

Informational Efficiency in Securitization

After Dodd-Frank*

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Abstract

We analyze how Dodd-Frank mandated risk retention affects the information investors extract from issuers' retention choices in the CMBS market. We show that the required retention level is both binding and stringent. Although this implies issuers cannot signal using the level of retention, we provide a model showing that signaling can occur by varying retention *structure*. The model is consistent with spreads being empirically lower in deals with a purely first-loss retention structure. A stated concern of rulemakers was asymmetric information. However, we show that, post-crisis, the level of asymmetric information in this market is quite low.

JEL: G14, G18, G21, G28.

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1 Introduction

The Dodd-Frank Act mandated sweeping changes to asset-backed securities (ABS), including virtually all types of mortgage-backed securities. These changes affect ABS issuers' cost of capital, and thus the rates consumers and businesses have to pay on their loans, and yet little is known about the effect of the new rules.¹ One of the most important changes under Dodd-Frank is a new “risk retention” requirement that stipulates ABS issuers must retain at least 5% of the fair market value of the deals they issue. While the exact rationale for 5% is unclear, many commentators have argued that security issuers having too little “skin in the game” in mortgage-backed securities was part of the reason for the financial crisis that began in fall 2007. For example, in October 2014, then SEC Commissioner Luis Aguilar stated that “credit risk retention rules...are intended to address a glaring flaw of the asset-backed securities (ABS) market revealed by the financial crisis: the misalignment of interests between the ABS securitizer and the ABS investor” (Aguilar (2014)). Two assumptions underlying the regulation may have been that 1) ABS investors are not sophisticated enough to understand issuers incentives and 2) that there is substantial asymmetric information in this market. Indeed, the rulemaking on risk retention discusses asymmetric information at length several times (see Department of the Treasury et al. (2014)).

We study the effect of such skin-in-the-game regulations theoretically and empirically by focusing on the implementation of the Dodd-Frank rule in the \$543 billion commercial mortgage-backed securities (CMBS) market.² This rule came into effect for the CMBS market on December 24, 2016, thus we focus on the CMBS market since January 2017.

We show that the 5% requirement is both binding and stringent. We manually inspect deal documents for 2017-2018 deals and find that the risk retention requirement is binding in all cases in which we can obtain the data: issuers never choose materially more than 5%. The 5% minimum is well above what most investors might reasonably expect losses to be

¹The inter-agency rulemaking on risk retention discusses several ways the rule may affect the quantity and cost of credit; see Department of the Treasury et al. (2014).

²SIFMA reports that the outstanding stock of CMBS stood at \$543 billion as of 2018Q4.

based on historical experience.

In addition to being stringent in light of historical performance, we show the new minimum requirement is likely to be stringent for deals originated after the regulation went into force, because CMBS *collateral* for 2017-2018 deals is less risky based on observable characteristics than collateral in pre-regulation vintages, particularly vintages immediately prior to the 2008 crisis.

Given that issuers all choose the legal minimum, the market can no longer use the *level* of retention to extract information about quality. We thus examine how issuers instead choose the *structure* of retention as a signal of quality. The new rule allows CMBS issuers to choose between three forms of risk retention to satisfy the 5% level: “horizontal”, “vertical”, and a combination of the two (“hybrid”). In the horizontal structure, issuers take a purely first-loss exposure: they retain a set of subordinate securities that will absorb the first 5% of losses on the collateral pool. The horizontal structure is analogous to retaining the deal’s “B-piece.”³ In the vertical structure, issuers retain 5% of every security in the deal, thus they are exposed to the performance of a combination of first-loss and senior securities.

Using hand-collected data on yield spreads at issue, we find that securities from deals with horizontal retention sell at lower spreads. The relation is economically significant: horizontal retention is associated with a 7 to 10 basis point reduction in spreads relative to vertical or hybrid retention. Since the average spread on our securities is approximately 130 basis points, this corresponds to about 6% of the spread. Moreover, the pricing impact is driven by lower-rated investment grade tranches, consistent with such tranches being more information sensitive than *AAA* tranches. Bonds rated *BBB* are priced at spreads between 0.60% and 1% lower in horizontal deals (about 27% of the average spread on *BBB* securities), and the effects for all non-*AAA* bonds (*BBB* to *AA*) are similar.

Overall, our empirical results indicate that issuers can sell securities at higher prices when they choose a purely first-loss structure as opposed to retaining a portion of every security

³In practice issuers sell the horizontal piece to a qualified buyer at a significant discount to par value. We discuss the role of the B-piece buyer in the next section.

in the capital stack. We show that these results are consistent with a model of securitization based on asymmetric information that includes some of the same basic assumptions as DeMarzo and Duffie (1999). The key difference is that, in our model, the issuer makes the security design decision (vertical or horizontal retention) *after* it learns private information about the underlying asset. As a result, the security design choice is a signal of the issuer’s private information. In contrast, the security design decision in DeMarzo and Duffie (1999) is made *ex-ante* — the security is chosen prior to the issuer learning the value of the asset. Thus, the choice of security type cannot convey any private information in their setting, and signaling instead happens through the *quantity* of the security the issuer retains after learning private information.

Our empirical estimates allow us to calibrate the model and thus quantify the amount of asymmetric information in this market. Based on our benchmark estimate of a difference in spreads of 7.7 basis points between deals with vertical and horizontal risk retention, the calibration implies that only 1 percent of the cash flows in a CMBS deal are subject to asymmetric information between issuers and investors.

Our paper is the first to study the impact of retention on security pricing following the implementation of the Dodd-Frank Act rules. Although Agarwal et al. (2019) and Furfine (Forthcoming) provide empirical evidence on how the Dodd-Frank Act changed the pricing and allocation of capital in the CMBS market, showing that the requirements have important real effects, they do not consider the signaling implications of retention structure. Our finding regarding the low level of asymmetric information in this market suggests that there may not be a need to protect naïve security investors from unscrupulous ABS issuers.

By showing that issuers can effectively signal quality despite a binding level of retention, we also add to the literature on optimal risk retention. Hartman-Glaser et al. (2012) show that a first loss piece closely replicates the optimal contract if issuers can take a costly action to improve the quality of collateral at issuance. In contrast, Pagès (2013) studies effort provision by issuers in which they engage in costly actions to monitor the quality of

the collateral on an ongoing basis. In that setting, they find that a cash reserve account, rather than a first loss piece, is the optimal private contract. For CMBS, it is special servicers, rather than issuers, that take actions after issuance to affect loss given default.

We also add more broadly to the literature on signaling models, including Leland and Pyle (1977), DeMarzo and Duffie (1999), and DeMarzo (2005). Begley and Purnanandam (2017) find empirical support for these models in the RMBS market pre-crisis insofar as they find that deals with larger equity tranches experienced lower delinquency rates. While the results in Begley and Purnanandam (2017) suggest that investors were already aware of the potential moral hazard and retained equity to overcome the problem, Ashcraft et al. (Forthcoming) show that issuers were able to confuse investors in the CMBS market by selling the equity piece into Collateralized Debt Obligations (CDOs). Our results suggest that, post-crisis, investors are quite sophisticated and that there is relatively little asymmetric information in the ABS market.

The remainder of the paper proceeds as follows. We provide details on the Dodd-Frank Act risk retention rules and the data we use in Section 2. In Section 3, we provide historical context and conduct an empirical analysis of the stringency of the rules. In Section 4 we develop a simple model that generates predictions for the relation between security pricing and issuers' risk retention choice. Section 5 presents evidence from CMBS yield spreads at issue consistent with the predictions of the model. We discuss some policy implications of our analysis in Section 6 and provide concluding remarks in Section 7.

2 Institutional Detail and Data

2.1 Institutional Detail

Risk retention rules for CMBS under the Dodd-Frank Act are part of a wider set of requirements for risk retention.⁴ In ABS, the justification for the requirement is “to align the incentives of sponsors and ABS investors by requiring sponsors to retain a financial interest and maintain skin in the game” (Aguilar (2014)). Prior to the crisis, it was common for issuers/sponsors to avoid skin in the game by selling the “B-piece” into a CDO.⁵ Ashcraft et al. (Forthcoming) document this practice and offer evidence that suggests that the senior tranches in deals for which the B-piece was sold performed worse, on average, than senior securities in other deals. Their evidence therefore suggests that retaining skin in the game may be linked to the ex-post performance of senior securities.

For the CMBS market, the final rule came into effect December 24, 2016. It stipulates that an issuer must retain an interest in each CMBS deal equivalent to 5% of market value at the time the securities in the deal are sold. It is unclear how legislators decided on 5% as the threshold, and the text of the final rule provides no explicit justification. However, the requirement can be satisfied in multiple ways, and in practice we observe three primary methods. First, the issuer itself can retain a piece of every security in the capital structure such that the total amount retained is equal to 5% of market value. This is referred to as retaining an “Eligible Vertical Interest,” or the “vertical” option. Second, the issuer can retain a 5% interest in the deal in the form of first-loss, subordinate tranches (“Eligible Horizontal Residual Interest,” or the “horizontal” option).⁶ Finally, in the “hybrid” or “L-shaped” option, the issuer can retain a combination of vertical and horizontal interest such that the total interest achieves the 5% level. Figure 1 displays these three retention methods

⁴Gupta and Sachdeva (2018) studies the effects of the Dodd-Frank Act’s mandated disclosure of equity stakes in hedge funds.

⁵The B-piece refers to one or more of the most junior securities in the capital stack.

⁶The horizontal retention can also be achieved by depositing the equivalent of 5% of the market value of the deal in a cash reserve account. We only observe this for one deal for which we have final prospectus documents.

visually.

A key aspect of the horizontal option is that the rule allows the issuer to sell the subordinate securities (the B-piece) to a third party, or, at most, two third parties each with a pari-passu portion. The third party must then hold the security for a minimum of 5 years. In practice, issuers that choose the horizontal option always sell the security such that the ultimate owner of the B-piece (the horizontal interest) is a party that is unaffiliated with the transaction. This contrasts with the vertical and hybrid structures, because the retention requirement in these options is at least partially satisfied by one or more of the issuers directly affiliated with the transaction.

The B-piece buyer in a CMBS transaction serves a somewhat different role than the buyer of the first-loss pieces in a residential MBS transaction. The B-piece buyer has the ability to appoint and change the special servicer, which, due to the complexity and size of commercial real estate loans, plays a larger role in CMBS than in RMBS.⁷ Moreover, in a CMBS transaction, the B-piece buyer is often identified first, prior to the structurer identifying potential buyers for the senior securities. The B-piece buyer then has a significant role in choosing the collateral and structuring the deal itself. For example, the B-piece buyer can request that certain loans be removed (“kicked out”) from the collateral pool. Consistent with the B-piece buyer being involved early in the structuring process, the price of the B-piece is typically agreed upon prior to the pricing of senior tranches.

B-piece buyers are thus generally considered to have the same information as the issuer about the collateral and more information than investors in the senior tranches. Therefore, even though the residual interest is sold to a third party in the horizontal retention option, because the sale price of the B-piece reflects ex-ante expectations about collateral performance and expected losses, the issuer is still exposed to the expected performance of the B-piece at the time of the transaction.

To illustrate differences between retention types more clearly, consider the horizontal

⁷See Liu and Quan (2013) and Wong (2018) for discussions of special servicers in CMBS.

conduit deal UBSCM 2017-C3. The lead deal sponsors and managers include UBS, Societe General, and Natixis. Deal documents list the fair value of the horizontal residual interest tranches at 5.23% of the fair value of the entire deal. The documents further indicate that KKR Real Estate Credit Opportunity Partners, a party unaffiliated with the origination of the underlying collateral, will act as “third party purchaser that will acquire an eligible horizontal residual interest.”

In contrast, the conduit deal BANK 2017-BNK4 features a vertical residual interest designed to satisfy the retention requirement. Deal documents stipulate that the vertical interest of 5% will be jointly retained by the deal’s three lead managers, Wells Fargo, Bank of America, and Morgan Stanley, all of which are affiliated with the transaction in that they originated portions of the underlying collateral.

2.2 Data

We observe retention data for 206 conduit and large loan/single-borrower⁸ U.S. CMBS deals issued between January 1, 2017, and September 30, 2018. Given that the Dodd-Frank risk retention rules took effect at the end of December 2016, this constitutes the majority of CMBS issued since the rule came into place. Our primary sources of data are CRE Direct, Trepp, and Bloomberg. From CRE Direct we gather information on the type of risk retention, the par value of the retained interest, and other deal-level characteristics. We gather security-level characteristics from Trepp and Bloomberg.

Table 1 provides variable definitions and Table 2 provides summary statistics for the securities in our estimation sample. We exclude interest-only (IO) tranches from our summary statistics and estimation. We have a total of 82 conduit and 124 large loan/single-borrower deals. The average security in our sample is in a deal of \$730 million in size with 13 tranches. Because conduit deals typically include more tranches than large loan/single-borrower deals,

⁸Large loan deals contain multiple loans, whereas single-borrower (SASB) deals contain a single loan issued to a single borrower. Although the two deal types are technically different from one another, we combine the two together in our analysis.

57% of the securities in our sample are from conduit deals. We have 98 horizontal deals, 89 vertical deals, and 19 deals structured with a combination of vertical and horizontal. The proportion of securities in deals structured with horizontal (*horizrr*) is 46%, and the proportion in vertical deals (*verticalrr*) is 39%.

A key aspect of our data is that it contains the size of the retained portion by par value. Table 2 shows that the average size of horizontal retention is 7.4% of par (*horsizeofpar*), whereas the average size of vertical retention is 4.4% of par (*vertsize*). For securities in horizontally structured deals, the average level of horizontal retention is 8.1% of par value (*horsize_hrr*) and the median is 9.7% of par value. In contrast, for securities in purely vertical deals, the average level of vertical retention is 5% of par (*vertsize_vrr*) with no standard deviation. This difference is consistent with the most subordinate securities in a deal (which typically comprise the horizontally-retained B-piece) pricing well below par, while the senior securities (which comprise the majority of a deal on a value-weighted basis) typically price very close to or above par. For deals structured with hybrid or “L” retention, the horizontal portion is 5.5% of par value (*horsize_hyrr*), nearly double the vertical portion of 2.9% (*vertsize_hyrr*).

