RBC_{sit-1}^{ratings}, 0\right\} \times MBS_s \\ &+ \beta_4 \max\left\{\Delta RBC_{sit-1}^{ratings}, 0\right\} + \mu_s + \psi_{kt} + \eta_{it} + \epsilon_{sit}, \end{aligned} \tag{7}$$

where μ_s and η_{it} denote security and insurer-year fixed effects, respectively, and ψ_{kt} denotes rating by year and rating-change by year fixed effects for each asset class k.

The coefficient of interest is β_1, which indicates whether insurers sell downgraded MBS with a different likelihood following the regulatory reform. In column 4, we include (as is the case in column 2), rating (change) by year fixed effects for each asset class. We find that prior to the reform, higher capital requirements translate into greater propensity of insurers to sell downgraded fixed-income securities (as reflected by the positive coefficient for $\max\left\{\Delta RBC_{sit-1}^{ratings}, 0\right\}$), and even more so for MBS (positive coefficient for its interaction with MBS_s). This effect stays in place for all non-MBS fixed-income securities, as there is no post-reform reduction in insurers' propensity to sell them: the coefficient for $\max\left\{\Delta RBC_{sit-1}^{ratings}, 0\right\} \times Post_t$ is insignificant. In contrast, this effect is reduced significantly after the reform for MBS: the coefficient for $\max\left\{\Delta RBC_{sit-1}^{ratings}, 0\right\} \times MBS_s \times Post_t$ is negative and significant at the 1% level. This continues to hold true after including security-insurer fixed effects in column 5.[30]

In Table 7, we analyze heterogeneity of insurer responses based on the business line and according to various measures of financial constraints. The first sample split, presented in columns 1 and 2, shows that only life insurers respond to the reform by not reducing their propensity to sell downgraded MBS. This result may, in part, reflect life insurers' riskier liabilities, as measured by their reliance on variable annuities, and other financial constraints (Tables 4 and 5). Following Koijen and Yogo (2018), we examine whether the trading response by life insurers is related to their exposure to variable annuity liabilities. The coefficient for $\max\left\{\Delta RBC_{sit-1}^{ratings}, 0\right\} \times MBS_s \times Post_t$ is negative and significant only for insurance groups with a nonzero share of life insurers and variable annuity liabilities amounting to over 5% of their assets (column 3),

[30] A small fraction of our observations are trades of a small part of a position. We rerun regressions with an indicator for whether an insurer sold more than 50% of a position as dependent variable to focus on impactful trades. The results are in Table B.2 of the Internet Appendix and show similar results.

Table 7
Effect of regulatory reform on insurers' selling legacy securities: Heterogeneity

	Sold any fraction of security $\in \{0,1\}$							
Insurers	Life	P&C	High variable annuities	Low variable annuities	Low RBC	High RBC	Low BCAR	High BCAR
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\max\left\{\Delta \mathrm{RBC}^{\mathrm{ratings}},0\right\} \times$ MBS $\times$ Post	−0.627***	0.155	−0.769***	−0.228	−0.571**	−0.130	−0.921***	−0.005
	(0.154)	(0.342)	(0.204)	(0.221)	(0.251)	(0.381)	(0.231)	(0.407)
$\max\left\{\Delta \mathrm{RBC}^{\mathrm{ratings}},0\right\} \times$ Post	−0.114	−0.393*	−0.038	−0.257*	−0.108	−0.029	−0.039	−0.042
	(0.118)	(0.226)	(0.159)	(0.150)	(0.189)	(0.249)	(0.168)	(0.284)
$\max\left\{\Delta \mathrm{RBC}^{\mathrm{ratings}},0\right\} \times$ MBS	0.273**	−0.296	0.409**	−0.103	0.176	−0.033	0.429**	−0.294
	(0.137)	(0.309)	(0.182)	(0.198)	(0.218)	(0.351)	(0.205)	(0.360)
$\max\left\{\Delta \mathrm{RBC}^{\mathrm{ratings}},0\right\}$	0.596***	0.573***	0.539***	0.555***	0.489***	0.336	0.522***	0.481**
	(0.099)	(0.185)	(0.133)	(0.121)	(0.151)	(0.208)	(0.136)	(0.223)
Security-insurer FE	Y	Y	Y	Y	Y	Y	Y	Y
Rating-asset-class-year FE	Y	Y	Y	Y	Y	Y	Y	Y
ΔRating-asset-class-year FE	Y	Y	Y	Y	Y	Y	Y	Y
Insurer-year FE	Y	Y	Y	Y	Y	Y	Y	Y
N	2,868,370	2,395,741	1,643,292	1,974,816	1,282,420	927,797	1,538,301	833,108

The sample is a panel at the security-insurer-year level sit from 2006 to 2015, that is, nonmaturing security s held by insurer i (group level) in year $t-1$ and traded in year t. In column 1 (2), the sample is limited to insurance groups with the majority of their assets held by life (P&C) insurers. In column 3 (4), the sample is limited to insurance groups with a nonzero share of their assets held by life insurers and variable annuity liabilities amounting to over (at most) 5% of their assets in year $t-1$. In column 5 (6), the sample is limited to insurance groups with RBC ratios in the bottom (top) third of the distribution in year $t-1$. In column 7 (8), the sample is limited to insurance groups with (intra-group median) A.M. Best Capital Adequacy Ratios in the bottom (top) third of the distribution in year $t-1$. The dependent variable is an indicator variable for whether insurer i sold a nonzero fraction of security s in year t. $\max\left\{\Delta RBC^{ratings}_{sit-1},0\right\}$ is the absolute increase in risk-based charges (RBC, from 0 to 0.297) of security s as a function of the NAIC risk category according to credit ratings (also after the regulatory reform) for life and P&C insurers i in year-end $t-1$ (compared to the previous year). MBS_s is an indicator variable for whether security s is a mortgage-backed security, and $Post_t$ is an indicator variable for the year 2010 and onward. Rating-asset-class-year fixed effects are determined by security s's rating in year-end $t-2$, and ΔRating-asset-class-year fixed effects are determined by the change in ratings (in notches) between year-end $t-2$ and $t-1$. All singletons are dropped from the total number of observations N. Robust standard errors (clustered at the security level) are in parentheses. *p <.1; **p <.05; ***p <.01.

but not for the remaining insurance groups with a nonzero share of life insurers (column 4).[31]

In the remaining columns, we consider splits on financial constraints. This split is motivated by our Result 2, which requires regulatory constraints to bind. Naturally, we expect these constraints to be more relevant for financially constrained insurers. Empirically, we find that worse capitalized insurers respond more strongly, for example, insurance groups with RBC ratios in the bottom third of the distribution (column 5) compared to the top third (column 6). Similarly, the coefficient for $\max\left\{\Delta RBC^{ratings}_{sit-1}, 0\right\} \times MBS_s \times Post_t$ is negative and significant for insurance groups with (intra-group median) A.M. Best Capital Adequacy Ratios in the bottom, rather than the top, third of the distribution (column 7 vs. column 8).

