Risk Retention and Information in the Face of Regulation*

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Abstract

We analyze how mandated risk retention rules affect the information investors extract from security issuers' retention choices in the commercial mortgage-backed securities (CMBS) market. We show that the new required retention level is both binding and stringent in the context of historical losses and the quality of securities issued after the policies were implemented. Although this implies issuers do not signal using the level of retention, we provide a security design model showing that signaling can occur by varying retention *structure*. The model is consistent with spreads at issue being empirically lower in deals with a purely first-loss retention structure.

JEL: G14, G18, G21, G28.

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1 Introduction

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 a statement from October 2014 on the risk retention rule-writing process, 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)). As a result of these concerns, legislators enacted regulations post-financial crisis requiring issuers of asset-backed securities to retain some of the risk of the securities they issue.

We study the effect of such regulations theoretically and empirically. The data for our empirical tests comes from the commercial mortgage-backed securities (CMBS) market and we focus on the implementation of risk retention rules that forces issuers to retain at least 5% of the fair market value of a deal for a set period of time. This rule came into effect for the CMBS market on December 24, 2016, thus we focus on the CMBS market since January 2017.

Our results suggest that the 5% mandated minimum is stringent and always binding in this market. For conduit CMBS deals originated between 2000 and 2016, the 5% statutory level is significantly higher than the level of current cumulative deal losses (as of December 2017) in every vintage year except 2008. Additionally, the *historical* level of retention that issuers chose, which was well below 5% of market value, has been sufficient to absorb all losses to date for 2000-2003 and 2010-2016 vintage CMBS. Therefore, the 5% minimum is well above what most investors might reasonably expect losses to be in a deal.[1]

In addition to being stringent in light of historical performance, we further show the minimum requirement is likely to be stringent for deals originated in the post-regulation

[1] It is unclear why policymakers chose 5%, but it is conceivable the level was chosen precisely because it would be stringent in light of historical losses. If the goal was to protect investors from all but the most extreme losses, then a high mandated minimum would likely accomplish that.

period, because CMBS *collateral* for 2017-2018 deals is of very different quality from collateral in pre-crisis vintages. We conduct a loan-level analysis in which we compare loans securitized in the 2006-2008 period with loans securitized in 2017-2018. The 2017-2018 vintage loans are less risky on average, having lower LTVs and higher debt-service coverage ratios. Consistent with this, we predict the losses for 2017-2018 loans were they to have been securitized in 2006-2008 and find that estimated losses are at most only 60% of the *realized losses* suffered by 2006-2008 loans.

Although the 5% minimum is high, it is still possible for issuers to choose materially higher levels as a costly signal of quality. For example, an issuer might retain 6% or 7% in order to send a strong signal of the underlying collateral quality. Our results show this is not the case. 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 always choose the legal minimum of 5%.

Given that issuers all choose the legal minimum, the market can no longer use the *level* of retention to extract information about quality. In our final set of tests, we thus examine how issuers instead choose the *structure* of retention as a signal of quality. The new rule allows issuers to choose between three forms of risk retention: "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."[2] In the vertical structure, issuers retain 5% of all securities in the deal, thus they are exposed to 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 yields. 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

[2]In 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.

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 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 paper is important because it is the first to study the impact of retention structure on security pricing following the implementation of the Dodd-Frank Act rules.[3] More generally, we show that an unintended consequence of regulation of security design may be a reduction in the information available to investors.[4] 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

[3]Furfine (2018) studies the effect of the Dodd-Frank Act risk retention rule on the observable characteristics of securitized commercial mortgages but does not consider signaling implications of retention structure.

[4]DeMarzo and Duffie (1999) and DeMarzo (2005) show that issuers can retain a portion of the collateral pool as a costly signal of unobservable quality. Thus, the unintended consequence of retention requirements may be precisely that investors are no longer able to extract information from the level of retention.

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 problem and retained equity to overcome the problem, Ashcraft et al. (2017) show that issuers were able to confuse investors in the CMBS market by selling the equity piece into Collateralized Debt Obligations (CDOs).

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 of security design 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 provide concluding remarks in Section 6.

2 Institutional Detail and Data

Risk retention rules for CMBS under the Dodd-Frank Act are part of a wider set of requirements for risk retention.[5] 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

[5]Gupta and Sachdeva (2018) studies the effects of the Dodd-Frank Act's mandated disclosure of equity stakes in hedge funds.