Obtaining market pricing for the securities in our sample is difficult, thus the data for spreads at issue is limited. Rather than construct the spreads from issue yields and benchmarks, we observe the spreads directly. For rated securities, we gather spreads from Bloomberg and supplement whenever possible with hand-collected data from CRE Direct’s website. For the 1,207 securities for which we can obtain a spread, pricing is an average of 1.3% over the relevant benchmark.⁹

We gather the market values of the B-pieces by hand collecting the market values at a security level from the deal documents where available. Although our data only contains the size of retention by par value, we analyze final prospectus documents for each deal with horizontal retention. We collect these documents from Bloomberg and the SEC’s public

⁹The benchmarks are typically comparable-maturity swaps for fixed rate securities and 1-month LIBOR for floating rate securities.

EDGAR database. When these documents are available, the market value of the vertical or horizontal interest is typically listed. In some cases, the disclosed market value is based on actual sales prices and final tranche sizes, whereas in other cases it is approximated by the sponsor. In the latter cases, the prospectus typically states that the sponsor will disclose the fair value based on actual sales prices to bondholders at a “reasonable time after the Closing Date” (see Appendix Figure A.1). Based on conversations with practitioners, we believe that, in the latter cases, the estimated fair value listed in the prospectus is extremely close (or identical) to the actual fair value at the time the transaction takes place. Therefore, we do not distinguish between the two types of fair values in our analysis of the deal documents.¹⁰

3 Stringency of Mandated Retention Rules

We first document that the rules appear to be binding in all cases using the data described above. We then analyze how stringent the new rules are by inferring whether investors could reasonably expect losses in CMBS deals to exceed the mandated 5% level. We analyze historical losses and also compare the quality of collateral issued after the regulations were implemented with the quality of collateral issued immediately preceding the financial crisis.

3.1 Retention requirements always bind

If issuers in practice often retain significantly more than 5% of market value, then the requirement may not be stringent from the point of view of sponsors. Importantly, this

¹⁰The Appendix shows two examples of the market value data from the deal documents. In the first deal, CCUBS 2017-C1, Figure A.1 lists the actual market value (based on final transaction prices) for each of the securities in the horizontal piece is listed. Summing the percentages in the third column yields the fair value of the entire horizontal piece equal to 5%. Additionally, the fourth column in the table lists the fair value of the securities as a percentage of the par value, indicating that all horizontal securities priced at about 50% of par. In the second deal, GSMS 2017-GS8, Figure A.2 the issuer lists the approximate market value for the entire horizontal piece at 5.01% of total market value but does not break down the price of individual securities. Additionally, the issuer stipulates that “A reasonable time after the Closing Date, the sponsor will be required to disclose to, or cause to be disclosed to, Certificateholders the following: (a) the fair value of the HRR Certificates that will be retained by the Retaining Third-Party Purchaser based on actual sale prices and finalized tranche sizes...” which is consistent with the fact that the listed fair value is approximated.

would indicate that issuers are still able to signal quality by varying the level of retention. Although we cannot determine the precise reason for the 5% threshold mandated by Dodd-Frank, policymakers likely anticipated that it would be binding for large portions of the securitization market well prior to the implementation of the law. An IMF report from October 2009 suggests that “a 5 percent retention proposal would be binding for most, so careful consideration is needed before an across-the-board requirement is applied” (IMF (2009)).

Our analysis is consistent with the IMF’s views and suggests that, in fact, the threshold is *always* binding. We reach this conclusion by studying both horizontally and vertically structured deals. Table 3 details the amount of risk retention for every deal for which we can observe data.

In terms of vertical retention, we rely on the CRE Direct data to understand whether the retention requirements bind. For vertical deals, our data indicates that the *par value* of the retained portion is always exactly 5% (see Table 3 and also the summary stats for the variable *vertsize_vrr* in Table 2). This is consistent with the fact that, when we inspect available deal documents for vertical deals, the “Eligible Vertical Interest” retained by the sponsor is listed as 5%.

For horizontal deals, we rely exclusively on deal documents to obtain the market value of the horizontal piece, as this data is not available elsewhere. We examine all horizontally structured deals for which these documents are available, which constitutes 22 deals from 2017 and 2 deals from 2018. In all such deals, the fair value of the horizontal piece is between 4.99% and 5.22%.

For the deals for which the issuer structures both horizontal and vertical (so-called hybrid or “L” retention), we combine the CRE Direct data with data collected from deal documents to compute the level of retention. The CRE Direct data provides the value of the vertical portion and, when the deal documents are available, we can also observe the market value of the horizontal portion. We have 11 deals in 2017 and 2 deals in 2018 deals for which we can

observe both vertical and horizontal amounts. For these deals the total amount of retention ranges from 5% to 5.15%.

Our data clearly show that the retention levels are either exactly at 5% or exceed this minimum requirement by economically insignificant amount. The fact that some deals with horizontal and hybrid retentions slightly exceed 5% level is likely because of uncertainty about the market value of the CMBS issues. Making the B-tranche slightly larger ensures that the issuer is going to be in compliance with the regulation even when the CMBS sale price falls short of expectations.

3.2 Retention requirements in historical context

We next analyze how stringent the new rule is by examining whether *historical losses* in CMBS would dictate a threshold of 5%. For example, if losses only amounted to 4% of market value, on average, in the years prior to the implementation of the rule, we can infer that a 5% rule is likely to be stringent.

To assess the stringency of the 5% requirement, we focus on the deals with horizontal retention. We compare the 5% mandated size with (1) the average level of cumulative losses for deals issued from 2000-2016, and (2) the average size of the B-piece for deals issued from 2000-2016. We compute both cumulative losses and the size of the B-piece for 2000-2016 vintage deals using the Trepp data. Due to data limitations, we cannot observe the *market value* of losses or the market value of the B-piece during the 2000-2016 period, so we focus on the observable par values.

Although we conduct the analysis from 2000 to 2016, we are primarily interested in the 2000-2008/2009 period. This is because we wish to understand the relation between pre-crisis vintage CMBS losses and the size of the B-piece. This consideration leads us to restrict this part of the analysis to conduit deals only, although we include both conduit and large loan/single-borrower deals in the multivariate analysis in Section 5.

We exclude large loan/single-borrower deals from our analysis in this subsection due

to lack of necessary data from the time periods of interest. For the 2000-2008/2009 time period, we can only identify the B-piece for 32 large loan/single-borrower deals total, and there are multiple years in which we have 0 or 1 deals with an identifiable B-piece. In contrast, we observe B-pieces for 370 conduit deals during the same time period. Lack of data for the B-piece in the pre-2017 period of interest makes the statistics of interest unreliable. Additionally, the data for the post-regulation time period for large loan/single-borrower deals is even sparser. From January 2017 to September 2018, we can only find the market value of the B-piece for 5% of horizontal large loan/single-borrower deals, compared with 90% of horizontal conduit deals.

Our data from 2017 and 2018 CMBS issues indicate that, for securities in conduit deals that feature horizontal retention, the average size of the retention is nearly always 10% of par value. Because we find that the retention requirement binds in all cases where we can observe it, we can infer that 5% of fair value corresponds to 10% of par value, which is consistent with the securities in the horizontal piece pricing at about 50% of par. We confirm this by directly measuring the market value of the B-piece as a percentage of par value.

In some cases we do not have deal documents, and in these cases we cannot reliably back out the value of the B-piece based on the deal proceeds and market values of the senior non-IO securities. This is due to lack of data on the identity of the B-piece securities themselves (i.e., we do not know which of the subordinate securities constitutes the portion set aside for risk retention and thus cannot determine the subset of securities to back out), and/or the prices of the securities that are not senior but also not part of the B-piece (typically these are other residual or IO tranches). For the 19 conduit deals for which we can reliably determine the market value, the B-piece prices at between 48% and 53% of its par value. Although we cannot observe this for all deals in the 2017-2018 sample, this nevertheless supports the assertion that a B-piece equal to 10% of par value constitutes 5% of market value of the deal.

Historically, with the exception of deals issued in 2008, Panel A of Figure 2 shows cumu-

lative principal losses as of December 2017 across all vintage 2000-2016 conduit deals are *less* than 9% of the total original principal balance.¹¹ We note also that there were only 9 deals issued in 2008 while the average number of deals for all years prior to the Dodd-Frank risk retention rule is 74.¹² Thus, assuming that a correspondence of 5% market value to 10% par value held during the historical period, the 5% threshold would have been well in excess of what was necessary to protect senior bondholders in conduit deals from any principal losses.

Consistent with cumulative principal losses falling *below* a 5% market value threshold, the average size of the B-piece during the 2000-2016 vintage period was likely well below 5%. Although we cannot observe the market value of the B-piece from the data during this time period, assuming the values were not drastically different from those we observe during the 2017-2018 period, a par value less than about 10% would strongly suggest that it was less than 5% market value, given that the B-pieces from 2017-2018 price at roughly 50% of par. Panel B of Figure 2 shows that B-piece size for conduits was usually less than 5% *of par* value for 2000-2016 vintage deals. Figure 3 plots the distribution of the B-piece size and illustrates that the B-piece was more than 10% of par value in less than 1% of all conduit deals during 2000-2016.

Figure 4 overlays Panels A and B of Figure 2 onto one graph. It thus illustrates how likely losses would have been to wipe out the entire B-piece, on average. For 2000-2003 vintages, losses as of December 2017 have not yet approached the level of the B-piece at origination. For 2004-2008 vintages, the B-piece has certainly been wiped out. However, for the 2005-2008 vintages this would have been the case even if the B-piece were twice its size, on average.

More importantly, it is only for the 2008 vintage that cumulative losses as of December 2017 would likely have exceeded the 10% par/5% market value threshold. This is illustrated by the fact that the horizontal line at 10% of par value is only exceeded for that vintage.

¹¹Our cumulative loss numbers for conduit CMBS are slightly larger than the values in Ciochetti and Larsson (2017) because we measure losses as of December 2017, whereas they measure losses as of 2015.

¹²See Appendix B for deal counts by year and additional data details.

Thus, it appears that the 5% market value requirement is well above what most investors might reasonably expect losses to be in a deal. This is particularly true given that the characteristics of deals originated *after* the regulation was put in place (i.e., vintage year 2017 onward) are likely quite different from the characteristics of the 2006-2008 vintage. Although we do not yet have a sufficient time span to observe losses in any vintage after 2013, we conduct a loan-level counterfactual analysis to understand how 2017-2018 *loans* would have performed had they been originated and securitized in the 2006-2008 period. The goal of this analysis is to illustrate that 2017-2018 loans and, by extension, 2017-2018 deals, would *not* have incurred losses sufficient to breach the 5% threshold were they to have been originated and securitized in 2006-2008. Our counterfactual loss analysis indicates that, taking into account current collateral characteristics makes the risk retention requirements appear even more stringent. The results are in Appendix C.

In this section, we have documented that issuers always choose the minimum retention level. Because of this, they do not signal quality of their collateral through levels of retention. As a result, we do not observe the type of a signaling equilibrium described by Leland and Pyle (1977), DeMarzo and Duffie (1999), and DeMarzo (2005). The likely explanation for this outcome is that the retention requirements are too stringent in the sense that the size of horizontal retention is much higher than the expected losses on post Dodd-Frank deals. As a result, retaining more than the minimum amount does not send a meaningful signal to the market, since it does not translate into retaining more risk.

4 Issuer Choice with Mandated Risk Retention

In this section, we develop a simple model of securitization with mandated risk retention that is based on asymmetric information. Our model is consistent with the facts presented in Section 3. We show there is a partially separating equilibrium in which the issuer signals a high value CMBS deal by choosing horizontal retention. In the equilibrium, CMBS deals

with horizontal retention have higher market values than those with vertical retention.

The basic assumptions of our model are similar to those of DeMarzo and Duffie (1999), hereinafter referred to as DD. Specifically, the model's participants consist of a risk-neutral CMBS issuer and a set of risk-neutral outside investors. The issuer owns a pool of commercial mortgages that generates future cash flow given by a nonnegative random variable A with a probability distribution that has as its support an interval $[A_0, 1]$. For simplicity we assume that the issuer knows the exact value of A , while the outside investors know only the distribution.

We assume that the issuer has an incentive to sell the mortgage pool.¹³ In particular, we suppose that the issuer discounts future cash flows at a rate higher than the market rate. For notational convenience, we normalize the market discount factor to one. Then, there exists a discount factor $\delta \in (0, 1)$ that represents the fractional value to the issuer of unsold assets. This implies that one dollar worth of assets to the outside investors is worth only $\delta < 1$ to the issuer.

An important difference between our approach and that of DD is that in our setting the issuer chooses security design (vertical or horizontal retention) after it learns private information about the mortgage pool.¹⁴ As a result, the *risk retention type* is a signal of the issuer's private information. In contrast, in DD the security design decision is an ex-ante problem, i.e., the security is chosen before the issuer learns the value of its asset. As a result, the choice of security design cannot convey any private information in the DD setting. Instead, signaling in DD happens through the *quantity* of the security that the issuer decides to retain after learning private information.

For notational convenience, we normalize the total principal of the mortgage pool to 1, which is the highest possible value of A . This can be justified by assuming that all loans in the pool are zero coupon bonds, in which case their combined principal must be equal to

¹³The issuer may face credit constraints or binding minimum capital requirements, or may need cash for profitable investment opportunities.

¹⁴In practice, there are no requirements for CMBS issuers to commit to a certain retention choice prior to forming mortgage pools.

the highest possible cash flow generated by the pool. In reality, commercial mortgages pay interest above the risk-free rate. Accounting for these interest payments would not affect the insights generated by our model.

We model the mandated risk retention requirements by assuming that the issuer must retain either a fraction $v > 0$ of the entire pool, or the first-loss, subordinate tranche with a principal balance equal to fraction $h > 0$ of the entire pool. Because the principal of the entire pool is equal to one, v and h also represent the dollar amounts of the retained principal.

In the case of vertical retention, the payoff of the retained piece is given by vA , while the sold piece pays $(1 - v)A$. In the case of horizontal retention, if the value A of the mortgage pool is less than the principal $(1 - h)$ of the senior tranche, the investors in the senior tranche get the entire cash flow A , while the issuer gets nothing. However, when $A > (1 - h)$, the investors get their principal payment $(1 - h)$, while the issuer gets the residual value of the pool $A - (1 - h)$. Thus, with horizontal retention the investors will be paid $\min(A, 1 - h)$, while the issuer gets $\max(0, A - (1 - h))$.

The total payoffs to the issuer corresponding to the vertical and horizontal retention structures are given by

$$\begin{aligned}\pi_v(A) &= P_v + \delta vA, \\ \pi_h(A) &= P_h + \delta \max(0, A - (1 - h)),\end{aligned}$$

where P_v and P_h denote the market values of the sold pieces in vertical and horizontal deals, respectively. We note that the market values P_v and P_h cannot depend on A , since the investors do not know the issuer's private information.