Finally, these results also hold when we translate our tests to the more aggregate industry level. In Table B.3 of the Internet Appendix, we examine security holdings across all insurers following downgrades, and use the change of par value of a given security as dependent variable. We use as independent variable an indicator for whether a security was downgraded to a lower NAIC risk category in the previous year, which we interact with an indicator for the post-reform period from 2010 to 2015. Following the reform, insurers hold relatively more of downgraded MBS (compared to other security types), and this increase in risk-taking is due to insurers' selling, rather than buying, decisions. In Table B.4 of the Internet Appendix, we confirm that life, rather than P&C, and more constrained insurers, as measured by their reliance on variable annuities and weak capitalization (low RBC ratios and A.M. Best Capital Adequacy Ratios), react more strongly to the regulatory reform by not reducing their MBS holdings.

In sum, our analysis at the industry and insurer level draws the same picture regarding the effect of the reform on insurers' trading behavior in legacy assets. We provide evidence that the typical insurer is responsive to regulatory constraints (Koijen and Yogo 2015): the risk insensitivity of MBS capital requirements after the reform induces a lower propensity to sell downgraded MBS compared to other asset classes. Our heterogeneity analysis in is consistent with risk-taking being the channel. In line with standard theories of risk-taking, we document that more constrained insurers are more responsive in exploiting the risk-taking opportunities of the reform.

4.1.2 Insurance companies as investors in new security issues. As the reform also extends to newly issued MBS after the crisis, we next consider the effect of the reform on primary markets. Since all precrisis holdings will eventually mature or default, insurers' behavior in the market for new securities

[31] We restrict the sample to insurance groups with a nonzero share of their assets held by life insurers as this product is only offered by life insurance companies.

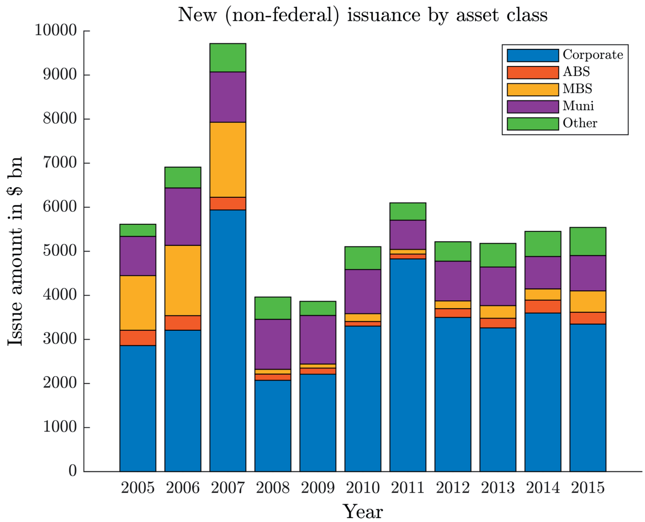

Figure 7
New issuance of fixed-income securities over time
The graphs plot the evolution of total new issues by asset class from 2005 to 2015 for all nonfederal issues.

determines the long-run impact of the reform. Moreover, the potentially confounding effects of illiquidity (see discussion at the end of Section 2.3) are largely irrelevant for asset allocations in the primary market.[32] Above and beyond the insurance sector, primary markets for MBS are important because they fund large amounts of assets and investments in the U.S. economy.

To investigate whether the reform has enabled insurers to actively invest in risky MBS, we use our comprehensive data on fixed-income securities issued between 2005 and 2015. Figure 7 provides an overview of these new issues, the total number of which is just short of 1.6 million (this only includes rated securities). Since MBS issuance is of particular interest to our study, it is useful to highlight that MBS issuance dropped significantly in 2008, recovered in 2012, but is still significantly below precrisis levels.

As can be seen in the respective summary statistics (panel B of Table 3), P&C insurers hold slightly larger shares than do life insurers on average across securities. However, this is because P&C insurers primarily participate in smaller issues: the total fraction of all new issues—approximately $10tn p.a.—in a given year held by life insurers (2.6% on average) is twice as large as that held by P&C insurers (1.3% on average).

32 Liquidity considerations may be relevant in a dynamic sense, as expected future illiquidity in secondary markets may affect insurers' willingness to invest in primary markets today.

Table 8
Fraction invested by insurance companies in newly issued securities

	Fraction by insurers $\in [0,1]$					Life	P&C
Sample	All	$\geq$ \$5m	$\geq$ \$5m	$\geq$ \$5m	$\geq$ \$20m	$\geq$ \$20m	$\geq$ \$20m
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
MBS × Post	0.042***	0.024***					
	(0.003)	(0.003)					
MBS × HY × Post			0.046***	0.045***	0.051***	0.042***	0.010**
			(0.007)	(0.007)	(0.010)	(0.009)	(0.004)
MBS × HY			−0.044***				
			(0.002)				
HY × Post			−0.060***				
			(0.002)				
High yield (HY)			−0.040***				
			(0.001)				
Asset-class FE	Y	Y	N	N	N	N	N
Year FE	Y	Y	N	N	N	N	N
Asset-class-year FE	N	N	Y	Y	Y	Y	Y
HY-asset-class FE	N	N	N	Y	Y	Y	Y
HY-year FE	N	N	N	Y	Y	Y	Y
N	1,552,612	403,506	403,506	403,506	221,580	221,580	221,580

The sample consists of all new securities s rated and issued at date t anytime from 2005 to 2015. The sample in the second to fourth (fifth to seventh) column is limited to all new issues with a size of at least \$5m (\$20m). The dependent variable in the first five columns is the fraction, between 0 and 1, of newly issued security s held by insurance companies. The dependent variable in the sixth and seventh column is the fraction of newly issued security s held by insurance groups with the majority of their assets held by life or P&C insurers, respectively. MBS_s is an indicator variable for whether security s is a mortgage-backed security, HY_s is an indicator variable for whether security s is a (high-yield) security rated BB+ or worse, and $Post_t$ is an indicator variable for the year 2010 and onward. All singletons are dropped from the total number of observations N. Robust standard errors (clustered at the security level) are in parentheses. $^*p$ <.1; $^{**}p$ <.05; $^{***}p$ <.01.

We now hypothesize that insurance companies are more likely to invest in newly issued MBS after the regulatory reform, as compared to other investors.[33] For each new security issue, we determine the total fraction purchased by insurance companies. We use the sum of insurers' year-end holdings (book values) in the issuance year as a proxy for insurers' purchases at issuance.

In column 1 of Table 8, we estimate a simple difference-in-differences specification, including only asset-class and year fixed effects. We use as dependent variable the fraction, between 0 and 1, of new issues held by insurance companies. The estimated coefficient for $MBS_s \times Post_t$ reflects that following the reform, the fraction of MBS purchased by insurers increases by 4.2 percentage points.

In column 2 (and here on out), we drop all securities with an issuance volume of less than \$5m (e.g., very small municipal bonds), leaving us with the top quarter of the volume distribution across all security categories. Our estimate of the increase in the fraction of MBS purchased by insurers after the reform drops to 2.4 percentage points, but remains significant at the 1% level.