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.[6] Ashcraft et al. (2017) 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).[7] 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.

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

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

[7]The 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.

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.[8]. 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, it is typically the case that the price of the B-piece is 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 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

[8]See Ambrose et al. (2016), Liu and Quan (2013), and Wong (2018) for discussions of special servicers in CMBS.

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.

2.1 Data

We observe retention data for 206 conduit and large loan/single-borrower[9] 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 $730 million in size with 13 tranches. Because conduit deals typically include more tranches than large loan/single-borrower deals, 57% of the securities in our sample are from conduit deals. We have 98 horizontal deals, 89 vertical deals, and 19 deals structured with a combination of vertical and horizontal. The proportion of securities in deals structured with horizontal ($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

[9] Large 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.

(*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.[10]

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 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 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

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

between the two types of fair values in our analysis of the deal documents.[11]

3 Stringency of Mandated Retention Rules

Using the data described above, we 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. We then document that the rules appear to be binding in all cases.

3.1 Retention requirements in historical context

We first 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

[11] Two examples of the market value data from the deal documents are shown in the Appendix. 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.

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 1 shows cumulative principal losses as of December 2017 across all vintage 2000-2016 conduit deals are *less* than 9% of the total original principal balance.[12] 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. 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 1 shows that B-piece size for conduits was usually less than 5% *of par* value for 2000-2016 vintage deals. Figure 2 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.

[12]Our 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.

3.2 Historical loss counterfactual analysis

Figure 3 overlays Panels A and B of Figure 1 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 that we observe for horizontal conduit deals in the 2017-2018 data. This is illustrated by the fact that the horizontal line at 10% of par value is only exceeded for that vintage.

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 *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 loans and, by extension, 2017 deals, would *not* have incurred losses sufficient to breach the 5% threshold were they to have been originated and securitized in 2006-2008.

We conduct this 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.[13] Because our loan-level data are cumulative as of 2017, the loss rate represents any

[13]Most of the loans in our sample are securitized within a few months of origination, thus the balance at the

liquidations and losses between the time the loan was originated and December 2017.

Table 3 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 1 would indicate, but not meaningfully so. Additionally, the mean for loans in *conduit* deals is 9%, which is consistent with the aggregate results in Panel B of Figure 3. 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%:

$$lossindicator_{i,j,t} = \beta_0 + \beta_x Cont_{i,j,t} + \epsilon_{i,j,t} \tag{1}$$

The dependent variable in equation 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, gross coupon rate at issuance, occupancy rate at issuance, years

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.

to maturity at issuance, and year, deal type, state, and property type fixed effects.[14] [15]

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

$$lossrate\_face_{i,j,t} = \beta_0 + \beta_x Cont_{i,j,t} + \epsilon_{i,j,t} \quad (2)$$

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), gross coupon rate, occupancy rate, years to maturity, and year, deal type, state, and property type fixed effects. Equation 2 does *not* include loan size as a control given that the dependent variable is already scaled by loan size.

Table 3 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 3 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 4 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, lower gross coupon rates, 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.

[14]Black 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.

[15]Property 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.

The third and final step in our loan-level analysis is to estimate equations 1 and 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 1 using a probit model, and we estimate equation 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.[16]

Table 5 reports the results of estimating equation 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 between 6% and 13% depending on the specification. Similarly, 2017 loans originated during 2006-2008 would have incurred a loss of greater than 10% between 4% and 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 6 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 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 6, 2017-2018 loans are predicted to incur losses of 2.5% to 5.6%.

Based on the significantly lower predicted loss probabilities and rates for 2017-2018 loans,

[16]We use the Stata function *fracreg* to estimate equation 2.

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 3: It is likely that the 5% requirement is quite stringent based on the characteristics of loans originated after the requirement was put in place.

3.3 Do retention requirements bind?

Given the 5% requirement is stringent in light of both historical losses and the expected performance of deals originated after the requirement, we next analyze whether the requirement binds. If issuers in practice often retain significantly more than 5% of market value, then the requirement may not be that stringent from the point of view of sponsors. Importantly, this 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. We examine all horizontally structured deals for which these documents are available, which constitutes 24 of 60 horizontal deals. In all such deals, the fair value of the horizontal piece is almost always exactly 5%, or just slightly above. For the deals for which the issuer structures both horizontal and vertical (so-called hybrid or "L" retention), we observe that the sum of the vertical and horizontal fair value is almost always equal to 5%. 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 the summary stats for the variable *vertsize_vrr* in Table 2).