We also note that the issuer's payoff is more sensitive to the pool value A under the horizontal retention structure. Figure 5 illustrates this concept for a numerical example in which we set $h = 0.1$ and $v = 0.05$. For any value of A above $(1 - h)A$, the payoff from the

risk retention security increases more quickly with A under horizontal than under vertical retention. Hence, we conjecture that the issuer can signal better quality of the mortgage pool by choosing horizontal retention. The following theorem verifies that such an equilibrium exists.

Theorem 1 *Let $\bar{A} = E[A]$. If*

$$\frac{\bar{A} - \delta}{1 - \delta} < \frac{1 - h}{1 - v} < A_0, \quad (1)$$

then there is a partially separating equilibrium with mandated risk retention, in which issuers with $A \leq \hat{A}$ choose vertical retention, while issuers with $A > \hat{A}$ choose horizontal retention, where

$$\hat{A} = \frac{P_v - (1 - \delta)(1 - h)}{\delta(1 - v)}, \quad (2)$$

The market values of the sold pieces are given by

$$P_v = (1 - v)E[A|A \leq \hat{A}], \quad (3)$$

$$P_h = 1 - h. \quad (4)$$

Proof See Appendix D.

Theorem 1 establishes that there is a partially separating equilibrium in which the issuer signals a high value CMBS deal by choosing horizontal retention. This result holds for any distribution of A .

An important empirical implication of Theorem 1, which we test in the next section, is that CMBS deals with horizontal retention command a higher market price than those with vertical retention. Indeed, the *sold* piece in a horizontal deal is priced at par according to equation (4), while the *sold* piece in a vertical deal is priced at a discount according to equation (3) since $E[A|A \leq \hat{A}] < 1$. We also note that since the *retained* piece in a horizontal deal absorbs all the losses in the pool, it will be on average more heavily discounted than

the retained piece in a vertical deal.

The primary focus of our model is on asymmetric information in the CMBS market. One should interpret $(1 - A_0)$ as the measure of informational asymmetry due to some soft information about the securitized loans, which is available to the issuer but not to the investors or credit rating agencies. The lower A_0 , the higher the informational asymmetry between the issuer and the investors. In practice, there are many payoff relevant variables that do not contribute to the informational asymmetry, such as publicly disclosed LTV and debt-service coverage ratios or expectations about future states of the economy. Adding those variables to the model would not change the main prediction that horizontal deals are priced more favorably by the market.

4.1 An Example with a Uniform Distribution

Our model allows a complete closed-form solution when the value of the mortgage pool A is uniformly distributed on $[A_0, 1]$. In this case $\bar{A} = (A_0 + 1)/2$ and $E[A|A \leq \hat{A}] = (A_0 + \hat{A})/2$. Hence, the market values of the sold pieces are equal to

$$P_v = (1 - v) \frac{A_0 + \hat{A}}{2}, \quad (5)$$

$$P_h = 1 - h. \quad (6)$$

Substituting (5) into (2) and solving for $\hat{A}$ yields

$$\hat{A} = \frac{1}{2\delta - 1} \left[A_0 - \frac{2(1 - \delta)(1 - h)}{1 - v} \right]. \quad (7)$$

Thus, we have proven the following corollary of Theorem 1.

Corollary 1 *If A is uniformly distributed on $[A_0, 1]$ and condition (1) holds, then there is a partially separating equilibrium with mandated risk retention, in which issuers with $A \leq \hat{A}$ choose vertical retention, while issuers with $A > \hat{A}$ choose horizontal retention, where $\hat{A}$ is*

given by (7). The market values of the sold pieces are given by (5) and (6).

We use the following numerical example to demonstrate the nature of the equilibrium. We set $v = 0.05$ and $h = 0.1$, which is consistent with our empirical observation that vertical retention is always equal to 5% of the pool principal and horizontal retention is typically equal to 10% in conduit deals.¹⁵

We assume $A_0 = 0.99$, meaning that asymmetric information accounts for 1% of the pool value. While this may not seem like a large number, it may have important implications for the issuer's profit, as 1% of a \$750 million deal amounts to \$7.5 million. Our analysis in Appendix C indicates that losses for 2017-2018 CMBS issues can exceed 5% of par value if they experienced the stress scenario of 2007-2009 crisis. However, not all the losses are related to informational asymmetries between CMBS issuers and outside investors. For example, states of the economy can affect CMBS payoffs, but CMBS issuers may not have any superior information about the future states of the economy. Thus, $A_0 = 0.99$ is not inconsistent with the data.

Finally, we assume that $\delta = 0.95$. This means that an impatient issuer values future CMBS cash flows 5% less than other investors. For the five-year mandatory retention period this translates into 1% per year. One can interpret it as an issuer being able to earn abnormal annual returns of 1% on its capital.

Our parametrization results in the following equilibrium outcome: $\hat{A} = 0.9947$, $P_v = 0.9427$ and $P_h = 0.9$. Figure 6 shows the total payoffs $\pi_v(A)$ and $\pi_h(A)$ corresponding to the vertical and horizontal retention for $A \in [0.99, 1]$. The issuer's payoff with horizontal retention has a slope of 0.95 and is much more sensitive to the privately observed asset value A than the payoff with vertical retention that has a slope of 0.0475. The payoffs intersect when $A = \hat{A} = 0.9947$.

In the equilibrium, issuers with $A \in (0.9947, 1]$, which represents 53% of all issuers, retain

¹⁵In our example, the market value of the vertical retention will be exactly 5% of the deal market value, but the horizontal piece will price above 5%. This is because our model does not take into account losses not related to the informational asymmetries. Incorporating those losses into the model would lower the value of horizontal retention, while the market value of the vertical retention will remain at 5%.

10% subordinated piece and sell the senior tranche at par. The other 47% of issuers, i.e., issuers with $A \in [0.9900, 0.9947]$, choose to retain the 5% vertical piece and sell the rest of the mortgage pool for 0.9427, or 0.76% below its par value of 0.95, which translates into 7.7 basis point yield difference for deals with a 10-year maturity. In other words, choosing vertical retention results in a 7.7 basis point higher yield on the sold piece. The next section shows that differences in yields between deals with vertical and horizontal retention are of the same order of magnitude.

5 Empirical Security Pricing and Retention Structure

To illustrate the empirical relevance of the model in Section 4, we estimate the relation between retention type and the market pricing of securities at issue. If one type of retention can better signal quality than another type, differences in signaling value should be associated with differences in security-level pricing.

To understand how retention type is related to pricing, we focus on the yield spread at issue of securities. This contrasts with previous literature which has either focused on coupon spreads (see, e.g., Flynn and Ghent (2018) or Ashcraft et al. (Forthcoming)) or attempted to back out yields using secondary market pricing data (see Ciochetti and Larsson (2017)).

Although spreads at issue are difficult to obtain, it is advantageous to use them because using coupon spreads to proxy for market pricing assumes securities price at par. However, our data indicates significant variation in pricing at issue. Although the average security in our sample prices at 100.1% of par value, the median is 101%, the standard deviation is 6.7%, and the upper 25% of our sample prices at or above 103% of par value. Given the average par balance for this upper 25% of the sample is \$107 million,¹⁶ this indicates a premium of over \$3 million. The yield spread captures this premium.

In our baseline specification, we regress the yield spread at issue on the retention type

¹⁶Note that we do not have pricing data for the full sample of securities. The average par balance for the upper 25% of all securities in the sample is lower than \$107 million.

and deal- and security-level controls:

$$spread_{i,j,t} = \beta_0 + \beta_1 horizr_{j,t} + \beta_2 hybridr_{j,t} + \beta_x Cont_{i,j,t} + \epsilon_{i,j,t} \quad (8)$$

The dependent variable is the yield spread to benchmark of security i in deal j issued in year t . Given that the spread is computed relative to a comparable-maturity, liquid benchmark rate, it represents the price of incremental credit and liquidity risk. The independent variable of interest is an indicator equal to 1 if deal j is structured with horizontal retention and 0 if it is structured with either hybrid or vertical retention. We also include an indicator for hybrid retention.

Control variables include broad rating category fixed effects, tranche subordination level and weighted average life (which is akin to duration), deal size, number of tranches (to proxy for deal complexity, see Ghent et al. (2019)), weighted average maturity of the collateral, weighted average debt service coverage ratio of the collateral, weighted average LTV of the collateral, weighted average coupon of the collateral, original tranche balance, total deal volume for the lead manager of deal j in year t , an indicator for whether the lead manager is a depository institution, an indicator for whether the security is floating rate, and deal type and year fixed effects. Certain specifications also include lead manager and B-piece buyer fixed effects.¹⁷

The relation between retention type and market pricing indicated by β_1 in equation 8 is the average effect and thus will mask important cross-sectional variation at the rating level. Securities rated in the broad BBB category should be relatively more sensitive to retention type because these are the first investment-grade securities to take losses. In contrast, the AAA securities should be relatively less sensitive as they have the highest subordination level.

¹⁷Given the ability of B-piece buyers to perform risk retention in the CMBS market, an issuer's choice of whether to do vertical or horizontal retention may depend on its cost of capital. In the language of the model of Section 4, lead managers may differ from one another and from B-piece buyers in δ . To avoid the confounding influence of such differences, we include an indicator for whether the lead manager is a depository institution in some specifications and fixed effects for lead managers in other specifications.

Given these differences, we would expect retention type to matter incrementally more for BBB-rated securities than for the investment grade securities further up the capital stack. In order to understand whether this is the case, we estimate a variation of equation 8 in which we interact retention type with rating indicators. We use two indicators. First, we define BBB-rated securities relative to all investment grade securities above BBB+. Second, we define below-AAA investment grade securities relative to AAA-rated securities.

We estimate

$$spread_{i,j,t} = \beta_0 + \beta_1 horizrr_{j,t} + \beta_2 RtgIndic_{i,j,t} + \beta_3 horizrr_{j,t} * RtgIndic_{i,j,t} + \beta_x Cont_{i,j,t} + \epsilon_{i,j,t} \quad (9)$$

The variable $RtgIndic_{i,j,t}$ is either an indicator for BBB securities, or an indicator for securities rated between AA+ and BBB- (*nonAAAsr*). Equation 9 is estimated only on investment grade securities.

Table 6 reports results of estimating equation 8. In column 1 we show results for all securities, and in columns 2-4 we show results for investment grade securities only. Columns 3-4 include lead manager fixed effects (we restrict the sample to only those managers who have at least five deals). Column 4 includes additional controls: original tranche balance, weighted average debt service coverage ratio, weighted average LTV, and weighted average coupon. Column 5 includes B-piece buyer fixed effects.¹⁸

The results indicate that securities in deals structured with horizontal retention are priced relatively better (a lower spread indicates a higher final sale price) than securities in deals with hybrid or vertical retention. The magnitude of the coefficient is such that the presence of horizontal retention is associated with an average of 6.5 to 9.6 basis points lower spread depending on the specification. The result is robust in magnitude and significance across a variety of specifications that include deal- and security-level controls and various fixed effects.

¹⁸We include B-piece buyer fixed effects only for deals on which we can identify a single, distinct B-piece buyer. Thus, we exclude deals that list two or more B-piece buyers.

To investigate cross-sectional variation in the relation between horizontal retention and pricing, we estimate equation 9 and report the results in Table 7. In columns 1, 3, and 5, we interact the indicator for BBB securities with the horizontal indicator, and in columns 2, 4, and 6, we interact an indicator for AA, A, and BBB securities with the horizontal indicator. The estimation sample is restricted to investment grade securities only.

Consistent with BBB-rated securities benefiting the most from a credible signal of underlying collateral quality, the interaction between BBB and horizontal retention, *BBB_h*, is negative and significant. This indicates that BBB-rated securities are priced incrementally better in deals structured with horizontal retention relative to BBB securities in deals with vertical or hybrid. Although we lose significance for the main horizontal risk retention coefficient in all but one specification, the interaction coefficient is robust across specifications. In column 2 of Table 7, the negative coefficient on *nonAAAsr_h* shows that all sub-AAA securities benefit from the horizontal retention, but that the AA and A securities do not benefit as much given the smaller magnitude relative to *BBB_h* in column 1.

The magnitude of the price impact for lower-rated securities is economically meaningful. Column 1 of Table 7 shows that a BBB-rated bond prices at a spread about 1.6% higher than the average spread of securities above it. However, horizontal retention reduces the spread by 0.60%, meaning that the spread for BBB-rated securities is only 1% higher on average. The pricing difference is similar in the more stringent specifications in columns 3 and 5. Similarly, column 2 indicates that the average non-AAA senior security (comprised of tranches between AA+ and BBB-) receives a pricing boost of between 0.16% and 0.31% depending on the specification.

5.1 Magnitude of Information Asymmetry

In this subsection, we combine our theoretical model with the empirical findings documented above to estimate the degree of information asymmetry between issuers and investors in 2017-2018 CMBS market. In our model, the difference between the best and the worst CMBS

types is given by $(1 - A_0)$, with higher A_0 corresponding to lower information asymmetry.

Let $S \equiv 1 - A_0$. To estimate the magnitude of information asymmetry S , we rely on the fact that issues with horizontal retention are priced more favorably than issues with vertical retention. In the example in Section 4.1, we assume that A is distributed uniformly on $[A_0, 1]$. Then, according to our model, the average asset values A_h and A_v associated with horizontal and vertical retention are given by

$$A_h = \frac{1 + \hat{A}}{2}, \quad (10)$$

$$A_v = \frac{A_0 + \hat{A}}{2}. \quad (11)$$

Let $\Delta A \equiv A_h - A_v$ be the average difference in asset value between deals with horizontal and vertical retention. Equations (10) and (11) imply that

$$\Delta A = \frac{1 - A_0}{2} = \frac{S}{2}.$$

Hence, estimating S requires estimating ΔA , since

$$S = 2\Delta A.$$

Let Δy be a yield difference between deals with horizontal and vertical retention. Then,

$$\Delta A \approx -D\Delta y,$$

where D is deals' modified duration.¹⁹ Thus,

$$S \approx -2D\Delta y. \quad (12)$$

¹⁹Note that commercial mortgages are effectively noncallable bonds because they feature strong prepayment protection and can typically only be prepaid through defeasance.

Using 2017-2018 data, we estimate $D = 6.0$ years.²⁰ According to Table 7, choosing horizontal retention results in a reduction in yields in the range from 0.065% to 0.096% depending on the specification. Plugging these numbers in equation (12), we estimate that the magnitude of information asymmetry for 2017-2018 CMBS issues lies between 0.78% and 1.15% of deal value.