The findings from columns 1 and 2 are in line with our conjecture, as the regulatory reform solely affects (nonagency) MBS and there is no similar reform

33 Note that even MBS issues that are highly rated at issuance benefit from the reform in a dynamic sense as (potential) future downgrades will not lead to increases in capital requirements.

for other investors. However, within this subset of securities, we would expect even stronger effects for high-yield MBS, which we define as MBS rated BB+ or worse. To test this, we estimate the following regression specification at the security level:

$$\begin{aligned} &\textit{Fraction insurers}_{st} \\ &\quad = \beta_1 MBS_s \times HY_s \times Post_t + \beta_2 MBS_s \times HY_s + \beta_3 HY_s \times Post_t \\ &\qquad + \beta_4 HY_s + \psi_{kt} + \epsilon_{st}, \end{aligned} \tag{8}$$

where $\textit{Fraction insurers}_{st}$ is the fraction, between 0 and 1, of newly issued security s (belonging to asset class k) in year t held by insurance companies, MBS_s is an indicator variable for whether security s is a mortgage-backed security, HY_s is an indicator variable for whether security s is a (high-yield) security rated BB+ or worse, $Post_t$ is an indicator variable for the year 2010 and onward, and ψ_{kt} denotes asset class by year fixed effects. Standard errors are clustered at the security level. In additional specifications, we also control for interactions of HY_s and year fixed effects, as well as interactions of HY_s and asset-class fixed effects.

We estimate (8) in column 3. As we exploit variation in high-yield versus non-high-yield securities within MBS, we can also include asset class by year fixed effects, which capture any differential trajectory across fixed-income asset classes. In comparison to other MBS, the fraction of high-yield MBS purchased by insurers is 4.6 percentage points higher after the regulatory reform. This estimate is not only larger than that in column 2 but also economically significant in absolute terms, as the sample mean is 4.7%, with a standard deviation of 17.9%. This confirms our hypothesis also for the purchasing, rather than selling, behavior of insurance companies.

In column 4, we add interactions of the high-yield indicator with asset-class and year fixed effects, and our estimate is virtually unchanged. When we drop all securities with an issuance volume of less than \$20m in column 5, the estimate increases somewhat compared to that in column 4. Excluding municipal bonds, this sample corresponds to the top 60% of all issues according to their issuance volume.

In the last two columns of Table 8, we calculate the dependent variable separately for life and P&C insurers, so that the two respective estimates add up to our estimate from column 5. The coefficient for the fraction invested by life insurers in new issues (column 6) is more than four times as large as that for P&C insurers (column 7).[34]

We conclude our analysis of purchases of new issues by zooming in on the relative importance of insurer-level covariates for the type of risk-taking

[34] As a robustness check, we use an indicator for whether insurance companies have strictly positive holdings of new issues (reported in Table B.5 of the Internet Appendix). The results are very similar to those in Table 8.

Table 9
Insurers' portfolios of new issues post-reform

	Fraction MBS of new-issue purchases in %		Fraction HY MBS of MBS new-issue purchases in %		
Mean dependent variable	2.773	2.773	0.038	0.038	0.038
Variable	(1)	(2)	(3)	(4)	(5)
Life share	1.003**	0.671*	0.057**	0.060**	0.052**
	(0.400)	(0.378)	(0.027)	(0.027)	(0.024)
Stock share	−0.024	0.088	−0.009	−0.010	−0.011
	(0.403)	(0.390)	(0.022)	(0.023)	(0.022)
Mutual share	0.446	0.558	−0.009	−0.010	−0.017
	(0.451)	(0.439)	(0.023)	(0.023)	(0.023)
ln(Assets)	0.552***	0.425***	0.019***	0.020***	0.015***
	(0.068)	(0.071)	(0.005)	(0.006)	(0.005)
Variable annuities/assets	−0.156	−0.582	−0.127	−0.123	−0.116
	(2.678)	(2.656)	(0.114)	(0.112)	(0.114)
ROE	0.589	0.882	−0.196*	−0.199*	−0.210*
	(1.233)	(1.205)	(0.117)	(0.117)	(0.118)
RBC ratio	0.003	0.002	0.000	0.000	−0.000
	(0.002)	(0.002)	(0.000)	(0.000)	(0.000)
A.M. Best Capital Adequacy Ratio	−0.001	−0.001	0.000	0.000	0.000
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Share MBS 2005 − 2008		11.423***		−0.115	−0.251*
		(2.430)		(0.135)	(0.143)
Fraction MBS of new-issue purchases					0.012***
					(0.004)
Year FE	Y	Y	Y	Y	Y
N	4,857	4,857	4,857	4,857	4,857
R^2	.082	.096	.018	.018	.044

The sample is a panel at the insurer-year level it from 2010 to 2015, for all newly issued securities purchased by insurer i (group level) in year t. The dependent variable in the first two columns is the fraction of newly issued (nonagency) MBS to all new issues purchased by insurer i in year t, measured in % (from 0 to 100). The dependent variable in the last three columns is the fraction of newly issued (nonagency) MBS with a rating of BB+ or worse to all newly issued (nonagency) MBS purchased by insurer i in year t, measured as a percentage (from 0 to 100). *Life share*$_{it-1}$ is the share of assets held by life insurers within insurance group i in year $t-1$. *Stock share*$_{it-1}$ is the share of assets held by insurers owned by their shareholders within insurance group i in year $t-1$. *Mutual share*$_{it-1}$ is the share of assets held by insurers owned by their policyholders within insurance group i in year $t-1$. Each insurer is classified as stock, mutual, or other. *Variable annuities*$_{it-1}$ captures variable annuity liabilities, measured as the total related account value plus the gross amount of reserves minus the reinsurance reserve credit, of insurer i in year $t-1$. *Assets*$_{it-1}$ and *ROE*$_{it-1}$ denote, respectively, total admitted assets and the return on equity ratio of insurer i in year $t-1$. *RBC ratio*$_{it-1}$ is the risk-based capital ratio, equal to total adjusted capital over authorized control level risk-based capital, of insurer i in year $t-1$. i in year $t-1$. A.M. Best Capital Adequacy Ratios range from 0 to 999.9, and we include the intra-group median value for each insurer i in year $t-1$. *Share MBS 2005–2008*$_i$ equals the average ratio of (nonagency) MBS to total assets of insurer i in the period 2005 − 2008. All singletons are dropped from the total number of observations N. Robust standard errors (clustered at the insurer level) are in parentheses.

behavior we just documented. For this purpose, we build an insurer-year panel for the post-reform period from 2010 to 2015, and use as dependent variable the fraction of newly issued (nonagency) MBS to all new issues purchased by a given insurer i in year t. We note that the mean fraction of new assets invested in MBS is smaller than the overall portfolio share in MBS (cf. Table 4), which is a consequence of the drastic decline in new MBS issues (see Figure 7).

Columns 1 and 2 of Table 9 show that life and large insurers are particularly prone to allocating more funds to new MBS issues among their total investment in new issues in general. Controlling for business line, the organizational form—that is, whether insurance groups are held by their shareholders or policyholders—is not correlated with the propensity to hold MBS. Neither is their reliance on variable annuities. This continues to hold true after controlling for the historical fraction of MBS over total assets in 2005 − 2008, as a proxy for losses incurred during the financial crisis. Interestingly, insurers that used to invest more in MBS in the precrisis period continued to do so after the crisis, suggesting some persistence in the "asset management style" that is not captured by the other covariates.

In columns 3 and 4, we use the fraction of new high-yield MBS issues in the portfolio of new MBS issues as dependent variable, thereby isolating the riskiest tranches of new purchases. Again, the life business model and size (total admitted assets) exhibit the strongest correlation. This holds even after controlling for the fraction of MBS out of all new issues (column 5). All of these insights continue to hold true when moving from the group to the individual company level (Table B.6 in the Internet Appendix).

Overall, both the business model and size drastically differ for insurers that benefited from the reform versus those that did not in Table 5. This suggests a substantial overlap in the set of insurers that used to invest in MBS before the crisis and those that continue to do so.