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.[17] 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.[18] As a result, the *security design choice* is a signal

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

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

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 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

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

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 4 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 but only when the level of the horizontal retention is sufficiently high. To simplify the statement of the theorem, we assume that the expected asset value $\bar{A} \equiv E[A]$ is less than δ.[19]

Theorem 1 *If*

$$h > 1 - (1-v)A_0, \tag{3}$$

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

$$\hat{A} = \frac{P_v - (1-\delta)(1-h)}{\delta(1-v)}. \tag{4}$$

[19]When $\bar{A} > \delta$, the existence of an equilibrium would require an upper boundary on h. However, this boundary is not going to be binding in practice. For more details, see the proof of Theorem 1.

The market values of the sold pieces are given by

$$P_v = (1-v)E[A|A \le \hat{A}], \quad (5)$$

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

Proof 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

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

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

$$P_h = 1-h.$$

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

$$\pi_v(A) = P_v + \delta v A,$$

$$\pi_h(A) = (1-\delta)(1-h) + \delta A.$$

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

$$A_0 < \hat{A} < 1. \quad (7)$$

First, we verify that condition $\hat{A} < 1$ always holds. Equation (5) 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 (5) implies that

$$\begin{aligned} \hat{A} &\leq \frac{(1-v)\bar{A} - (1-\delta)(1-h)}{\delta(1-v)} \\ &= 1 + \frac{(1-v)(\bar{A}-\delta) - (1-\delta)(1-h)}{\delta(1-v)} < 1. \end{aligned}$$

The last inequality follows from the assumption that $\bar{A} < \delta$.

Finally, we show that condition $A_0 < \hat{A}$ is equivalent to (3). Using equation (4), inequality $A_0 < \hat{A}$ can be rewritten as follows

$$P_v - \delta(1-v)A_0 < (1-\delta)(1-h). \tag{8}$$

Since P_v is weakly increasing in $\hat{A}$, $A_0 < \hat{A}$ if and only if inequality (8) 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 (8) yields

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

which can be further simplified to equation (3). Q.E.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 (6), while the *sold* piece in a vertical deal is priced at a discount according to equation (5) 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 is going to be on average more heavily discounted that that 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 in the model is not going to change its main prediction that horizontal deals are priced more favorably by the market.

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 differential 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. (2017)), or attempted to back out yields using secondary market pricing data (see Ciochetti and Larsson (2017)). Although issue yields are difficult to obtain, it is advantageous to use them because securities may price at significant premiums or discounts.

In our baseline specification, we regress the yield spread at issue on the retention type and deal- and security-level controls:

$$spread_{i,j,t} = \beta_0 + \beta_1 horizrr_{j,t} + \beta_2 hybridrr_{j,t} + \beta_x Cont_{i,j,t} + \epsilon_{i,j,t} \tag{9}$$

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. (Forthcoming)), 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, 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.[20]

The relation between retention type and market pricing indicated by β_1 in equation 9 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.

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 9 in which we interact retention type with rating indicators. We use two indicators. First, we

[20]Given 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.

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

$$spread_{i,j,t} = \beta_0 + \beta_1 horizrr_{j,t} + \beta_2 RtgIndic_{i,j,t} + \beta_3 horizrr_{j,t} * RtgIndic_{i,j,t} + \beta_x Cont_{i,j,t} + \epsilon_{i,j,t} \quad (10)$$

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 10 is estimated only on investment grade securities.

Table 7 reports results of estimating equation 9. 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 collateral controls: weighted average debt service coverage ratio, weighted average LTV, and weighted average coupon. Column 5 includes B-piece buyer fixed effects.[21]

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.

To investigate cross-sectional variation in the relation between horizontal retention and pricing, we estimate equation 10 and report the results in Table 8. 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.

[21]We 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.

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 8, 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 8 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.

6 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 enacted in the CMBS market in 2017 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.