Consistent with the existence of a signaling equilibrium that we documented in Section 4, our estimates of the magnitude of information asymmetry provide additional evidence that post-regulation CMBS investors are quite sophisticated. The fact that no more than 1.15% of the CMBS value can be related to asymmetric information shows that the investors in this market are well informed about the quality of securitized loans.

6 Policy Implications

The experience of the 2007-2009 crisis motivated mandated retention as a way to protect naïve, uninformed investors from better informed ABS issuers with their own agendas. In the pre-crisis ABS market, first-loss tranches from ABS deals were often quickly sold into collateralized debt obligations (CDOs) that subsequently suffered heavy losses during the financial crisis. The ability to off-load low-rated tranches to less sophisticated CDO buyers allowed ABS issuers to originate poor quality securities without facing consequences.²¹ Our results suggest, however, that there is little asymmetric information in this market in the post-crisis period. In addition, investors who bought securities in 2017-2018 CMBS issues appear to be quite sophisticated, as they recognize the existence of a signaling equilibrium and price CMBS securities accordingly. These findings point to the possibility that the original motivation behind the mandated retention rules may no longer be relevant, as there are not many naïve investors in the modern CMBS market.

²⁰This estimate is based on 84.89 months mean weighted average maturity at origination and 4.37% mean weighted average coupon from Table 2.

²¹Ashcraft et al. (Forthcoming) show that the percentage of the B-piece in pre-crisis CMBS deals sold to CDOs significantly increases the probability that more senior tranches ultimately default.

The partially separating equilibrium documented in this paper is in line with policy makers' expectations that horizontal risk retention can signal stronger collateral than vertical risk retention. For example, page 486 of Department of the Treasury et al. (2014) states

...horizontal risk retention allows sponsors to provide a stronger signal about their private information about asset quality than vertical risk retention because of the increased amount of credit exposure for sponsors. Hence, a sponsor choosing to retain risk in a more expensive horizontal form over a vertical form would have greater exposure to credit risk, and that sponsor's incentives should be better aligned with investors'. As previously described, by choosing a higher cost method of retaining risk, such as through the horizontal form, a sponsor can signal to the market greater certainty about the quality of assets and the level of risk in the senior tranches because the sponsor is willing to incur the losses in the lower subordination.

While the partially separating equilibrium is more informationally efficient than a pooling equilibrium, the information revealed to outside investors in the equilibrium is pretty coarse. The investors can only learn whether the deal quality is above or below a certain threshold. The theory literature that includes Leland and Pyle (1977), DeMarzo and Duffie (1999), and DeMarzo (2005) shows that an informed seller can reveal exact quality of the asset through the *level* of retention.

It appears that policy makers may have thought that issuers could use the level of risk retention to signal the quality of collateral. For example, pages 435-436 of Department of the Treasury et al. (2014) states

In general, although ABS investors may find it difficult to assess the securitized assets' risks on their own, sponsors can signal the quality of the underlying assets by purchasing a first loss position at a price that reflects its fundamental value only if loan defaults turn out to be low. Relatively larger residual interest

tranches may be required when the assets being securitized suffer from more acute information asymmetries or higher uncertainty about their true default risk.

However, we do not see signaling through the level of retention in the market. Our data shows that issuers always choose the minimum retention level. This is likely because the retention requirements are too stringent. Appendix C shows that the size of horizontal retention is much higher than the expected losses on post Dodd-Frank deals even in a rare event such as the stress scenario of 2007-2009 crisis. Under these circumstances, retaining more than the minimum amount does not send a meaningful signal to the market, since it does not translate into retaining more risk.

Thus, our results point to a potentially unintended consequence of the regulation – a reduction in the information available to investors. Because of the stringent retention rules, issuers do not signal quality of their collateral through levels of retention. As a result, the CMBS market is less informationally efficient than it could potentially be with less stringent retention requirements. While we believe that mandated retention can make the ABS market more informationally efficient, our results suggest additional discussion and analysis of the particular *level* may be helpful. Such a discussion should consider that the current sophistication of investors and low information asymmetry could be temporary. Optimistic expectations about collateral quality may encourage new and inexperienced investors to enter the market. The low information asymmetry we find may also be a product of current collateral quality; a decline in the quality of collateral may result in greater information asymmetry (see, for example, Hanson and Sunderam (2013)).

We view two aspects of the policy as unambiguously positive. First, requiring the B-piece buyer to retain it for at least 5 years implies that the B-piece buyer is truly exposed to default risk. As such, horizontal retention can send a stronger signal than if the B-piece buyer can immediately sell its stake. Second, requiring horizontal retention to be based on market values, rather than par values, ensures that the true cost of horizontal retention does not decrease as collateral quality worsens. For a given market value of a B-piece, lower quality

deals would require more principal allocated to the B-piece. If instead the required horizontal retention was calculated relative to par values, the market value of a B-piece would be lower for lower quality deals.

7 Conclusion

We study the impact of mandated minimum risk retention levels on the ability of investors to extract information about unobservable security quality. Our results suggest that risk retention rules can eliminate the ability of issuers to signal higher quality using the level of retention, as the stringent requirements bind in all cases we observe. Despite this, we show that issuers can signal higher quality through the retention structure they choose. Satisfying the retention requirement with a purely first-loss horizontal structure results in significantly better pricing relative to vertical and hybrid structures that combine exposure to first-loss and senior securities. The pricing impact in horizontal deals is concentrated in the lowest, most information-sensitive investment-grade securities.

Our results are consistent with a securitization model with asymmetric information in which issuers face a mandated level of risk retention. We show there is an equilibrium in which issuers signal higher quality collateral by choosing horizontal retention. Thus, securities in deals with horizontal retention have higher market values than those in deals with vertical retention, because investors realize the costly signal of horizontal risk retention indicates less risky collateral. Calibrating our model to our spread estimates indicates a low level of asymmetric information in the post-crisis MBS market.

Our findings also suggest that, post-crisis, MBS investors are sophisticated enough to understand both issuers' incentives and their optimal responses in the new risk retention regime. It is unclear what the rationale is for the 5% minimum and, in particular, whether it was designed to protect such sophisticated investors or to reduce systemic risk. If the goal was to protect investors from all but the most extreme losses, the stringent mandated

minimum would likely accomplish that. We leave it to future work to model how risk retention requirements interact with investor sophistication and systemic risk.

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Figure 1: Risk retention types

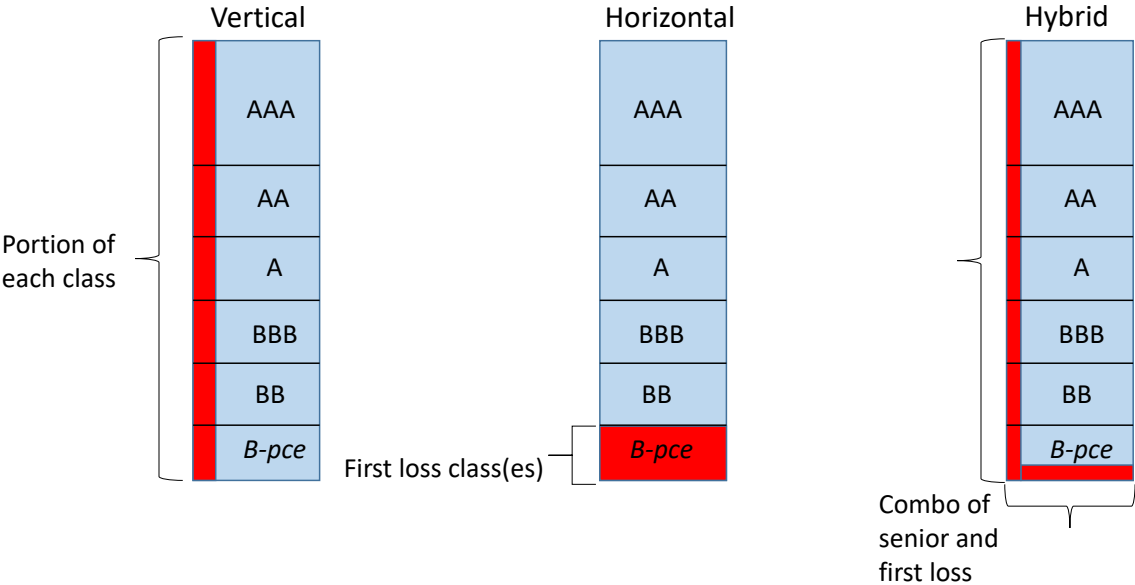
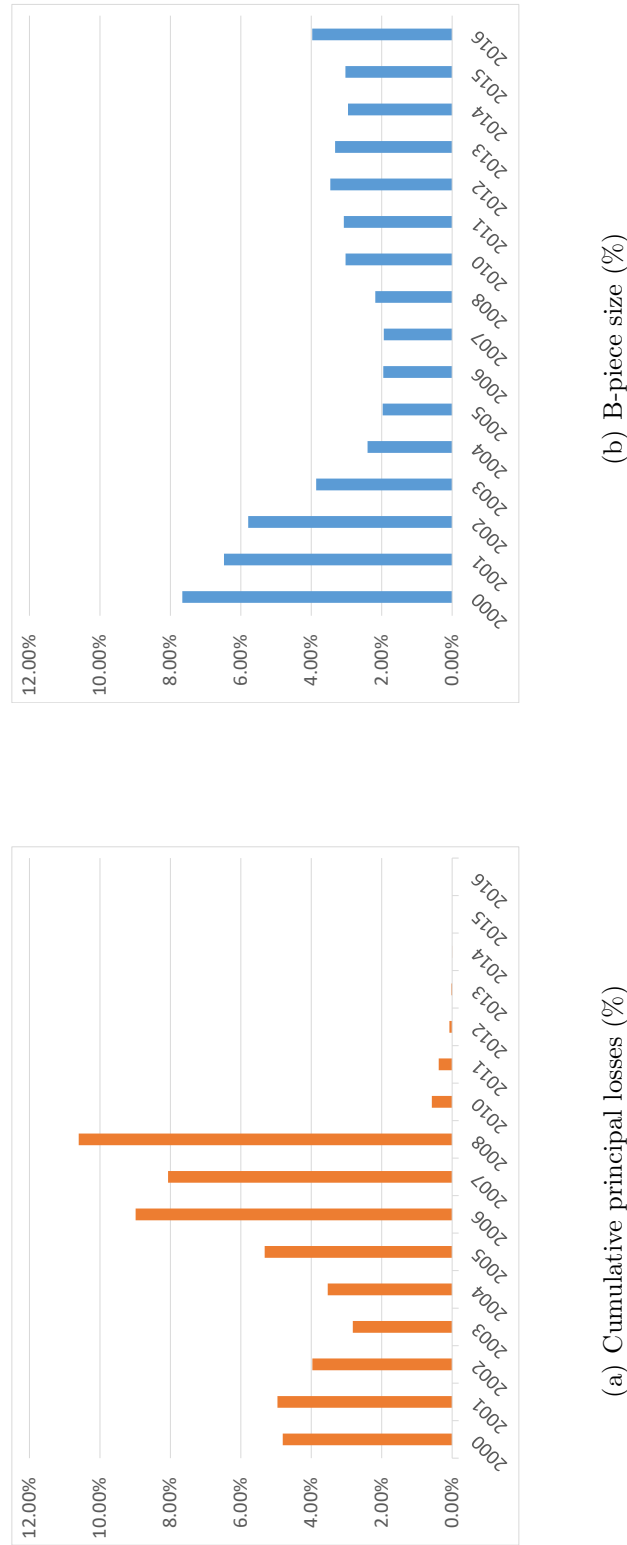
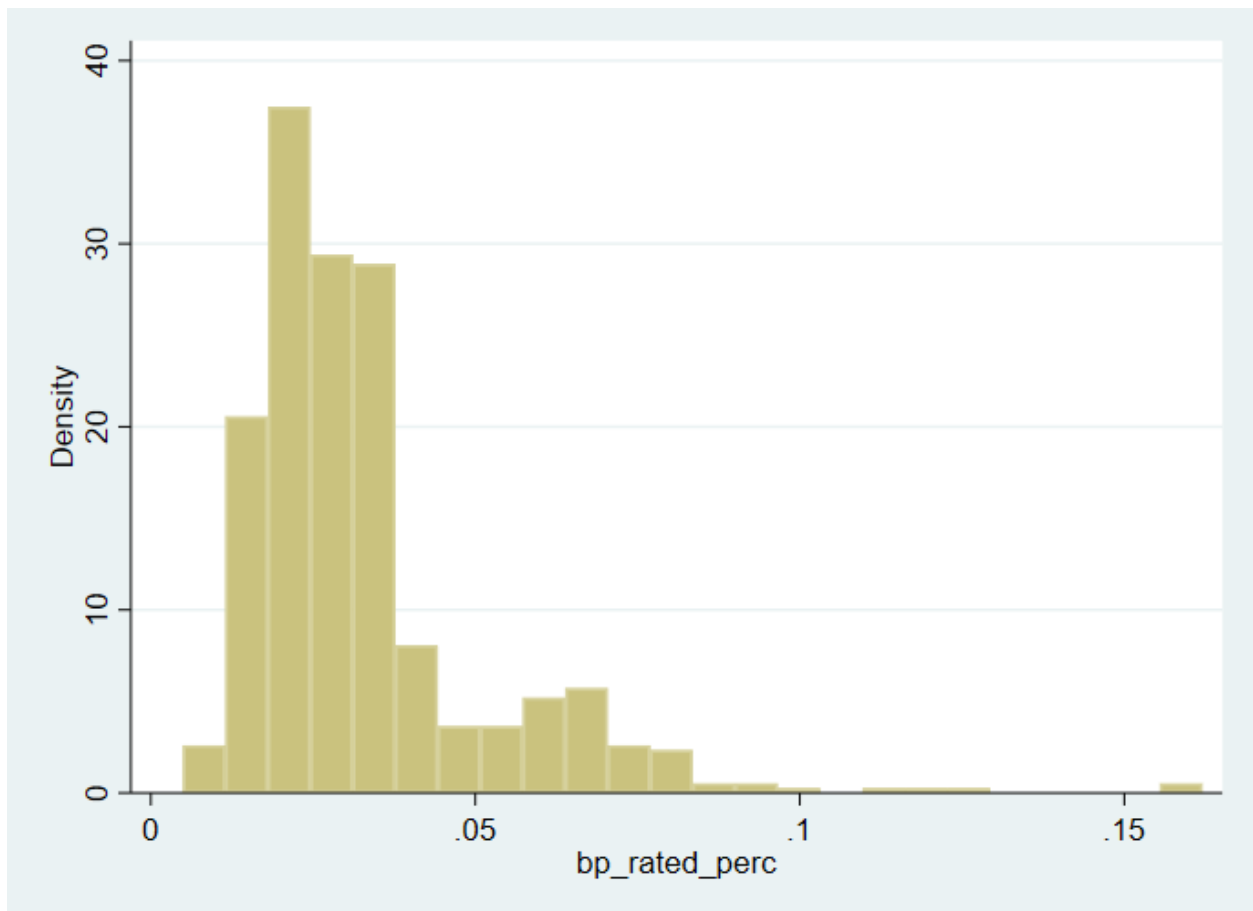