4.2 Quasi-random capital requirements

Our evidence in the previous section indicates that the reform enables insurers to hold on to downgraded MBS and to participate in new issues of risky MBS. This analysis relies only on the approximation that MBS fall into the category with the lowest capital requirements (NAIC-1) because they are marked to market, they have been impaired in the past, or because $ELOSS \approx 0$. However, while this is indeed true for the majority of MBS positions (see Section 2.2), a subset of securities have book prices sufficiently above the NAIC-1 cutoff that they face higher capital requirements. These are securities that have been marked to market and for which *MP* sufficiently exceeds IP, even though *MP* is highly correlated with IP and often below IP (see Figure 2); or securities that are not required to be marked to market because their amortized cost is not too far away from IP.[35]

This subsample of MBS allows us to identify insurers' direct trading response to capital requirements after the regulatory reform by exploiting that the book price markup $\frac{BP-IP}{BP}$ maps discontinuously into capital requirements. Hence, we can employ a regression discontinuity design around the five NAIC threshold values for the determination of capital requirements. This identification is thus as close as one can get to the theoretical thought experiment of exogenously increasing capital requirements, which results in the prediction of lower holdings (cf. first hypothesis of Result 2).

As ELOSS values are provided at the end of each year for the purpose of calculating MBS capital requirements, we analyze the trading response in the

[35] This happens as some insurers may have purchased MBS at sufficiently low prices after the financial crisis.

subsequent year. We, hence, limit our security-insurer-year data set to all RMBS held anytime from year-end 2009 to year-end 2014 and CMBS held anytime from year-end 2010 to year-end 2014.

Cutoffs, which vary for life and P&C insurers, are based on $\frac{BP_{sit}-IP_{st}}{BP_{sit}}$ (see Table 1). As the highest cutoff is at 0.265, and to remove outliers that are too far away from the highest and the lowest cutoffs, we limit the sample to securities for which $-0.5 \leq \frac{BP_{sit-1}-IP_{st-1}}{BP_{sit-1}} \leq 0.5$, thereby removing a relatively small number of 13,946 out of 114,035 security-year observations. In addition, we drop all securities with zero expected loss, as these securities are automatically assigned the lowest capital requirement (NAIC-1) and, hence, the discontinuity does not apply. This restriction affects half of the remaining security-year observations (47,912 out of 100,089 security-year observations).

To estimate the effect of capital requirements on insurers' selling of MBS, we run the following regression at the MBS-insurer-year-level sit, and use the same dependent variable as before (see Table 6):

$$Sold_{sit} = \sum_{k=1}^{5} \beta_k Threshold\ to\ NAIC\text{-}k{+}1_{sit-1} + \gamma \frac{BP_{sit-1} - IP_{st-1}}{BP_{sit-1}} + \eta_{it} + \epsilon_{sit}, \tag{9}$$

where *Threshold to NAIC-X*$_{sit-1}$ equals 1 whenever $\frac{BP_{sit-1}-IP_{st-1}}{BP_{sit-1}}$ is equal to or exceeds the cutoff for the category NAIC-*X* (where *X* ranges from 2 to 6). BP_{sit-1} and IP_{st-1} are short-hand notations for book price ($=\frac{BV_{sit-1}}{PV_{sit-1}}$) and intrinsic price (based on *ELOSS*). η_{it} denotes insurer-year fixed effects. We double-cluster standard errors at the security and insurer levels, as the identifying variation is jointly determined at the security (due to *ELOSS*) and insurer levels (different book values across insurers).

In Table 10, we show the results from estimating (9) separately for life and P&C insurers in columns 1 to 5 and 6 to 10, respectively. Life insurers respond to various thresholds, and the respective increases in capital requirements, with different intensities. For example, based on our estimates in column 1, life insurers are more likely to sell any fraction of their legacy MBS by 3.4, 5.7, and 7.8 percentage points when the associated capital requirements increase from NAIC-2 to NAIC-3, from NAIC-3 to NAIC-4, and from NAIC-5 to NAIC-6, respectively. For these thresholds, the percentage-point increases in selling probabilities are proportional to the corresponding capital requirement increases (see Table 1). That is, insurance companies respond more when the percentage-point increase in capital requirements is larger.

After we add insurer-year fixed effects as well as quadratic and cubic splines in column 2, the first threshold is also associated with an increase in insurers' selling propensity (albeit a modest one, by one percentage point). In addition, life insurers are now 2.8 percentage points more likely to sell any fraction of their legacy MBS when the associated capital requirements increase from NAIC-4 to NAIC-5.

Table 10
Effect of regulatory reform on insurers' selling legacy securities: Regression discontinuity

Sample	Sold any fraction of security $\in\{0,1\}$ ELOSS $\neq 0$, $-0.5 \leq \frac{BP_{sit-1}-IP_{st-1}}{BP_{sit-1}} \leq 0.5$										
Insurers	Life	Life	Life	Life	Life	P&C	P&C	P&C	P&C	P&C	All
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
RBC					0.343***					0.252**	0.338***
					(0.103)					(0.123)	(0.089)
RBC × Mark-to-mkt											−0.057
											(0.051)
Mark-to-market											0.013**
											(0.007)
Threshold to NAIC-2	0.001	0.011**	0.005	0.004		−0.024*	−0.015	−0.004	−0.013		
	(0.006)	(0.005)	(0.005)	(0.005)		(0.012)	(0.011)	(0.011)	(0.011)		
Threshold to NAIC-3	0.034***	0.040***	0.016***	0.021***		0.017	0.015	−0.016	0.008		
	(0.009)	(0.012)	(0.006)	(0.008)		(0.018)	(0.015)	(0.015)	(0.014)		
Threshold to NAIC-4	0.057***	0.063***	0.008	0.040***		0.017	0.012	−0.012	0.004		
	(0.012)	(0.016)	(0.009)	(0.011)		(0.021)	(0.017)	(0.016)	(0.016)		
Threshold to NAIC-5	0.015	0.028**	0.002	0.010		0.059**	0.076***	0.030	0.047**		
	(0.011)	(0.012)	(0.009)	(0.010)		(0.026)	(0.025)	(0.022)	(0.023)		
Threshold to NAIC-6	0.078***	0.050**	0.032*	0.017		0.066*	0.030	0.002	0.012		
	(0.021)	(0.020)	(0.019)	(0.018)		(0.036)	(0.030)	(0.039)	(0.031)		
Linear spline	−0.208***	−0.343***	−0.102**	−0.134*	−0.087	−0.080**	−0.155**	0.008	−0.036	−0.048	−0.077
	(0.047)	(0.118)	(0.045)	(0.077)	(0.069)	(0.035)	(0.064)	(0.077)	(0.062)	(0.061)	(0.056)
$BP_{sit-1}-MP_{st-1}$				−0.036**	−0.030*				−0.064*	−0.069*	−0.034**
				(0.016)	(0.017)				(0.036)	(0.037)	(0.016)
Quad. & cubic splines	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
Insurer FE	Y	N	N	N	N	Y	N	N	N	N	N
Year FE	Y	N	N	N	N	Y	N	N	N	N	N
Insurer-year FE	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
Security FE	N	N	Y	N	N	N	N	Y	N	N	N
Rating-year FE	N	N	N	Y	Y	N	N	N	Y	Y	Y
N	83,010	82,756	80,113	82,756	82,756	23,222	22,451	21,202	22,450	22,450	105,207