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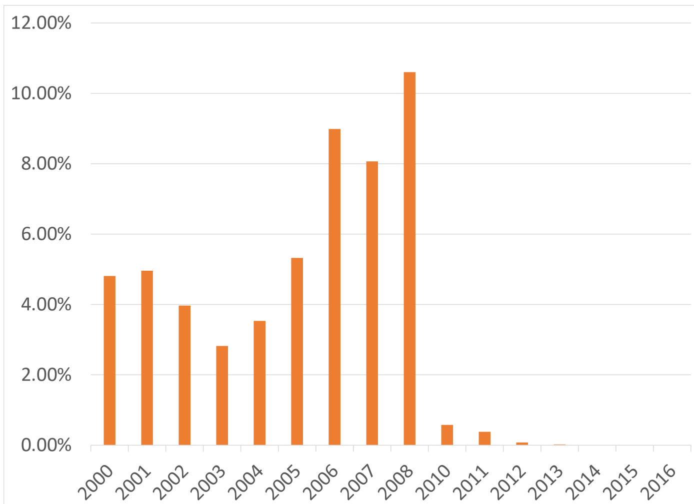
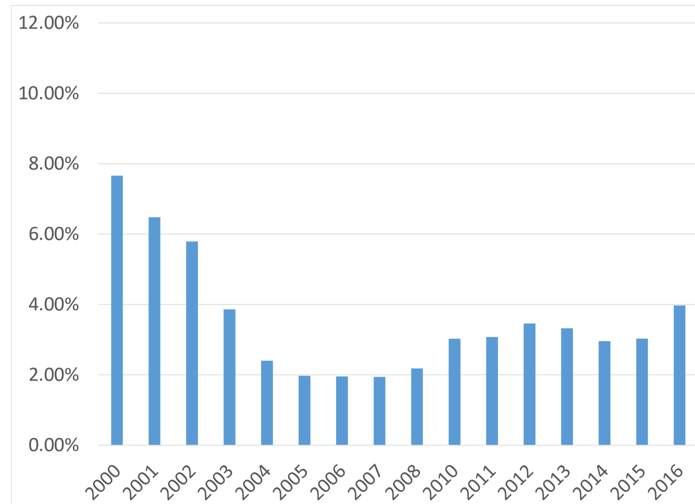
Figure 1: Cumulative losses and B-piece size, 2000-2016 vintage conduit CMBS



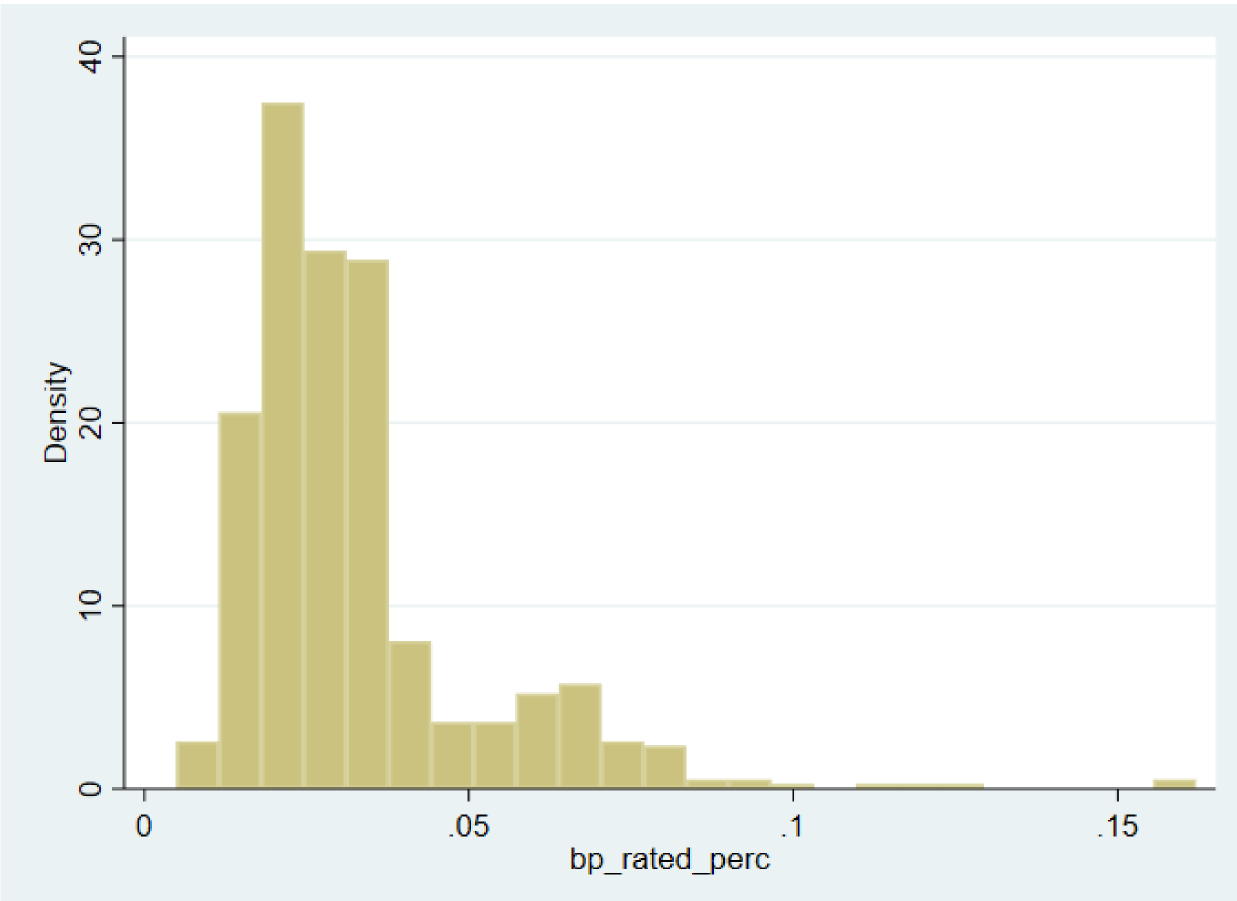
(a) Cumulative principal losses (%)