Figure 2: Cumulative losses and B-piece size, 2000-2016 vintage conduit CMBS



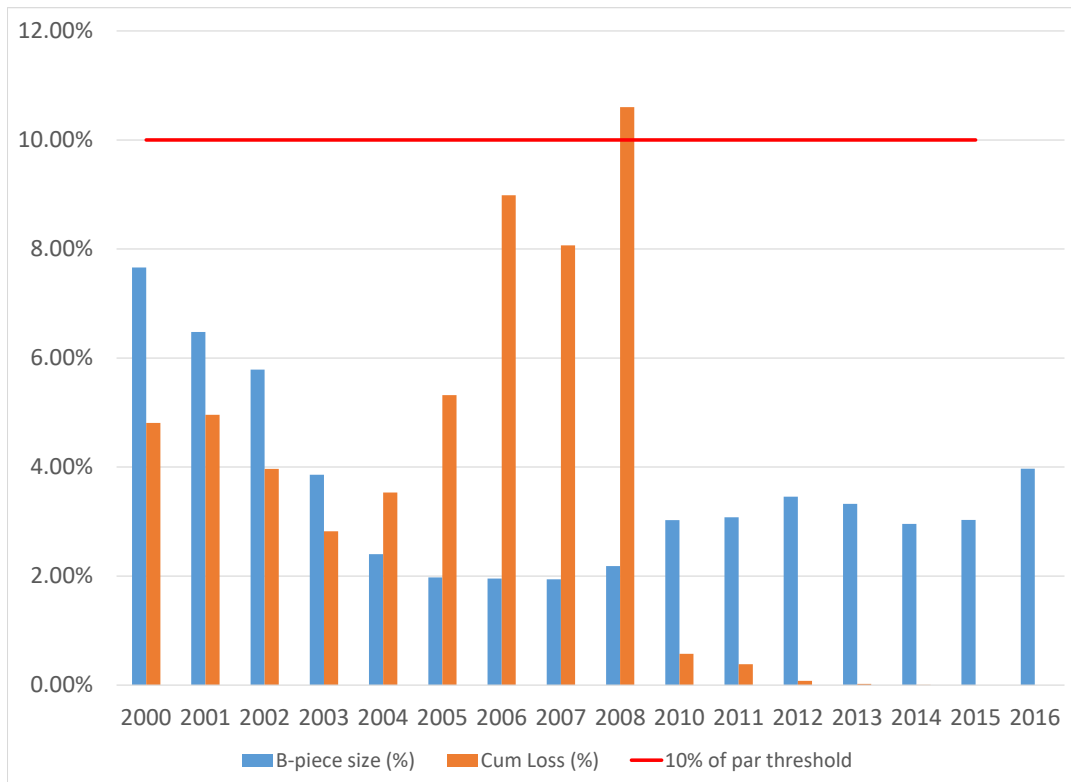
Notes: Left panel is cumulative principal losses across non-IO tranches as a percent of original deal balance as of December 2017. Right panel is B-piece size as percentage of original deal balance. The B-piece is defined as the set of non-IO tranches with average credit rating of less than BBB-. The size of the B-piece is the total par value of B-piece securities divided by the total par value of all non-IO tranches.

Figure 3: Density of B-piece size for 2000-2016 vintage conduit CMBS



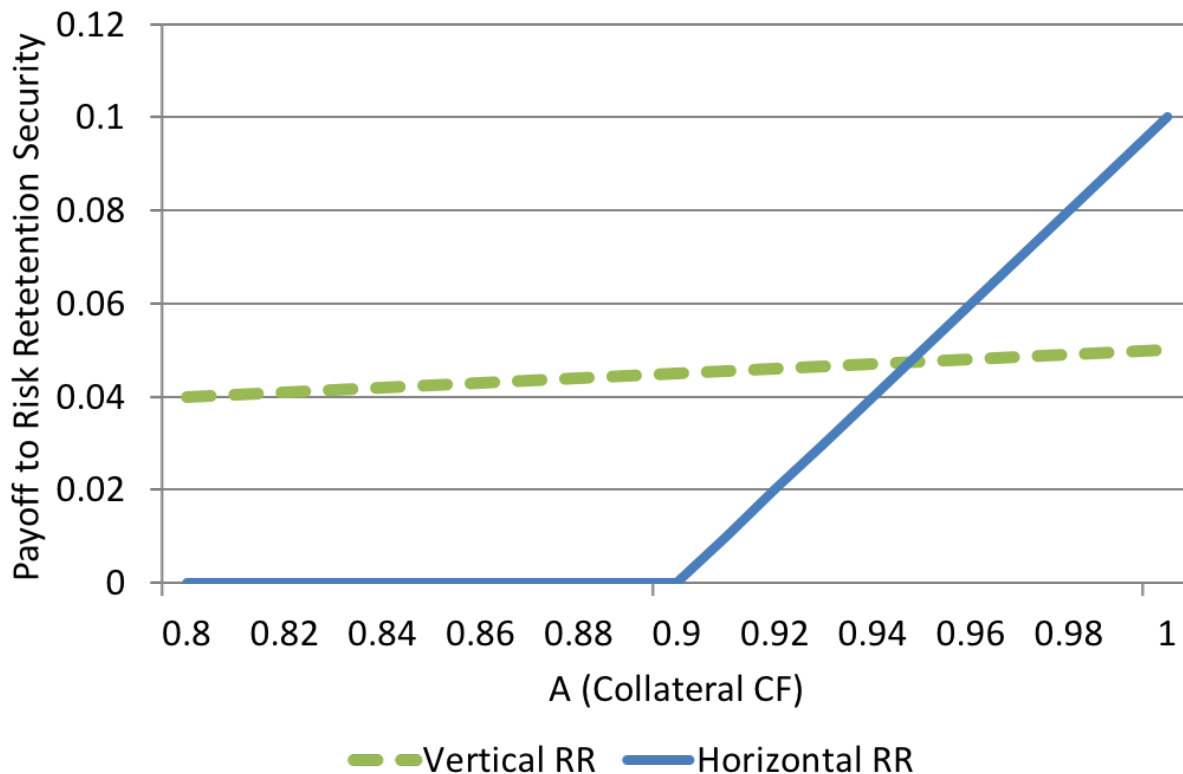
Notes: The figure plots the distribution of the average BBB- subordination level (as a percentage of original deal level) for conduit CMBS.

Figure 4: B-piece size vs cumulative losses for 2000-2016 vintage conduit CMBS



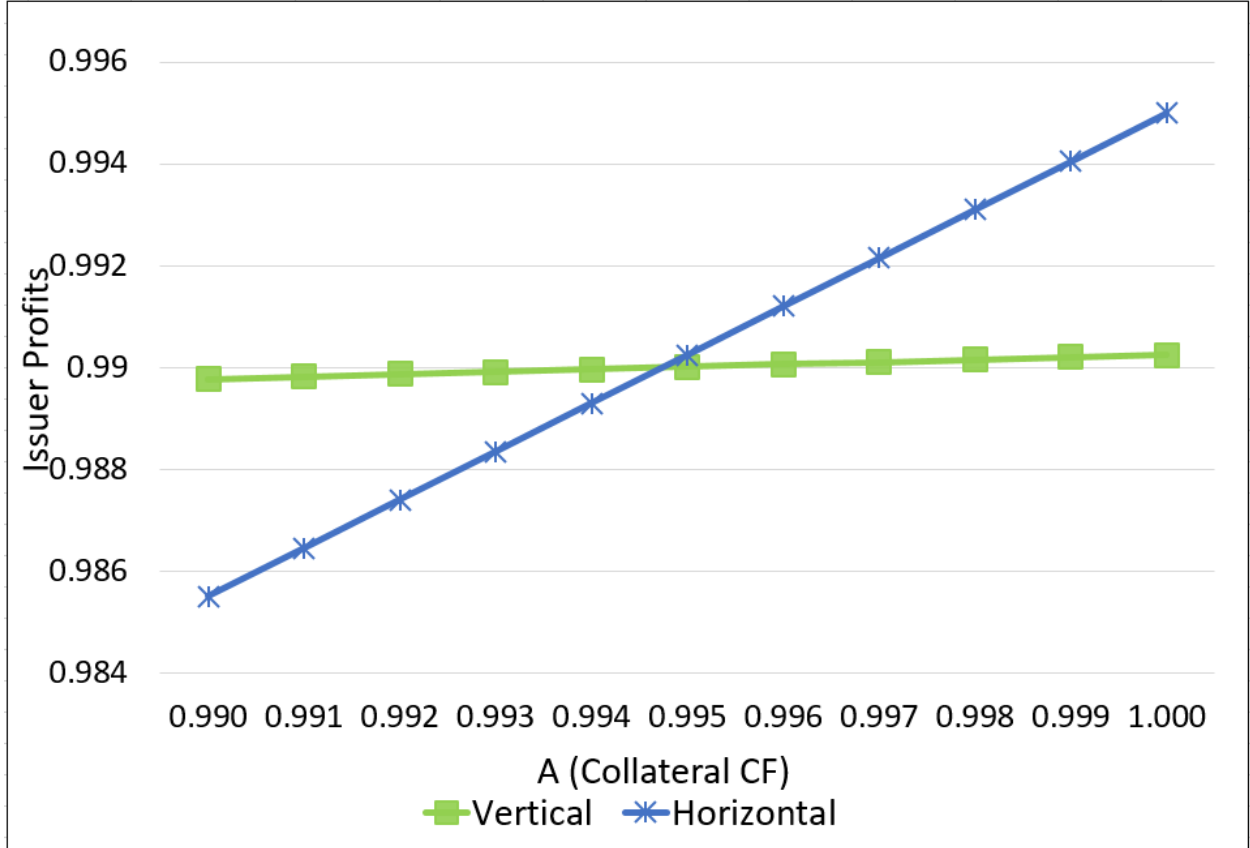
Notes: This figure overlays cumulative principal losses as a percentage of original deal balance (as of December 2017) with average BBB- subordination level for conduit CMBS. Additionally, it displays a line for 10% of par value, which roughly corresponds to 5% of market value based on estimates from the 2017-2018 data.

Figure 5: Risk Retention Security Payoffs for Numerical Illustration of Model



Notes: 1) Figure shows payoffs to risk retention security as a function of A conditional on $h = 0.1$ and $v = 0.05$. 2) h and v are mandatory horizontal and vertical risk retention levels. 3) A , plotted along the x-axis, represents the portion of the cash flow from a pool of mortgages not predictable to outside investors based on observable characteristics. 4) The issuer observes the exact value of A when it chooses the form of risk retention; outside investors know only the distribution of A .

Figure 6: Issuer Profits with Horizontal and Vertical Retention



Notes: 1) Figure shows profits from risk retention security as a function of A conditional on $h = 0.1$, $v = 0.05$, $A_0 = 0.99$, and $A \sim \mathbf{U}[A_0, 1]$. 2) h and v are mandatory horizontal and vertical risk retention levels. 3) A , plotted along the x-axis, represents the portion of the cash flow from a pool of mortgages not predictable to outside investors based on observable characteristics. 4) The issuer observes the exact value of A when it chooses the form of risk retention; outside investors know only the distribution of A .

Table 1: Variable definitions

Variable	Description
<i>A</i>	Indicator equal to 1 if the tranche is rated A+, A, or A- at issue, 0 otherwise
<i>AA</i>	Indicator equal to 1 if the tranche is rated AA+, AA, or AA- at issue, 0 otherwise
<i>AAA</i>	Indicator equal to 1 if the tranche is rated AAA at issue, 0 otherwise
<i>AAA.h</i>	Interaction between horizr and AAA
<i>angloss</i>	Indicator equal to 1 if the loan has experienced any losses as of December 2017, 0 otherwise
<i>BB</i>	Indicator equal to 1 if the tranche is rated BB+, BB, or BB- at issue, 0 otherwise
<i>BBB</i>	Indicator equal to 1 if the tranche is rated BBB+, BBB, or BBB- at issue, 0 otherwise
<i>BBB.h</i>	Interaction between horizr and BBB
<i>conduit</i>	Indicator equal to 1 if deal is Conduit, 0 otherwise
<i>cutoffbalance</i>	Total collateral balance of the deal at origination in billions of dollars
<i>cutoffdscr.ncf</i>	Deal weighted average debt service coverage ratio at origination based on net cash flow
<i>cutoffdscr.not</i>	Deal weighted average LTV at origination
<i>cutoffltv</i>	Deal weighted average LTV at origination
<i>deal2018</i>	Indicator equal to 1 if the deal was originated in 2018, 0 otherwise
<i>depository</i>	Indicator equal to 1 if the lead manager is a depository institution, 0 otherwise
<i>face</i>	Loan balance at securitization in millions of dollars
<i>firstcoupon</i>	Tranche initial coupon in percentage points
<i>floatr</i>	Indicator equal to 1 if the tranche is floating rate, 0 otherwise
<i>horizrr</i>	Indicator equal to 1 if the deal is structured with horizontal retention, 0 otherwise
<i>horsize.hrrr</i>	Size of horizontally retained piece in a horizontal deal as a percentage of par value
<i>horsize.hgyr</i>	Size of horizontally retained piece in a hybrid deal as a percentage of par value
<i>horsizeofpar</i>	Size of horizontally retained piece as a percentage of par value
<i>hybridrr</i>	Indicator equal to 1 if the deal is structured with L-shaped retention, 0 otherwise
<i>leadmgrsize</i>	Total value of deals originated by lead manager in a given year in billions of dollars
<i>loanhhrr</i>	Indicator equal to 1 if loan is in deal structured with horizontal or hybrid retention, 0 otherwise
<i>loanhrr</i>	Indicator equal to 1 if loan is in deal structured with horizontal retention, 0 otherwise
<i>lossoverten</i>	Indicator equal to 1 if the loan has experienced losses greater than 10% of face value as of December 2017, 0 otherwise
<i>lossrate.face</i>	Loan realized loss rate, computed as realized loss divided by loan balance at securitization
<i>mtg.orig.wal</i>	Tranch weighted average life at origination
<i>nonAAA.sr</i>	Indicator equal to 1 if the tranche is rated between AA+ and BBB- at issue, 0 otherwise
<i>nonAAA.sr.h</i>	Interaction between horizr and nonAAA.sr
<i>ntranches</i>	Number of tranches in the deal
<i>orig_dscrmoi</i>	Loan debt service coverage ratio at origination
<i>orig.wam</i>	Deal weighted average maturity at origination
<i>origsubpct</i>	Subordination level of tranche in percentage at origination
<i>securltv</i>	Loan LTV at time of securitization
<i>securocc</i>	Loan property occupancy rate at securitization
<i>securuac</i>	Loan gross coupon rate at securitization
<i>securuac</i>	Deal weighted average coupon
<i>spread</i>	Tranche spread to benchmark at time of initial sale in percentage points
<i>term.secur</i>	Loan term to maturity at securitization
<i>tranchebalance</i>	Security par value at origination in millions of dollars
<i>verticalrr</i>	Indicator equal to 1 if the deal is structured with vertical retention, 0 otherwise
<i>vertsize</i>	Size of vertically retained piece as a percentage of par value
<i>vertsize.hgyr</i>	Size of vertically retained piece in a hybrid deal as a percentage of par value
<i>vertsize.vrrr</i>	Size of vertically retained piece in a vertical deal as a percentage of par value