The sample is a panel at the RMBS-insurer-year level sit from 2010 to 2015 (CMBS-insurer-year level from 2011 to 2015), that is, nonmaturing RMBS (CMBS) s held by insurer i (individual company level) in year $t-1$ and traded in year t after the regulatory reform. The sample is limited to MBS with nonzero expected loss and $-0.5 \leq \frac{BP_{sit-1}-IP_{st-1}}{BP_{sit-1}} \leq 0.5$. Furthermore, the sample is split into life (P&C) insurers in the first five columns (columns 6 to 10). The dependent variable is an indicator variable for whether insurer i sold a nonzero fraction of MBS s in year t. RBC_{sit-1} is equal to the risk-based charge (from 0.003 to 0.3) of security s incurred by insurer i in year-end $t-1$. *Threshold to NAIC-X*$_{sit-1}$ equals 1 whenever $\frac{BP_{sit-1}-IP_{st-1}}{BP_{sit-1}}$ is equal to or exceeds the cutoff for the category NAIC-X (where X ranges from 2 to 6, see Table 1). The linear spline is equal to $\frac{BP_{sit-1}-IP_{st-1}}{BP_{sit-1}}$. BP_{sit-1} and IP_{st-1} are short-hand notations for book price ($=\frac{BV_{sit-1}}{PV_{sit-1}}$) and intrinsic price (based on *ELOSS*), and MP_{st-1} refers to the market price. *Mark-to-market*$_{sit-1}$ is an indicator variable for whether security s's book price on insurer i's book deviates from its market price in year $t-1$ by less than 0.005 (in any direction), that is, $|BP_{sit-1}-MP_{st-1}|<0.005$. Rating-year fixed effects are determined by security s's rating in year-end $t-1$. All singletons are dropped from the total number of observations N. Robust standard errors (double-clustered at the security and insurer levels) are in parentheses.

In column 3, we include security fixed effects. As book prices tend to be persistent, and expected-loss assessments are time-invariant for 41% of the mortgage-backed securities in the regression sample, this forces the effects to be identified off variation across different cutoffs for different insurers holding the same security. This requirement is rather restrictive, and severely limits the number of securities being used for our estimation. Still, two coefficients remain statistically significant: life insurers' propensity to sell legacy MBS increases by 1.6 and 3.2 percentage points when the associated capital requirements increase from NAIC-2 to NAIC-3 and from NAIC-5 to NAIC-6, respectively.

Finally, in column 4, we reestimate the specification from column 2, but additionally include rating by year fixed effects. By holding constant—around each threshold—the rating in a given year, we control for any time-varying unobserved heterogeneity at the rating-class level, including the average credit spread or liquidity by rating. Furthermore, we also control for the difference between the book price and the market price. In line with insurers' gains trading (Ellul et al. 2015), the coefficient for the latter is negative and significant, while all other coefficients remain robust. Most importantly, our treatment effects are robust: the thresholds to NAIC-3 and NAIC-4 remain the important ones for life insurers' decision to sell MBS.

In contrast, the sensitivity of P&C insurers' selling behavior to capital requirements is weaker and most of the time insignificant. Across all specifications from column 6 to 9, their sensitivity appears to be concentrated on the NAIC-5 cutoff the crossing of which is associated with an economically significant increase in P&C insurers' selling probability of up to 7.6 percentage points.

These specifications allow the coefficient for each cutoff to differ, since the implied increase in capital requirements differs across the cutoffs. This approach is conservative but makes the economic interpretation more difficult, in particular given that the coefficients are estimated with different precisions. Now, to obtain a single, easily interpretable estimate of the sales elasticity with respect to capital requirements, we hypothesize that the sales probability is related to the absolute increase in capital requirements. In line with this, we replace the indicator variables for the different thresholds with the step function of actual capital requirements (see Figure 3), RBC_{sit-1}. Using the same set of controls and fixed effects as in columns 4 and 9, we find that a one-percentage-point increase in capital requirements causes an increase in the sales probability of 0.34 percentage points for life insurers and 0.25 percentage points for P&C insurers (see columns 5 and 10, respectively).

Hanley and Nikolova (2021) raise the potential concern that book value impairments might be endogenously chosen so as to reduce capital requirements. As this would run counter to one of the identifying assumptions, namely, that there is no endogenous sorting at the thresholds, we make sure that this concern does not drive our results. To this end, we consider how the results differ in the subsample for which insurers are required to mark to market.[36]

This subset exploits only quasi-random differences between market values and intrinsic values (see Figure 2). Thus, higher values of RBC_{sit-1}, that is, higher capital requirements, are driven entirely by instances in which $MP_{st-1} > IP_{st-1}$ whenever a security is marked to market, in which case we set $\textit{Mark-to-market}_{sit-1} = 1$. In column 11 of Table 10, we use the total sample of life and P&C insurers, and add an interaction term between RBC_{sit-1} and $\textit{Mark-to-market}_{sit-1}$, the coefficient for which is statistically insignificant. Most importantly, the coefficient is economically small. This implies that insurers' estimated response to capital requirements is virtually invariant even when we can rule out endogenous book values.

As the implementation of capital requirements following the regulatory reform is an RD setting with cumulative multiple cutoffs, we can further refine our cutoff-specific regression discontinuity treatment effects by employing local polynomial estimation and robust bias-corrected inference procedures (Cattaneo et al. 2016, 2020). While in Table 10, each observation above the NAIC-2 cutoff and below the NAIC-6 cutoff is used to estimate two different treatment effects, we can now choose the bandwidth to be nonoverlapping, which ensures that observations are used only once. For this purpose, we trim the sample a bit more, such that $0 \leq \frac{BP_{sit-1} - IP_{st-1}}{BP_{sit-1}} \leq 0.3$, so as to yield a balanced number of observations on both sides of each cutoff.

The regression discontinuity plots are presented in Figure 8, separately for life (top panel) and P&C insurers (bottom panel). To match our baseline specification in Table 10 (columns 2 and 4 for life, and columns 7 and 9 for P&C), we use as dependent variable the residual from the regression of $Sold_{sit}$ on insurer-year fixed effects, estimated on the same samples as in Table 10. As can be seen by comparing the averages on both sides of each cutoff (indicated as straight lines, i.e., zero-order polynomials), we find positive treatment effects on life insurers' propensity to sell MBS when capital requirements increase from NAIC-1 to NAIC-2, from NAIC-2 to NAIC-3, from NAIC-3 to NAIC-4, and from NAIC-5 to NAIC-6. This matches our regression results for life insurers in the first four columns of Table 10. Similarly, for P&C insurers, only crossing the NAIC-5 threshold is associated with an increase in P&C insurers' selling probability (see columns 6 to 9 of Table 10).

In summary, we have presented evidence that capital requirements matter in a causal way for insurance companies' selling of (mortgage-backed) securities. It is worth emphasizing that this result holds despite of the low level of liquidity

[36] Since marking-to-market is not directly observed, we use two definitions, both of which yield virtually the same results. First, in our benchmark definition employed in Table 10, we follow Ellul et al. (2015) by defining marking-to-market as fair value = book value. In our implementation, we allow for some small measurement error by labeling a security as marked to market whenever $|BP_{sit-1} - MP_{st-1}| < 0.005$. Alternatively, we label a security as marked to market if it has a strict "Unrealized Valuation Decrease" in a given year (as reported in Schedule D Part 1). Results are available on request.