(b) B-piece size (%)

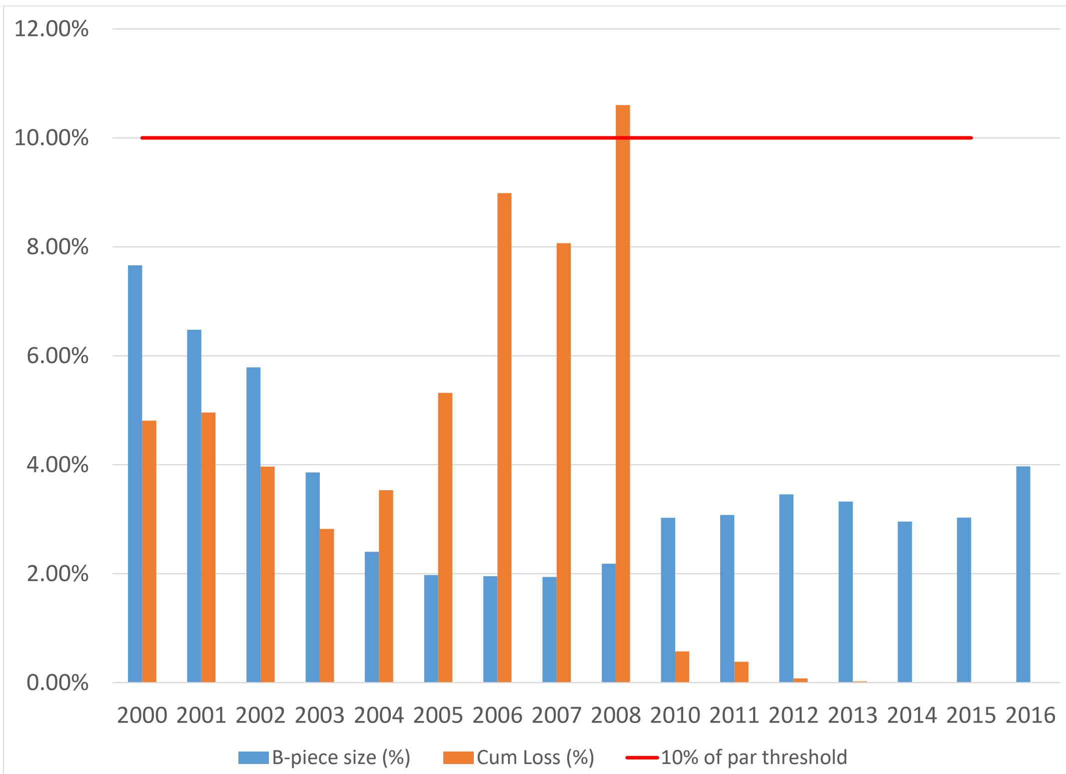
Notes: Left panel is cumulative principal losses across non-IO tranches as a percent of original deal balance as of December 2017. Right panel is B-piece size as percentage of original deal balance. The B-piece is defined as the set of non-IO tranches with average credit rating of less than BBB-. The 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 2: Density of B-piece size for 2000-2016 vintage conduit CMBS