Table 2: Summary Statistics—security level, 2017-2018 vintage

	N	mean	median	sd	min	max
<i>horizrr</i>	2266	0.46	0	0.5	0	1
<i>hybridrr</i>	2266	0.15	0	0.36	0	1
<i>verticalrr</i>	2266	0.39	0	0.49	0	1
<i>spread</i>	1207	1.31	1.1	0.85	0.05	6
<i>firstcoupon</i>	1251	3.72	3.64	1.11	0	12.85
<i>AAA</i>	1640	0.39	0	0.49	0	1
<i>AA</i>	1640	0.12	0	0.33	0	1
<i>A</i>	1640	0.12	0	0.32	0	1
<i>BBB</i>	1640	0.15	0	0.35	0	1
<i>BB</i>	1640	0.12	0	0.32	0	1
<i>nonAAAsr</i>	1269	0.5	0	0.5	0	1
<i>conduit</i>	2266	0.57	1	0.5	0	1
<i>origsubpct</i>	1897	22.24	21.13	18.02	0	93.25
<i>floater</i>	2202	0.28	0	0.45	0	1
<i>cutoffbalance</i>	2163	0.73	0.75	0.35	0.1	2.08
<i>leadmgrsize</i>	2266	7.17	7.91	3.48	0.14	12.49
<i>depository</i>	2235	0.41	0	0.49	0	1
<i>ntranches</i>	2262	13.1	14	5.01	2	30
<i>mtg_orig_wal</i>	1899	6.85	7.42	3.34	1.14	15.05
<i>orig_wam</i>	2252	84.89	110	39.25	20.96	121
<i>cutoffdscr_noi</i>	1885	2.54	2.3	0.76	0.49	6.71
<i>cutoffltv</i>	2213	57.38	58.19	7.75	24.3	79.22
<i>secwac</i>	1786	4.37	4.4	0.51	2	6.5
<i>deal2018</i>	2266	0.4	0	0.49	0	1
<i>horsizeofpar</i>	1334	7.41	6.83	2.64	0.94	12.6
<i>vertsize</i>	1194	4.41	5	1.03	1.9	5
<i>horsize_hrr</i>	989	8.08	9.74	2.49	5	12.6
<i>horsize_hyrr</i>	339	5.47	6.3	2.06	0.94	8.34
<i>vertsize_vrr</i>	847	5	5	0	5	5
<i>vertsize_hyrr</i>	339	2.93	2.7	0.81	1.9	4.22
<i>tranchebalance</i>	2262	61.47	34.42	91.2	0	858.88

Notes: 1) Data is for all nonagency conduit and large loan/single-borrower U.S. CMBS issued between January 1, 2017, and September 30, 2018. Data comes from Trepp, Bloomberg, and CRE Direct. 2). All variables are defined in Table 1.

Table 3: Risk retention amount

Horizontal	Retention	Vertical	Retention	Vertical (cont)	Retention	Hybrid	Retention
<i>BMARK 2018-B2</i>	5.02%	<i>MSC 2017-PRME</i>	5.00%	<i>BBCMS 2017-GLKS</i>	5.00%	<i>CD 2017-CD3</i>	5.00%
<i>UBSCM 2018-C8</i>	5.00%	<i>BACM 2017-BNK3</i>	5.00%	<i>BX 2017-CQHP</i>	5.00%	<i>GSMS 2017-GS5</i>	5.05%
<i>CCUBS 2017-C1</i>	4.99%	<i>BBCMS 2017-C1</i>	5.00%	<i>WFCM 2017-HSDB</i>	5.00%	<i>CGCMT 2017-P7</i>	5.08%
<i>CD 2017-CD6</i>	5.00%	<i>WFCM 2017-RC1</i>	5.00%	<i>UBSCM 2017-C6</i>	5.00%	<i>MSBAM 2017-C33</i>	5.15%
<i>CGCMT 2017-C4</i>	5.00%	<i>WFCM 2017-RB1</i>	5.00%	<i>CHT 2017-CSMO</i>	5.00%	<i>GSMS 2017-GS6</i>	5.03%
<i>COMM 2017-COR2</i>	5.17%	<i>BANK 2017-BNK4</i>	5.00%	<i>CSMC 2017-TIME</i>	5.00%	<i>CSAIL 2017-C8</i>	5.01%
<i>CSMC 2017-LSTK</i>	5.04%	<i>CD 2017-CD4</i>	5.00%	<i>WFCM 2017-BNK9</i>	5.00%	<i>WFCM 2017-C38</i>	5.06%
<i>GSMS 2017-GS7</i>	5.01%	<i>GSMS 2017-GPTX</i>	5.00%	<i>WFCM 2017-C42</i>	5.00%	<i>CD 2017-CD5</i>	5.08%
<i>GSMS 2017-GS8</i>	5.00%	<i>NCMS 2017-75B</i>	5.00%	<i>WFCM 2017-SMP</i>	5.00%	<i>CSAIL 2017-CX9</i>	5.03%
<i>HMH 2017-NSS</i>	5.00%	<i>HOSPITALITY 2017-HIT</i>	5.00%	<i>BAMLL 2017-SCH</i>	5.00%	<i>JPMDDB 2017-C7</i>	5.05%
<i>JPMCC 2017-JP5</i>	5.11%	<i>CFCRE 2017-C8</i>	5.00%	<i>AHPT 2017-ATRM</i>	5.00%	<i>CSAIL 2017-CX10</i>	5.04%
<i>JPMCC 2017-JP6</i>	5.02%	<i>OLT 2017-OT</i>	5.00%	<i>NCMS 2018-285M</i>	5.00%	<i>BMARK 2018-B1</i>	5.05%
<i>JPMCC 2017-JP7</i>	5.03%	<i>CLNS 2017-OT</i>	5.00%	<i>NCMS 2018-TECH</i>	5.00%	<i>WFCM 2018-C43</i>	5.07%
<i>JPMDDB 2017-C5</i>	5.02%	<i>CGDB 2017-BIO</i>	5.00%	<i>CGCMT 2018-TBR</i>	5.00%		
<i>MSC 2017-H1</i>	5.01%	<i>DBCG 2017-BBG</i>	5.00%	<i>THPT 2018-THL</i>	5.00%		
<i>MSC 2017-HR2</i>	5.00%	<i>BANK 2017-BNK5</i>	5.00%	<i>BANK 2018-BN10</i>	5.00%		
<i>PRK 2017-280P</i>	5.00%	<i>BCP 2017-GM</i>	5.00%	<i>IHPT 2018-STAY</i>	5.00%		
<i>UBSCM 2017-C1</i>	5.02%	<i>JPMCC 2017-MARK</i>	5.00%	<i>NCMS 2018-ALXA</i>	5.00%		
<i>UBSCM 2017-C2</i>	5.03%	<i>CSMC 2017-CHOP</i>	5.00%	<i>NCMS 2018-OSS</i>	5.00%		
<i>UBSCM 2017-C3</i>	5.22%	<i>WTOWN 2017-KNOX</i>	5.00%	<i>GSMS 2018-CHILL</i>	5.00%		
<i>UBSCM 2017-C5</i>	5.03%	<i>MSDB 2017-712F</i>	5.00%	<i>NCMS 2018-RIVA</i>	5.00%		
<i>UBSCM 2017-C7</i>	5.11%	<i>BANK 2017-BNK6</i>	5.00%	<i>NCMS 2018-PREZ</i>	5.00%		
<i>WFCM 2017-C39</i>	5.03%	<i>CGCMT 2017-MDRA</i>	5.00%	<i>CGCMT 2018-B2</i>	5.00%		
<i>WFCM 2017-C41</i>	5.09%	<i>BX 2017-SLCT</i>	5.00%	<i>BBCMS 2018-TALL</i>	5.00%		
		<i>MAD 2017-330M</i>	5.00%	<i>BANK 2018-BN11</i>	5.00%		
		<i>BX 2017-APPL</i>	5.00%	<i>AHT 2018-ASHF</i>	5.00%		
		<i>JPMCC 2017-FL10</i>	5.00%	<i>TSQ 2018-10TS</i>	5.00%		
		<i>CGDBB 2017-BIOC</i>	5.00%	<i>BANK 2018-BN12</i>	5.00%		
		<i>CGCMT 2017-B1</i>	5.00%	<i>BHR 2018-PRME</i>	5.00%		
		<i>BXP 2017-CC</i>	5.00%	<i>US 2018-USDC</i>	5.00%		
		<i>MOTEL 2017-MTL6</i>	5.00%	<i>GSMS 2018-SRP5</i>	5.00%		
		<i>SMPT 2017-MONT</i>	5.00%	<i>AHPT 2018-ATRM</i>	5.00%		
		<i>CGCMT 2017-P8</i>	5.00%	<i>WFCM 2018-1745</i>	5.00%		
		<i>BANK 2017-BNK7</i>	5.00%	<i>AHT 2018-KEYS</i>	5.00%		
		<i>COMM 2017-DLTA</i>	5.00%	<i>NCMS 2018-FL1</i>	5.00%		
		<i>UBSCM 2017-C4</i>	5.00%	<i>GSMS 2018-RIVR</i>	5.00%		
		<i>WFCM 2017-C40</i>	5.00%	<i>BBCMS 2018-CBM</i>	5.00%		
		<i>MSBAM 2017-C34</i>	5.00%	<i>GSMS 2018-TWR</i>	5.00%		
		<i>HYATT 2017-HYT2</i>	5.00%	<i>BANK 2018-BN13</i>	5.00%		
		<i>GSMS 2017-SLP</i>	5.00%	<i>BBCMS 2018-CHRS</i>	5.00%		
		<i>COMM 2017-PANW</i>	5.00%	<i>MSC 2018-MP</i>	5.00%		
		<i>BANK 2017-BNK8</i>	5.00%	<i>GSMS 2018-HULA</i>	5.00%		
		<i>JPMCC 2017-FL11</i>	5.00%	<i>MSC 2018-BOP</i>	5.00%		
				<i>BAMLL 2018-PARK</i>	5.00%		
				<i>BANK 2018-BNK14</i>	5.00%		
				<i>KCM 2018-S1</i>	5.00%		

Notes: (1) Total retention amount for all deals with available data. Data is for all U.S. nonagency conduit and large loan/single-borrower CMBS loans issued between January 2017 and September 2018. (2) Data on horizontal deals comes from deal documents, data on vertical deals comes from CRE Direct, and data for hybrid deals utilizes both deal documents and CRE Direct. (3) Retention for hybrid deals is the sum of vertical and horizontal portions.

Table 4: Summary Statistics—loan level

Panel A—2006-2008 vintages						
	N	mean	median	sd	min	max
<i>lossrate_face</i>	23325	0.09	0	0.22	0	1
<i>face</i>	23315	17.42	6.32	66.45	0.08	7407.65
<i>securltv</i>	23183	68.65	71.7	11.9	1.3	102
<i>orig_dscrnoi</i>	22158	1.67	1.49	2.47	-0.5	204.17
<i>securwac</i>	23225	6	5.95	0.39	1.21	11.81
<i>securocc</i>	22150	92.75	96.9	10.15	2.3	100
<i>term_secur</i>	23062	8.86	9.73	3.21	0.06	34.83
<i>origyear</i>	23325	2006.46	2006	0.51	2006	2008
<i>anyloss</i>	23325	0.20	0	0.39	0	1
<i>lossoverten</i>	23325	0.16	0	0.37	0	1

Panel B—2017-2018 vintage						
	N	mean	median	sd	min	max
<i>lossrate_face</i>	2490	0	0	0	0	0
<i>face</i>	2488	34.84	13	106.82	0	1660
<i>securltv</i>	2487	58.97	62.2	13.62	1.6	81.4
<i>orig_dscrnoi</i>	2354	2.39	1.87	2.38	1.06	48.78
<i>securwac</i>	2349	4.65	4.67	0.58	2	10.39
<i>securocc</i>	2412	90.69	93.9	9.91	24.2	100
<i>term_secur</i>	2470	9.17	9.9	2.44	1.31	24.9
<i>origyear</i>	2490	2017.06	2017	0.23	2017	2018

Notes: 1) Data is for all 2006, 2007, 2008, 2017, and Jan-March 2018 vintage nonagency conduit and large loan/single-borrower U.S. CMBS loans. Data comes from Trepp. 2). All variables are defined in Table 1.

Table 5: Loan-level characteristics: t-tests

	2006-2008 vintage	2017-2018 vintage	t-stat	p-value
<i>face</i>	17.42	34.90	-8.00	0.00
<i>securltv</i>	68.65	58.97	34.04	0.00
<i>orig_dscrnoi</i>	1.67	2.39	-13.78	0.00
<i>securvac</i>	6.00	4.65	110.55	0.00
<i>securocc</i>	92.75	90.69	9.67	0.00
<i>term_secur</i>	8.86	9.17	-5.81	0.00
<i>origyear</i>	2006.46	2017.06	-1869.86	0.00

Notes: 1) Results of comparing means for loan-level variables. T-stats and p-values reported in columns 4 and 5. Data is for all U.S. nonagency conduit and large loan/single-borrower CMBS loans issued between January 2006 and December 2008 (column 2) or between January 2017 and March 2018 (column 3). Data comes from Trepp. 2). All variables are defined in Table 1.