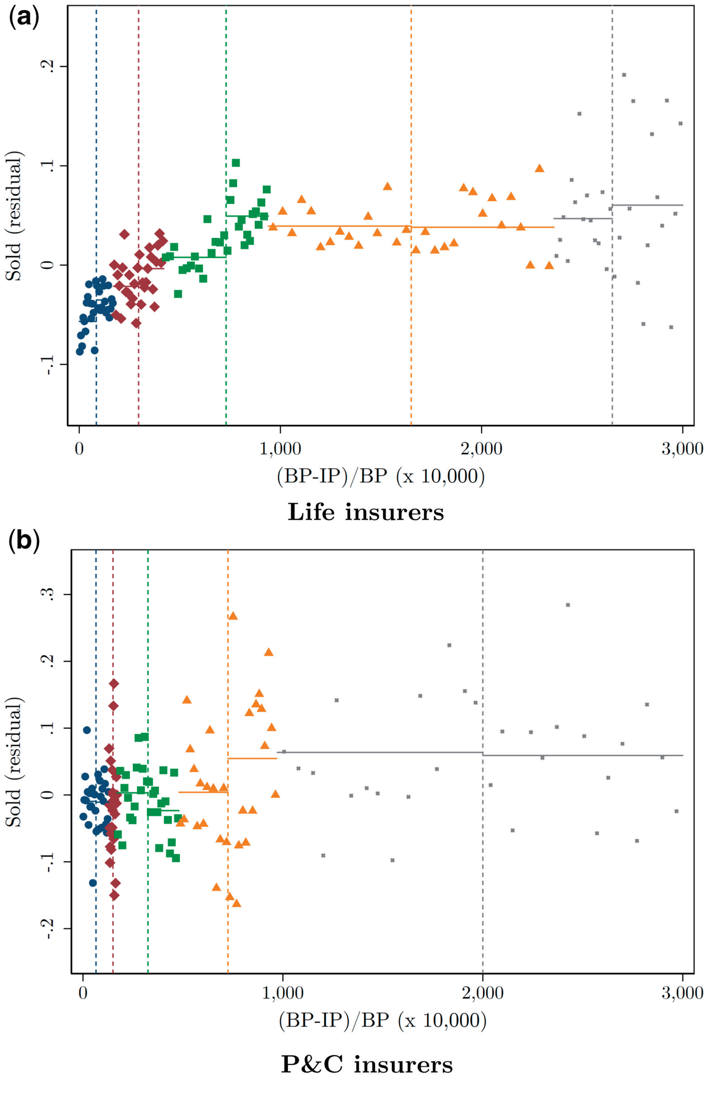

Figure 8
RD estimates using five cutoffs for life and P&C insurers
The graphs present cutoff-specific regression discontinuity treatment effects based on local polynomial methods (Cattaneo et al. 2016, 2020). The dependent variable is the residual from the regression of $Sold_{sit}$, which is an indicator variable for whether insurer i sold a nonzero fraction of security s in year t, on insurer-year fixed effects on the sample at the RMBS-insurer-year level sit from 2010 to 2015 (CMBS-insurer-year level from 2011 to 2015), that is, nonmaturing RMBS (CMBS) s held by insurer i (individual company level) in year $t-1$ and traded in year t after the regulatory reform. The sample is furthermore limited to MBS with nonzero expected loss. The estimates are plotted using 15 bins below and above each of the five cutoffs (see Table 1) separately for life (top panel) and P&C insurers (bottom panel). The running variable is $\frac{BP_{sit-1}-IP_{st-1}}{BP_{sit-1}} \in [0, 0.3]$.

for this asset class. This evidence, thus, lends support to the idea that insurers' propensity to sell downgraded MBS (see Table 6) has indeed decreased due to the regulatory reform.

5. Concluding Remarks

The U.S. insurance industry provides a unique setting for analyzing the effects of capital requirements for an important institutional investor with over $3.6tn in total assets. By putting many institutional details together, we uncover that a capital requirement reform aimed at "replacing flawed credit ratings" for mortgage-backed securities goes far beyond its stated purpose by essentially removing capital requirements for this asset class altogether.

One interpretation is that the reform reflects industry interests rather than the long-term goal of financial stability. Alternatively, the rules could reflect the short-term desire to avoid defaults and fire sales, which can be considered an improvised macroprudential regulation. However, these potential benefits need to be balanced against the associated long-run costs. In this paper, we have characterized risk-taking by insurance companies in the market for MBS as a potential building block of such long-run costs. Interestingly, while the new reform affects all insurers, our evidence suggests that life insurers and more financially constrained insurers are most prone to reacting to the reform. This cross-sectional evidence is consistent with the risk-taking channel, as standard theories predict that more constrained companies put more weight on short-term risk-taking benefits relative to the long-run charter value.

Was the reform good or bad in net terms? To answer this question, it is useful to keep in mind the very purpose of capital requirements. The textbook role of capital requirements is to ensure financial institutions' solvency to withstand bad tail realizations (unexpected losses). Thus, whether insurers' capital buffers—be they driven by regulatory requirements or self-interest—are sufficient can be judged only when these tail realizations occur. However, since the reform was instituted in 2009, the U.S. economy strongly rebounded from the Great Recession, and so did the values of insurers' MBS positions. During the period between 2010 and 2019, holding on to risky MBS (or any other risky asset) turned out to be an ex post profitable position. But the possibility of severe disruptions suggests that this does not mean it was a gamble worth taking ex ante.

Future research on this reform may examine other outcomes, such as spillover effects on prices and the real economy. In a world in which financial intermediaries, such as insurance companies, are marginal investors (see, e.g., He and Krishnamurthy 2013; Koijen and Yogo 2019) and the shadow cost of regulatory capital is positive, we should observe feedback effects of the regulatory regime on equilibrium prices.[37] These equilibrium prices, in turn,

[37] See Harris, Opp, and Opp (2021) for an asset pricing condition that relates expected returns to regulatory risk classifications.

should affect issuers' incentives to place securities in the primary market and, ultimately, affect real investment in the economy. While this type of analysis is beyond the scope of this paper, it would be interesting to analyze these important effects in future work.

Appendix A. Capital Requirements for U.S. Insurers

For all insurer types (life, P&C, and health), overall risk-based capital requirements are a function of the risk sources, R_s, that an insurer faces on the asset as well as on the liability (underwriting) side:

$$\text{Risk-based capital requirement} = R_0 + \sqrt{\sum_{i=1}^{5} R_i^2}. \tag{A1}$$

For example, for a P&C insurer, R_0 to R_2 represent asset risks (from affiliate companies, fixed income, and equities, respectively), whereas categories R_3 to R_5 account for credit risk, reserving risk, and premium risk (see Table A1). The (square-root) formula suggests that this regulation implicitly assumes that the risk sources 1 to 5 have zero correlation.[38]

The capitalization of an insurer is measured at an annual level by the risk-based capital (RBC) ratio, which relates total adjusted surplus (roughly an insurer's book equity) to the overall risk-based capital requirement given by (A1):

$$\text{RBC ratio} = \frac{\text{Total adjusted surplus}}{\text{Risk-based capital requirement}}. \tag{A2}$$

The more severe the capital shortage based on the RBC ratio, the stronger is the regulatory intervention. It ranges from the regulator mandating changes from the company to the regulator taking over control. The five action levels are:

1. No Action, which means that a company's RBC ratio is at least 2.
2. Company Action Level, which means that the RBC ratio is at least 1.5 but less than 2.
3. Regulatory Action Level, which means that the RBC ratio is at least 1 but less than 1.5.
4. Authorized Control Level, which means that the RBC ratio is at least 0.7 but less than 1.
5. Mandatory Control Level, which means that the RBC ratio is less than 0.7.