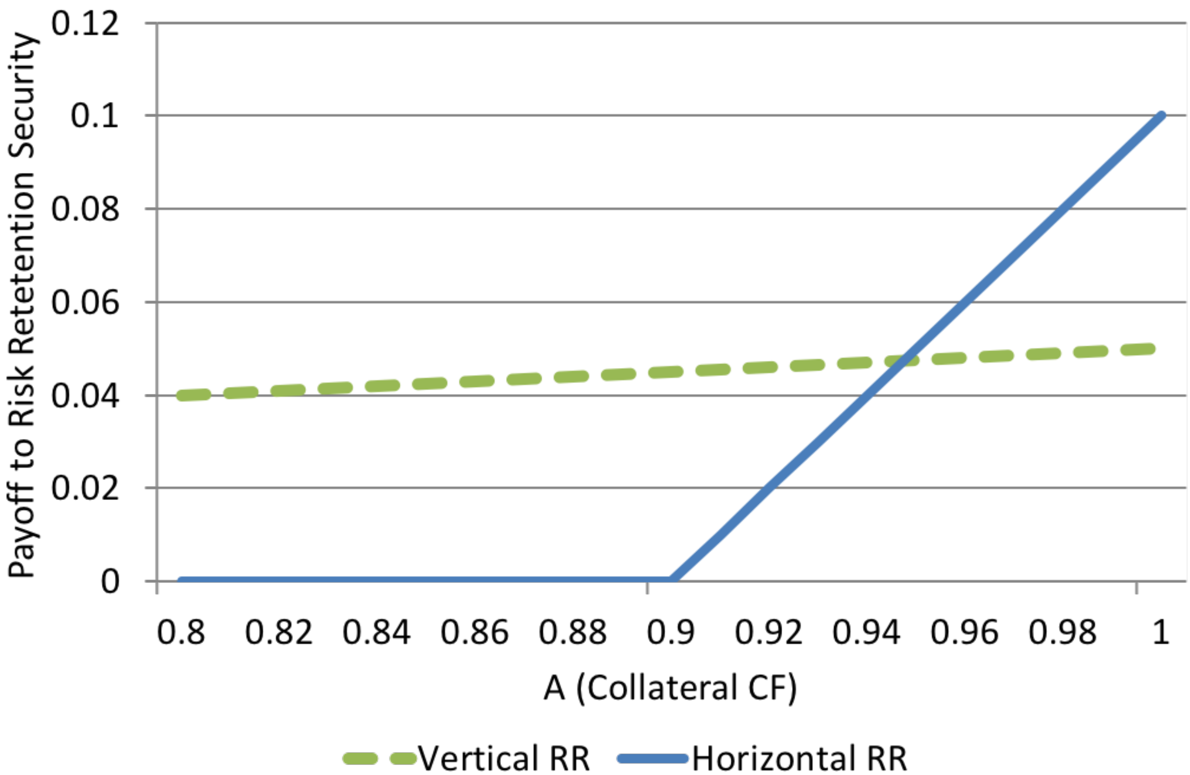
Notes: The figure plots the distribution of the average BBB- subordination level (as a percentage of original deal level) for conduit CMBS.

Figure 3: 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 4: 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.