Table 6: Yield spreads and the form of risk retention

	(1)	(2)	(3)	(4)	(5)
<i>horizrr</i>	-0.085** (0.033)	-0.089*** (0.033)	-0.077** (0.035)	-0.065** (0.028)	-0.096** (0.037)
<i>hybridrr</i>	-0.015 (0.039)	-0.016 (0.039)	-0.0024 (0.041)	0.022 (0.039)	0.043 (0.048)
<i>AAA</i>	-3.37*** (0.29)	-1.96*** (0.12)	-1.92*** (0.11)	-2.19*** (0.099)	-2.42*** (0.11)
<i>AA</i>	-2.89*** (0.26)	-1.48*** (0.089)	-1.44*** (0.084)	-1.68*** (0.087)	-1.84*** (0.095)
<i>A</i>	-2.49*** (0.25)	-1.09*** (0.072)	-1.05*** (0.067)	-1.22*** (0.075)	-1.33*** (0.086)
<i>BBB</i>	-1.39*** (0.25)				
<i>BB</i>	-0.98*** (0.17)				
<i>conduit</i>	0.61*** (0.089)	0.59*** (0.092)	0.51*** (0.078)	0.50*** (0.10)	0.35*** (0.11)
<i>origsubpct</i>	0.0048 (0.0038)	0.0041 (0.0039)	0.0046 (0.0037)	0.0081*** (0.0023)	0.015*** (0.0029)
<i>floater</i>	0.0021 (0.18)	0.021 (0.19)	0.19 (0.12)	0.15 (0.11)	-0.22 (0.19)
<i>cutoffbalance</i>	-0.065 (0.059)	-0.069 (0.060)	-0.038 (0.059)	-0.057 (0.050)	0.047 (0.076)
<i>leadmgrsize</i>	-0.0077 (0.0053)	-0.0082 (0.0052)	-0.0014 (0.0095)	0.00039 (0.0074)	-0.0065 (0.0081)
<i>depository</i>	-0.040 (0.034)	-0.041 (0.033)			
<i>ntranches</i>	-0.011** (0.0055)	-0.011* (0.0055)	-0.0045 (0.0048)	-0.0027 (0.0048)	-0.0056 (0.0045)
<i>mtg_orig_wal</i>	0.10*** (0.0049)	0.10*** (0.0049)	0.10*** (0.0041)	0.10*** (0.0032)	0.11*** (0.0029)
<i>orig_wam</i>	-0.0079*** (0.0019)	-0.0076*** (0.0020)	-0.0058*** (0.0011)	-0.0059*** (0.0011)	-0.0089*** (0.0020)
<i>deal2018</i>	-0.13*** (0.040)	-0.12*** (0.040)	-0.086** (0.037)	-0.14*** (0.039)	-0.076 (0.048)
Observations	1,032	1,014	998	794	643
R-squared	0.806	0.788	0.802	0.866	0.891
Additional controls	No	No	No	Yes	Yes
Lead mgr FE	No	No	Yes	Yes	Yes
B-piece buyer FE	No	No	No	No	Yes

Notes: 1) Results of estimating linear regressions of initial tranche pricing on risk retention indicators and controls. The dependent variable is the spread to benchmark at issue in percentage points. We do not show the constant term. 2). Column 1 includes all securities in the sample, and columns 2-4 include only securities with an initial rating of BBB- or higher. 3) Data is for nonagency conduit and large loan/single-borrower U.S. CMBS issued between January 1, 2017, and September 30, 2018. 4) All variables defined in Table 1. 5). *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$. Standard errors clustered at deal level.

Table 7: Heterogeneous effects of risk retention on yield spreads

	(1)	(2)	(3)	(4)	(5)	(6)
<i>horizrr</i>	0.024 (0.034)	0.032 (0.034)	0.011 (0.034)	-0.013 (0.036)	-0.054 (0.035)	-0.083** (0.038)
<i>hybridrr</i>	-0.019 (0.041)	0.0024 (0.044)	-0.011 (0.034)	0.010 (0.041)	0.040 (0.051)	0.044 (0.056)
<i>nonAAAsr</i>		0.76*** (0.056)		0.76*** (0.055)		0.64*** (0.12)
<i>nonAAAsr_h</i>		-0.16** (0.064)		-0.21*** (0.065)		-0.31*** (0.077)
<i>BBB</i>	1.57*** (0.10)		1.77*** (0.10)		1.81*** (0.12)	
<i>BBB_h</i>	-0.60*** (0.16)		-0.83*** (0.16)		-0.97*** (0.19)	
<i>conduit</i>	0.074 (0.094)	0.029 (0.11)	-0.30*** (0.11)	-0.47*** (0.15)	-0.016 (0.20)	0.037 (0.24)
<i>origsubpct</i>	-0.013*** (0.0029)	-0.017*** (0.0035)	-0.017*** (0.0030)	-0.023*** (0.0040)	-0.023*** (0.0054)	-0.034*** (0.0090)
<i>floater</i>	-0.0022 (0.20)	0.064 (0.25)	0.17 (0.13)	0.23 (0.15)	0.28 (0.27)	0.55 (0.36)
<i>cutoffbalance</i>	-0.092 (0.073)	-0.10 (0.081)	-0.045 (0.069)	0.0027 (0.087)	0.011 (0.076)	0.0076 (0.095)
<i>leadmgrsize</i>	-0.0085 (0.0058)	-0.011 (0.0067)	-0.0085* (0.0049)	-0.011* (0.0057)	-0.0058 (0.0079)	-0.0074 (0.0095)
<i>depository</i>	-0.055 (0.034)	-0.042 (0.035)	-0.014 (0.030)	0.0081 (0.033)		
<i>ntranches</i>	-0.0048 (0.0064)	0.0014 (0.0068)	0.0024 (0.0041)	0.0078 (0.0047)	0.0071 (0.0050)	0.0097 (0.0065)
<i>mtg_orig_wal</i>	0.12*** (0.0060)	0.095*** (0.0045)	0.12*** (0.0057)	0.094*** (0.0035)	0.12*** (0.0089)	0.091*** (0.0055)
<i>orig_wam</i>	-0.011*** (0.0023)	-0.0079*** (0.0028)	-0.0080*** (0.0016)	-0.0059*** (0.0019)	-0.0079*** (0.0027)	-0.0046 (0.0035)
<i>deal2018</i>	-0.11** (0.041)	-0.074* (0.044)	-0.22*** (0.032)	-0.22*** (0.036)	-0.036 (0.047)	-0.0059 (0.056)
Observations	1,014	1,014	803	803	643	643
R-squared	0.721	0.580	0.809	0.650	0.852	0.693
Addl ctrls	No	No	Yes	Yes	Yes	Yes
B-pce buyer FE	No	No	No	No	Yes	Yes

Notes: 1) Results of estimating linear regressions of initial tranche pricing on risk retention indicators, interactions between retention indicators and rating indicators, and controls. The dependent variable is the spread to benchmark at issue in percentage points. We do not show the constant term. 2). Data is for senior securities (BBB- and above) only. The variable *nonAAAsr* is an indicator for a rating of BBB- to AA+. 3) Data is for nonagency conduit and large loan/single-borrower U.S. CMBS issued between January 1, 2017, and September 30, 2018. 4) All variables are defined in Table 1. 5). *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$. Standard errors clustered at the deal level.

A Deal Document Examples

Figure A.1: Horizontal deal document excerpt - CCUBS 2017-C1

Material Terms of the Yield-Priced Principal Balance Certificates

The Third Party Purchaser will purchase the Class D-RR, Class E-RR, Class F-RR, Class G-RR and Class NR-RR certificates (the "Yield-Priced Principal Balance Certificates") identified in the table below that collectively comprise the eligible horizontal residual interest for cash on the Closing Date.

Eligible Horizontal Residual Interest

Class of Certificates	Initial Certificate Balance⁽¹⁾	Values of Retained Certificates (in % and \$)⁽¹⁾	Purchase Price⁽²⁾
Class D-RR.....	\$ 21,007,000	1.45%/\$10,342,105	49.23171%
Class E-RR.....	\$ 8,709,000	0.60%/\$4,287,590	49.23171%
Class F-RR.....	\$ 7,838,000	0.54%/\$3,858,455	49.22755%
Class G-RR.....	\$ 8,710,000	0.60%/\$4,270,566	49.03061%
Class NR-RR.....	\$ 26,128,121	1.80%/\$12,810,777	49.03061%

⁽¹⁾ The fair value of the applicable Certificate Balance of the indicated class of certificates expressed as a percentage of the fair value of all of Classes of Regular Certificates issued by the issuing entity and as a dollar amount.

⁽²⁾ Expressed as a percentage of the initial Certificate Balance of each class of Yield-Priced Principal Balance Certificates, excluding accrued interest. The aggregate purchase price expected to be paid for the Yield-Priced Principal Balance Certificates to be acquired by the Third Party Purchaser is approximately \$35,569,494 excluding accrued interest.

The aggregate fair value of the Yield-Priced Principal Balance Certificates in the above table is equal to approximately \$35,569,494 (excluding accrued interest) representing approximately 5.00% of the fair value of all of the Classes of Regular Certificates issued by the issuing entity.

The Retaining Sponsor is required to retain an eligible horizontal residual interest with a fair value as of the Closing Date of at least \$35,567,094 (representing 5.00% of the aggregate fair value of all the Classes of Regular Certificates), excluding accrued interest.

Notes: Downloaded from Bloomberg and SEC Edgar.

Figure A.2: Horizontal deal document excerpts - GSMS 2017-GS8

HRR Certificates

General

The aggregate purchase price and fair value of the HRR Certificates is equal to approximately \$52,373,515 (excluding accrued interest), representing approximately 5.01% of the aggregate fair value of all of the Regular Certificates.

The sponsor estimates that, if it had relied solely on retaining an “eligible horizontal residual interest” in order to meet the credit risk retention requirements of the Credit Risk Retention Rules with respect to this securitization transaction, it would have retained an eligible horizontal residual interest with an aggregate fair value dollar amount of approximately \$52,253,273 representing 5% of the aggregate fair value, as of the Closing Date, of all of the certificates (other than the Class R certificates).

As of the date of this prospectus, there are no material differences between (a) the valuation methodology or any of the key inputs and assumptions that were used in calculating the fair value or range of fair values disclosed in the preliminary prospectus under the heading “*Credit Risk Retention*” prior to the pricing of the certificates and (b) the valuation methodology or the key inputs and assumptions that were used in calculating the fair value set forth above under this “*Credit Risk Retention*” section.

A reasonable time after the Closing Date, the sponsor will be required to disclose to, or cause to be disclosed to, Certificateholders the following: (a) the fair value of the HRR Certificates that will be retained by the Retaining Third-Party Purchaser based on actual sale prices and finalized tranche sizes, (b) the fair value of the “eligible horizontal residual interest” (as such term is defined in the Credit Risk Retention Rules)

Notes: Downloaded from Bloomberg and SEC Edgar.

B Additional Data Details

Table B.1: Deal counts by vintage year

Vintage year	Deal count
2000	45
2001	59
2002	49
2003	60
2004	77
2005	89
2006	89
2007	78
2008	9
2009	4
2010	19
2011	28
2012	54
2013	99
2014	126
2015	143
2016	121
2017	139
2018 (Q1-Q3)	95

Notes: 1) Deal counts by vintage year for all U.S. nonagency conduit and large loan/single-borrower CMBS issued between Jan 1, 2000, and Sept 30, 2018. Data for 2000-2017 comes from Trepp, and data for 2018 comes from CRE Direct.

Table B.2: Summary Statistics—deal level

Panel A—Pre-crisis (2000-2008 vintages)						
	N	mean	median	sd	min	max
<i>conduit</i>	555	0.744	1	0.437	0	1
<i>cutoffbalance</i>	554	1590	1268	1155	5	7918
<i>ntranches</i>	555	22.4	23	10.0	1	102
<i>orig_wam</i>	555	106.2	109.6	61.8	1	480
<i>cutoffdscr_noi</i>	188	1.75	1.6	0.49	1.27	5.36
<i>cutoffdscr_ncf</i>	483	1.75	1.55	0.67	1.23	7.68
<i>cutoffflt</i>	520	64.9	68.0	8.8	15.2	90
<i>secwac</i>	518	6.13	5.85	1.08	1.92	10.32
<i>closeyear</i>	555	2004	2004	2.25	2000	2008

Panel B—Post-crisis (2009-2016 vintages)						
	N	mean	median	sd	min	max
<i>conduit</i>	594	0.448	0	0.498	0	1
<i>cutoffbalance</i>	594	759	725	530	28	8264
<i>ntranches</i>	594	12.6	11	6.6	1	46
<i>orig_wam</i>	594	84.9	106.7	46.7	1	540
<i>cutoffdscr_noi</i>	442	2.51	2.09	1.27	1.15	17.74
<i>cutoffdscr_ncf</i>	568	2.42	1.99	1.21	1.12	17.38
<i>cutoffflt</i>	586	59.4	61.4	9.9	24.5	89.4
<i>secwac</i>	509	4.45	4.43	1.20	1.11	10.53
<i>closeyear</i>	594	2014	2014	1.64	2009	2016

Notes: 1) Data is for all 2000-2016 vintage nonagency conduit and large loan/single-borrower U.S. CMBS. Data comes from Trepp. 2). All variables are defined in Table 1.

Table B.3: Deal-level characteristics: t-tests

	2000-2008 vintages	2009-2016 vintages	t-stat	p-value
<i>conduit</i>	0.74	0.45	10.74	0.00
<i>cutoffbalance</i>	1590.07	758.81	15.48	0.00
<i>ntranches</i>	22.39	12.59	19.46	0.00
<i>orig_wam</i>	106.19	84.91	6.55	0.00
<i>cutoffdscr_noi</i>	1.75	2.51	-10.76	0.00
<i>cutoffdscr_ncf</i>	1.75	2.42	-11.35	0.00
<i>cutoffltv</i>	64.94	59.43	9.76	0.00
<i>secwac</i>	6.13	4.45	23.56	0.00
<i>closeyear</i>	2004.04	2014	-85.27	0.00

Notes: 1) Results of comparing means for deal-level variables. T-stats and p-values reported in columns 4 and 5. Data is for all U.S. nonagency conduit and large loan/single-borrower CMBS from 2000-2016. Data comes from Trepp. 2). All variables are defined in Table 1.