Since the safety buffer to avoid regulatory action (RBC ratio of 2) is very low,[39] virtually all insurers exceed this minimum requirement in noncrisis times. Multiple studies (see, e.g., Merrill et al. 2014) suggest that the RBC ratio still matters, not just in crisis times. First, the RBC ratio is an input to credit ratings of insurance companies (which are used as a marketing tool to sell life-insurance policies to customers). Second, in a dynamic setting, capital requirements may matter even if the capital constraint does not bind in each period.

---

38 The term R_0 is outside of the square root to prohibit regulatory arbitrage via the legal structure of companies. Koijen and Yogo (2016b) show that captive reinsurance can be used to sidestep this.

39 To get a sense of the implicit safety buffer built into this regulation, consider a hypothetical insurer that only faces asset risks in the form of a stock portfolio (essentially acting as a mutual fund). The current regulation sets the capital requirement for stocks to 15% of the book value, that is, a \$100m stock portfolio would require a risk-based capital requirement of \$15m, translating into a \$30m minimum equity requirement to avoid regulatory interventions. Thus, the risk buffer for the relevant annual observation horizon is roughly equal to twice the annual stock market volatility of 15% (see Campbell et al. 2001).

Table A1
Overall risk components for life, P&C, and health insurers

	Life	P&C	Health
R_0	- Affiliate investment - Off-balance sheet risk - Business risk I	-Affiliate investment - Off-balance sheet risk	- Affiliate investment - Off-balance sheet risk
R_1	- Invested asset risk - Interest rate risk - Reinsurance risk	- Fixed-income asset risk	- Invested asset risk
R_2	- Equity asset risk	- Equity asset risk	- n/a
R_3	- Insurance risk	- Credit risk - 50% reinsurance risk	- Insurance risk
R_4	- Health provider credit risk	- Loss reserve risk - 50% reinsurance risk	- Credit risk
R_5	- Business risk II	- Premium risk - Growth risk	- Business risk

Appendix B. Marking-to-Market Rules

We provide a quick overview of marking-to-market rules (for details, see Merrill et al. 2014, who use the difference in accounting rules of life and P&C insurers for their identification strategy). A bond's book value is given by either its amortized cost (typically at par) or its market value.

Previous system. Life insurers have to mark to market if a bond is rated NAIC-6, that is, if its rating is "D" (see Table 1). P&C insurers have to mark to market if a bond is considered NAIC-3 or worse.

New system. The accounting treatment of MBS now depends on the intrinsic price. If the amortized cost per unit of par (AC) of a bond is sufficiently above the intrinsic price (IP), then the bond has to be marked to market, and can no longer be held at AC. The cutoffs for marking-to-market differ for life and P&C insurers. For life insurers, the cutoff is the NAIC 5–6 threshold, that is, if IP is 26.5% below AC. For P&C insurers, the cutoff is the NAIC 2–3 threshold, that is, if IP is 1.5% below AC. Once a bond is marked to market, so that $BP = MP$, the capital charge typically becomes NAIC-1, since the market price is below IP for most bonds (see Figure 2).

Appendix C. Bias of ELOSS

The market price of any bond (as percentage of par) should equal the present value (PV) of (expected) principal and coupon payments:

$$MP = PV(\text{Principal}) + PV(\text{Coupon}) \tag{C1}$$

$$= 1 - R_F - ELOSS_M + PV(\text{Coupon}). \tag{C2}$$

The portion of the value associated with principal repayments can be expressed as the difference of a risk-free zero coupon bond (with associated market price $1 - R_F$) and the expected discounted loss of principal, $ELOSS_M$. In contrast to *ELOSS*, the "true" market value of losses, $ELOSS_M$, is computed by discounting losses in each state of the world with the appropriate stochastic discount rate rather than the coupon rate. Now, using the definition of $IP := 1 - ELOSS$ and (C2), we obtain the following decomposition of IP:

$$IP = MP + ELOSS_M - ELOSS + R_F - PV(\text{Coupon}). \tag{C3}$$

We will now argue that $IP > MP$ for the typical security since $R_F \approx PV$(Coupon) and $ELOSS_M > ELOSS$. The first argument is empirical. Coupons are typically modest on structured securities (riskier tranches are often issued below par (low coupons) to avoid large cash flows to these tranches before senior claims have been paid). Thus, PV(Coupon) is likely of similar magnitude as R_F. Second, asset pricing theory suggests that $ELOSS_M > ELOSS$. The present-value calculation of *ELOSS* performed by PIMCO/BlackRock uses the coupon rate as the discount rate. In contrast, the market assessment, $ELOSS_M$, should depend on state-contingent prices. To make concrete predictions, we make the following (empirically supported) assumption.

Assumption 1. The typical risky structured security pays a coupon c that is greater than the risk-free rate, and has higher losses in bad aggregate states (high marginal utility).

Proposition 1. If Assumption 1 holds, then $ELOSS_M > ELOSS$.

Proof. Assume there exists a unique stochastic discount factor $\tilde{m}$ and let $\tilde{L}$ denote the stochastic realization of the loss of principal, then

$$ELOSS_M = \mathbb{E}\left[\tilde{m}\tilde{L}\right] = Cov\left(\tilde{m}, \tilde{L}\right) + \mathbb{E}[\tilde{m}]\mathbb{E}_M\left[\tilde{L}\right].$$

Moreover, let r_F denote the risk-free rate, which satisfies $1 + r_F = \frac{1}{\mathbb{E}_M[\tilde{m}]}$. Since losses are expected to be high in bad aggregate states (high marginal utility), $Cov_M\left(\tilde{m}, \tilde{L}\right) > 0$ (see Cochrane 2009). Thus,

$$ELOSS_M > \frac{\mathbb{E}\left[\tilde{L}\right]}{1 + r_F}.$$

Finally, since it is empirically true that (almost all) bonds have a coupon rate c that is greater than the risk-free rate, we obtain that

$$ELOSS_M > \frac{\mathbb{E}\left[\tilde{L}\right]}{1 + r_F} > \frac{\mathbb{E}\left[\tilde{L}\right]}{1 + c} = ELOSS.$$

■

Appendix D. Classification of Sales

To classify an active sale in NAIC Schedule D Part 4, we rely on information from two fields, that is, "*name of purchaser*" and "*realized gain (loss) on disposal*." First, we require that the *name of purchaser* do not contain information that precludes active trading. Based on inspection of the most common field entries, we create the following four broad categories, and list examples of relevant keywords after. (The full list of keywords, alongside Stata code, can be obtained from the authors on request.)

1. **(Scheduled) maturity of security:** "matured,""maturity"
2. **Partial prepayment:** "redemption,""principal paid,""paydown,""called at 100,""amortization"
3. **Default:** "write-off,""tranche loss,""principal loss"
4. **Other:** "conversion to equity,""security reclassification,""exchange"

In addition, we require that active sales imply either a strictly positive or a strictly negative value for "realized gain (loss) on disposal." The rationale underlying this restriction is that transactions in secondary markets will unlikely take place exactly at book values and, thus, generate either realized gains or losses. The data indicate that scheduled prepayments (almost) always lead to exactly zero gains or losses. As such, this restriction does not bind in the case in which the information from the field "name of purchaser" is sufficiently precise. However, it does have a bite and is helpful when the field "name of purchaser" is empty or is generic, for example, "various."

References

Almeida, H., and T. Philippon. 2007. The Risk-Adjusted Cost of Financial Distress. *Journal of Finance* 62:2557–2586.

Baghai, R. P., and B. Becker. 2018. Non-rating revenue and conflicts of interest. *Journal of Financial Economics* 127:94–112.

Becker, B., and V. Ivashina. 2015. Reaching for yield in the bond market. *Journal of Finance* 70:1863–1902.

Becker, B., and T. Milbourn. 2011. How did increased competition affect credit ratings? *Journal of Financial Economics* 101:493–514.

Becker, B., and M. M. Opp. 2013. Regulatory reform and risk-taking: Replacing ratings. Working Paper 19257, National Bureau of Economic Research.

Behn, M., R. Haselmann, and V. Vig. 2021. The limits of model-based regulation. *Journal of Finance* Forthcoming.

Benmelech, E., and J. Dlugosz. 2009a. The credit rating crisis. *NBER Macroeconomics Annual* 24:161–208.

Benmelech, E., and J. Dlugosz. 2009b. The alchemy of CDO credit ratings. *Journal of Monetary Economics* 56:617–634.

Bolton, P., X. Freixas, and J. Shapiro. 2012. The credit ratings game. *Journal of Finance* 67:85–111.

Brunnermeier, M. K., A. Crockett, C. Goodhart, A. Persaud, and H. Shin. 2009. *The fundamental principles of financial regulation*. Geneva, London: International Center for Monetary and Banking Studies Centre for Economic Policy Research.

Campbell, J. Y., M. Lettau, B. G. Malkiel, and X. Yexiao. 2001. Have Individual Stocks Become More Volatile? An Empirical Exploration of Idiosyncratic Risk. *Journal of Finance* 56:1–43.

Cattaneo, M., L. Keele, R. Titiunik, and G. Vazquez-Bare. 2016. Interpreting regression discontinuity designs with multiple cutoffs. *Journal of Politics* 78:1229–1248.

Cattaneo, M., L. Keele, R. Titiunik, and G. Vazquez-Bare. 2020. Extrapolating treatment effects in multi-cutoff regression discontinuity designs. *Journal of the American Statistical Association* Forthcoming.

Chen, B. S., S. G. Hanson, and J. C. Stein. 2017. The decline of big-bank lending to small business: Dynamic impacts on local credit and labor markets. Working Paper 23843, National Bureau of Economic Research.

Chodorow-Reich, G., A. Ghent, and V. Haddad. 2020. Asset Insulators. *Review of Financial Studies* 34:1509–1539.

Cochrane, J. H. 2009. *Asset Pricing (Revised Edition)*. Princeton University Press.

Ellul, A., J. Chotibhak, C. T. Lundblad, and W. Yihui. 2015. Is Historical Cost Accounting a Panacea? Market Stress, Incentive Distortions, and Gains Trading. *Journal of Finance* 70:2489–2538.

Ellul, A., C. Jotikasthira, A. V. Kartasheva, C. T. Lundblad, and W. Wagner. 2018. Insurers as asset managers and systemic risk. *Kelley School of Business Research Paper* pp. 18–18.

Ellul, A., C. Jotikasthira, and C. T. Lundblad. 2011. Regulatory pressure and fire sales in the corporate bond market. *Journal of Financial Economics* 101:596–620.

Ellul, A., P. Jotikasthira, C. Lundblad, and Y.-H. Wang. 2014. Mark-to-Market Accounting and Systemic Risk in the Financial Sector. *Economic Policy* 29:299–341.

Froot, K. A., D. S. Scharfstein, and J. C. Stein. 1993. Risk Management: Coordinating Corporate Investment and Financing Policies. *Journal of Finance* 48:1629–1658.

Greenwood, R., and D. S. Scharfstein. 2013. The Growth of Finance. *Journal of Economic Perspectives* 27:3–28.

Griffin, J. M., and D. Y. Tang. 2012. Did subjectivity play a role in CDO credit ratings? *Journal of Finance* 67:1293–1328.

Gropp, R., T. Mosk, S. Ongena, and C. Wix. 2019. Banks' response to higher capital requirements: Evidence from a quasi-natural experiment. *Review of Financial Studies* 32:266–299.

Hanley, K. W., and S. Nikolova. 2021. Rethinking the Use of Credit Ratings in Capital Regulations: Evidence From the Insurance Industry. *Review of Corporate Finance Studies* 10:347–401.

Harris, M., C. C. Opp, and M. M. Opp. 2021. Bank capital and the composition of credit. Working paper, Stockholm School of Economics.

He, J. J., J. Q. Qian, and P. E. Strahan. 2012. Are all ratings created equal? The impact of issuer size on the pricing of mortgage-backed securities. *Journal of Finance* 67:2097–2137.

He, Z., and A. Krishnamurthy. 2013. Intermediary Asset Pricing. *American Economic Review* 103:732–770.

Koijen, R., and M. Yogo. 2018. The Fragility of Market Risk Insurance. Working Paper 24182, National Bureau of Economic Research.

Koijen, R. S. J., and M. Yogo. 2015. The cost of financial frictions for life insurers. *American Economic Review* 105:445–475.

Koijen, R. S. J., and M. Yogo. 2016a. Risks of Life Insurers: Recent Trends and Transmission Mechanisms. In R. S. K. Felix Hufeld and C. Thimann (eds.), *The Economics, Regulation, and Systemic Risk of Insurance Markets*, chap. 4. Oxford: Oxford University Press.

Koijen, R. S. J., and M. Yogo. 2016b. Shadow Insurance. *Econometrica* 84:1265–1287.

Koijen, R. S. J., and M. Yogo. 2019. A Demand System Approach to Asset Pricing. *Journal of Political Economy* 127:1475–1515.

Kroszner, R. S., and P. E. Strahan. 1999. What Drives Deregulation? Economics and Politics of the Relaxation of Bank Branching Restrictions. *Quarterly Journal of Economics* 114:1437–1467.

Mas-Colell, A., M. D. Whinston, and J. R. Green. 1995. *Microeconomic Theory*. New York: Oxford University Press.

Merrill, C. B., T. Nadauld, R. M. Stulz, and S. M. Sherlund. 2014. Were there fire sales in the RMBS market? Working paper, Ohio State University.

NAIC. 2021. Structured Securities Project. https://content.naic.org/cipr_topics/topic_structured_securities_project.htm. Accessed August 12, 2021.

Olson, M. 1965. *The fundamental principles of financial regulation*. Cambridge, MA: Harvard University Press.

Opp, C. C., M. M. Opp, and M. Harris. 2013. Rating Agencies in the Face of Regulation. *Journal of Financial Economics* 108:46–61.

Peltzman, S. 1976. Toward a More General Theory of Regulation. *Journal of Law & Economics* 19:211–240.

Shleifer, A., and R. W. Vishny. 1992. Liquidation values and debt capacity: A market equilibrium approach. *Journal of Finance* 47:1343–1366.

Stigler, G. J. 1971. The Theory of Economic Regulation. *Bell Journal of Economics and Management Science* 2:3–21.