C Counterfactual Loss Analysis

We conduct our counterfactual loss analysis in three steps. First, we gather realized loss data for loans originated and securitized into either conduit or large loan/single-borrower deals in 2006, 2007, and 2008. We then compute the realized loss rate as the realized loss (Trepp variable *realizedloss*, computed as the difference between the unpaid balance at liquidation and the liquidation proceeds net of expenses) divided by the loan balance at the time of securitization.²² The loss rate represents any liquidations and losses between the time the loan was originated and December 2017.

Table 4 illustrates the loss rates for the 2006-2008 vintages loans. The variable *lossrate_face* has a mean of 8.5% across all loans in all deal types. This is slightly higher than the aggregate results reported in Panel A of Figure 2 would indicate, but not meaningfully so. Additionally, the mean for loans in *conduit* deals is 9%, which is consistent with the aggre-

²²Most of the loans in our sample are securitized within a few months of origination, thus the balance at the time of securitization is essentially equal to the origination balance in most cases. We do, however, conduct robustness checks in which we calculate realized loss rate with origination balance in the denominator, and the results do not change.

gate results in Panel B of Figure 4. Given that conduit deals comprise the vast majority of the sample on a value-weighted basis, and given the fact that the loss rate is computed with face value, not origination balance, in the denominator, the fact that the loan-level results do not perfectly match the deal-level results when large loan/single-borrower deals are included is not concerning.

The fact that *lossrate_face* has a median of 0% indicates that many of the loans have experienced no losses as of December 2017. The variable *anyloss* indicates that less than 20% of the loans experience a realized loss. The likelihood of a loan experiencing a loss in excess of 10% is about 16% (*lossoverten*).

The second step in our loan-level analysis is to estimate losses conditional on observable loan characteristics. Because only 1 in 5 loans experiences a loss, we take two approaches. First, we estimate the probability of a loss and, similarly, the probability of a loss in excess of 10%:

$$lossindicator_{i,j,t} = \beta_0 + \beta_x Cont_{i,j,t} + \epsilon_{i,j,t} \quad (C.1)$$

The dependent variable in equation C.1 is either *anyloss* or *lossoverten*, indicators for whether loan i in deal j originated in year t experienced any loss, or, alternatively, a loss in excess of 10%. The controls include face value at origination (only when the dependent variable is *anyloss*), LTV at issuance, debt service coverage ratio (computed using net operating income) at loan origination, occupancy rate at issuance, years to maturity at issuance, and year, deal type, state, and property type fixed effects.^{23 24}

²³Black et al. (2017) show that characteristics and performance of securitized commercial real estate loans differ from loans retained in banks' portfolios. Our analysis considers securitized loans only, thus we do not take steps to control for such differences in the empirical methodology.

²⁴Property type fixed effects are constructed using the property type definition from the Trepp data (variable *proptype*). We standardize the property type definitions and group them into six broad categories: Multifamily, Office, Retail, Industrial, Hospitality, and Other.

Second, we estimate the size of the realized loss itself using an equation of the form:

$$lossrate_face_{i,j,t} = \beta_0 + \beta_x Cont_{i,j,t} + \epsilon_{i,j,t} \quad (C.2)$$

The dependent variable is the realized loss as of December 2017 divided by the loan value at securitization. The controls include LTV, debt service coverage ratio (computed using net operating income), occupancy rate, years to maturity, and year, deal type, state, and property type fixed effects. Equation C.2 does *not* include loan size as a control given that the dependent variable is already scaled by loan size.

Table 4 summarizes the 2006-2008 and 2017-2018 loan vintage characteristics. Panel A includes 2006-2008 loans, and Panel B includes 2017-2018 loans. We only observe losses for 2006-2008 loans, and loans in these vintage years experienced an average loss rate of about 8.9% of the securitization balance. The observed loss rate for just the 2007-2008 vintages is nearly identical, so we do not report it separately.

As can be seen by comparing Table 4 Panels A and B, the origination characteristics of loans in the pre-crisis period were markedly different from the characteristics of loans originated in the year after the risk retention requirements went into place. Table 5 summarizes these differences. We compare means for the loan characteristics, with the 2006-2008 vintages in column 2 and the 2017 vintage in column 3. The differences in means are all highly significant, most of them economically so. Loans from 2017-2018 are on average \$18 million larger than loans from 2006-2008, and they have about 10% lower LTV and roughly the same maturity. Additionally, the debt service coverage ratios, as measured with net operating income in the numerator, are significantly higher in 2017-2018.

The third and final step in our loan-level analysis is to estimate equations C.1 and C.2 and use the regression coefficients to predict both the probability and size of losses that 2017-2018 originated loans would have incurred had they been securitized in 2006, 2007, or 2008. We estimate equation C.1 using a probit model, and we estimate equation C.2 using a

fractional linear model that both accounts for the left and right censoring of the dependent variable and generates predicted values in the unit interval.²⁵

Table C.1 reports the results of estimating equation C.1 for 2006-2008 vintages. Columns 1-4 use *anyloss* on the left-hand side, and columns 5-8 use *lossoverten* on the left-hand side. The mean predicted probabilities are listed in the last row. The results illustrate that 2017-2018 loans are significantly less likely to incur losses than 2006-2008 loans were they securitized during the 2006-2008 period. The in-sample likelihood of a 2006-2008 loan incurring any loss is 20%, whereas the predicted likelihood of a 2017-2018 loan incurring any loss is roughly 13% across specifications. Similarly, 2017-2018 loans originated during 2006-2008 would have incurred a loss of greater than 10% roughly 10% of the time, whereas actual 2006-2008 loans had a 16% chance of incurring a greater than 10% loss.

Consistent with significantly lower loss probabilities, Table C.2 shows that 2017-2018 loans would have incurred losses much smaller in magnitude had they been originated and securitized in 2006-2008 CMBS. Columns 1-4 report results of estimating equation C.2 using a fractional response model that accounts for the fact that realized loss rates are bounded between 0 and 1 (columns 1-4), as well as an OLS model (columns 5-8). We report predicted losses for both types of models but note that, because the OLS model can generate predictions outside the unit interval, certain specifications produce negative loss rates. Actual 2006-2008 loans have incurred losses on average of 9% of face value as of December 2017. In contrast, as shown in the last row of Table C.2, 2017-2018 loans are predicted to incur losses of 5.5% to 6.1%.

Based on the significantly lower predicted loss probabilities and rates for 2017-2018 loans, the analysis indicates that post-regulation CMBS *deals* would not have performed as poorly during the financial crisis. This lends further support to the deal-level data in Figure 4: It is likely that the 5% requirement is quite stringent based on the characteristics of loans originated after the requirement was put in place.

²⁵We use the Stata function *fracreg* to estimate equation C.2.

Table C.1: Pre-crisis loan loss indicator regression: 2006-2008 vintages

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	<i>anyloss</i>	<i>anyloss</i>	<i>anyloss</i>	<i>anyloss</i>	<i>lossoverten</i>	<i>lossoverten</i>	<i>lossoverten</i>	<i>lossoverten</i>
<i>face</i>	0.000070 (0.00015)	0.000070 (0.00015)	-0.00026 (0.00038)	-0.00067 (0.00045)				
<i>securltv</i>	0.028*** (0.0016)	0.028*** (0.0016)	0.029*** (0.0015)	0.030*** (0.0016)	0.031*** (0.0015)	0.031*** (0.0015)	0.031*** (0.0016)	0.034*** (0.0017)
<i>orig_discrnoi</i>	-0.015* (0.0087)	-0.015* (0.0088)	-0.016 (0.013)	-0.018 (0.012)	-0.019 (0.012)	-0.019 (0.012)	-0.025 (0.017)	-0.028* (0.017)
<i>securocc</i>			-0.0098*** (0.0014)	-0.012*** (0.0017)			-0.010*** (0.0014)	-0.011*** (0.0017)
<i>term_secur</i>			-0.020*** (0.0073)	-0.022*** (0.0073)			-0.0047 (0.0065)	-0.0060 (0.0065)
Constant	-2.80*** (0.12)	-2.79*** (0.12)	-2.07*** (0.25)	-3.02*** (0.57)	-3.13*** (0.12)	-3.12*** (0.12)	-2.53*** (0.25)	-7.11*** (0.30)
Observations	22,140	22,140	20,929	20,885	22,148	22,148	20,937	20,861
Pseudo R-squared	0.0343	0.0348	0.0368	0.0836	0.039	0.0394	0.04	0.0947
Year FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Deal Type FE	No	No	Yes	Yes	No	No	Yes	Yes
State FE	No	No	No	Yes	No	No	No	Yes
Prop Type FE	No	No	No	Yes	No	No	No	Yes
Mean predicted prob 2017-2018	0.133	0.135	0.132	0.131	0.104	0.105	0.104	0.103
Actual probability 2006-2008	0.195	0.195	0.195	0.195	0.162	0.162	0.162	0.162

Notes: 1) Results of estimating probit regressions of realized loan loss indicator variables on controls. The “Mean predicted prob” is the average predicted probability of the outcome based on the coefficient estimates, and the “Actual probability” is the sample frequency of the outcome. 2) Data is for loans originated and securitized in nonagency conduit and large loan/single-borrower U.S. CMBS deals between January 2006 and December 2008. 3) All variables are defined in Table 1. 5). * * * $p < 0.01$, * * $p < 0.05$, and * $p < 0.1$. Standard errors clustered at the deal level.

Table C.2: Pre-crisis loan loss size regression: 2006-2008 vintages

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	<i>Censored</i>	<i>Censored</i>	<i>Censored</i>	<i>Censored</i>	<i>OLS</i>	<i>OLS</i>	<i>OLS</i>	<i>OLS</i>
<i>securltn</i>	0.027*** (0.0013)	0.027*** (0.0013)	0.028*** (0.0013)	0.029*** (0.0014)	0.030*** (0.00017)	0.0029*** (0.00017)	0.0033*** (0.00015)	0.0032*** (0.00016)
<i>orig_dscrnoi</i>	-0.0086 (0.0069)	-0.0087 (0.0070)	-0.0092 (0.014)	-0.012 (0.013)	3.0e-06 (0.00071)	-3.6e-06 (0.00071)	0.00067 (0.0016)	0.00080 (0.0016)
<i>securocc</i>			-0.0080*** (0.0012)	-0.0088*** (0.0014)			-0.0012*** (0.00022)	-0.0012*** (0.00024)
<i>term_secur</i>			-0.0020 (0.0057)	-0.0031 (0.0056)			-0.00029 (0.00084)	-0.00028 (0.00079)
Constant	-3.27*** (0.097)	-3.27*** (0.097)	-2.73*** (0.22)	-4.89*** (0.37)	-0.11*** (0.012)	-0.11*** (0.012)	-0.042* (0.023)	-0.12*** (0.028)
Observations	22,148	22,148	20,937	20,909	22,148	22,148	20,937	20,909
Pseudo R-squared	0.0314	0.0317	0.0315	0.0789				
R-squared					0.024	0.024	0.026	0.076
Year FE	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Deal Type FE	No	No	Yes	Yes	No	No	Yes	Yes
State FE	No	No	No	Yes	No	No	No	Yes
Prop Type FE	No	No	No	Yes	No	No	No	Yes
Mean predicted loss 2017-2018	0.056	0.056	0.057	0.056	0.061	0.061	0.058	0.055
Mean actual loss 2006-2008	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090

Notes: 1) Results of estimating fractional response regressions (columns 1-4) and OLS regressions (columns 5-8) of realized loan losses (*lossrate_face*) on controls. The “Mean predicted loss” is the average predicted loss (as a percent of par value) based on the coefficient estimates, and the “Mean actual loss” is the mean realized loss (as a percent of par value) in the sample. 2) Data is for loans originated and securitized in nonagency conduit and large loan/single-borrower U.S. CMBS deals between January 2006 and December 2008. 3) All variables are defined in Table 1. 5). * * * $p < 0.01$, * * $p < 0.05$, and * $p < 0.1$. Standard errors clustered at the deal level.

D Proof of Theorem 1

In the case of vertical retention, the investors' payoff is given by $(1 - v)A$. As a result the market value of the sold piece must be

$$P_v = (1 - v)E[A|A \leq \hat{A}].$$

Similarly, in the case of horizontal retention, the investors are paid $\min(A, 1 - h) = 1 - h$, since $A \geq A_0 > 1 - h$. Hence,

$$P_h = 1 - h.$$

The payoff functions for the issuer become linear in the asset value A , and can be rewritten as follows

$$\begin{aligned}\pi_v(A) &= P_v + \delta v A, \\ \pi_h(A) &= (1 - \delta)(1 - h) + \delta A.\end{aligned}$$

One can easily verify that when $A = \hat{A}$, $\pi_v(A) = \pi_h(A)$, i.e., the issuer is indifferent between the horizontal and vertical retention structures. In addition, when $A < \hat{A}$, we have $\pi_v(A) > \pi_h(A)$; and when $A > \hat{A}$, we have $\pi_v(A) < \pi_h(A)$. This means that issuers with $A < \hat{A}$ prefer vertical retention, while issuers with $A > \hat{A}$ prefer horizontal retention. Thus, there is a partially separating equilibrium provided

$$A_0 < \hat{A} < 1. \tag{D.1}$$

First, we examine condition $\hat{A} < 1$. Equation (3) says that $P_v = (1 - v)\bar{A}$ when $\hat{A} \geq 1$. Since P_v is weakly increasing in $\hat{A}$, we have $P_v \leq (1 - v)\bar{A}$ for any $\hat{A}$. Hence, equation (3)

implies that

$$\hat{A} \leq \frac{(1-v)\bar{A} - (1-\delta)(1-h)}{\delta(1-v)}. \quad (\text{D.2})$$

One can verify that the right hand side of (D.2) is less than 1 iff

$$\frac{\bar{A} - \delta}{1 - \delta} < \frac{1 - h}{1 - v},$$

which proves the first inequality in (1).

Finally, we show that condition $A_0 < \hat{A}$ is equivalent to the second inequality in (1).

Using equation (2), inequality $A_0 < \hat{A}$ can be rewritten as follows

$$P_v - \delta(1-v)A_0 < (1-\delta)(1-h). \quad (\text{D.3})$$

Since P_v is weakly increasing in $\hat{A}$, $A_0 < \hat{A}$ if and only if inequality (D.3) holds when $\hat{A} = A_0$.

We note that $P_v = (1-v)A_0$ when $\hat{A} = A_0$. Substituting $P_v = (1-v)A_0$ into (D.3) yields

$$(1-v)A_0 - \delta(1-v)A_0 < (1-\delta)(1-h),$$

which can be further simplified to

$$\frac{1-h}{1-v} < A_0.$$

Q.E.D.