Table 1: Variable definitions

Variable	Description
A	Indicator equal to 1 if the tranche is rated A+, A, or A- at issue, 0 otherwise
AA	Indicator equal to 1 if the tranche is rated AA+, AA, or AA- at issue, 0 otherwise
AAA	Indicator equal to 1 if the tranche is rated AAA at issue, 0 otherwise
AAA_h	Interaction between horizrr and AAA
anyloss	Indicator equal to 1 if the loan has experienced any losses as of December 2017, 0 otherwise
BB	Indicator equal to 1 if the tranche is rated BB+, BB, or BB- at issue, 0 otherwise
BBB	Indicator equal to 1 if the tranche is rated BBB+, BBB, or BBB- at issue, 0 otherwise
BBB_h	Interaction between horizrr and BBB
conduit	Indicator equal to 1 if deal is Conduit, 0 otherwise
cutoffbalance	Total collateral balance of the deal at origination in billions of dollars
cutoffdscr_ncf	Deal weighted average debt service coverage ratio at origination based on net cash flow
cutoffdscr_noi	Deal weighted average debt service coverage ratio at origination based on NOI
cutoffltv	Deal weighted average LTV at origination
deal2018	Indicator equal to 1 if the deal was originated in 2018, 0 otherwise
depository	Indicator equal to 1 if the lead manager is a depository institution, 0 otherwise
face	Loan balance at securitization in millions of dollars
firstcoupon	Tranche initial coupon in percentage points
floater	Indicator equal to 1 if the tranche is floating rate, 0 otherwise
horizrr	Indicator equal to 1 if the deal is structured with horizontal retention, 0 otherwise
horsize_hrr	Size of horizontally retained piece in a horizontal deal as a percentage of par value
horsize_hyrr	Size of horizontally retained piece in a hybrid deal as a percentage of par value
horsizeofpar	Size of horizontally retained piece as a percentage of par value
hybridrr	Indicator equal to 1 if the deal is structured with L-shaped retention, 0 otherwise
leadmgrsize	Total value of deals originated by lead manager in a given year in billions of dollars
loanhhyrr	Indicator equal to 1 if loan is in deal structured with horizontal or hybrid retention, 0 otherwise
loanhrr	Indicator equal to 1 if loan is in deal structured with horizontal retention, 0 otherwise
lossoverten	Indicator equal to 1 if the loan has experienced losses greater than 10% of face value as of December 2017, 0 otherwise
lossrate_face	Loan realized loss rate, computed as realized loss divided by loan balance at securitization
mtg_orig_wal	Tranch weighted average life at origination
nonAAAsr	Indicator equal to 1 if the tranche is rated between AA+ and BBB- at issue, 0 otherwise
nonAAAsr_h	Interaction between horizrr and nonAAAsr
ntranches	Number of tranches in the deal
orig_dscrnoi	Loan debt service coverage ratio at origination
orig_wam	Deal weighted average maturity at origination
origsubpct	Subordination level of tranche in percentage at origination
securltv	Loan LTV at time of securitization
securocc	Loan property occupancy rate at securitization
securwac	Loan gross coupon rate at securitization
secwac	Deal weighted average coupon
spread	Tranche spread to benchmark at time of initial sale in percentage points
term_secur	Loan term to maturity at securitization
verticalrr	Indicator equal to 1 if the deal is structured with vertical retention, 0 otherwise
vertsize	Size of vertically retained piece as a percentage of par value
vertsize_hyrr	Size of vertically retained piece in a hybrid deal as a percentage of par value
vertsize_vrr	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
horizrr	2266	0.46	0	0.5	0	1
hybridrr	2266	0.15	0	0.36	0	1
verticalrr	2266	0.39	0	0.49	0	1
spread	1207	1.31	1.1	0.85	0.05	6
firstcoupon	1251	3.72	3.64	1.11	0	12.85
AAA	1640	0.39	0	0.49	0	1
AA	1640	0.12	0	0.33	0	1
A	1640	0.12	0	0.32	0	1
BBB	1640	0.15	0	0.35	0	1
BB	1640	0.12	0	0.32	0	1
nonAAAsr	1269	0.5	0	0.5	0	1
conduit	2266	0.57	1	0.5	0	1
origsubpct	1897	22.24	21.13	18.02	0	93.25
floater	2202	0.28	0	0.45	0	1
cutoffbalance	2163	0.73	0.75	0.35	0.1	2.08
leadmgrsize	2266	7.17	7.91	3.48	0.14	12.49
depository	2235	0.41	0	0.49	0	1
ntranches	2262	13.1	14	5.01	2	30
mtg_orig_wal	1899	6.85	7.42	3.34	1.14	15.05
orig_wam	2252	84.89	110	39.25	20.96	121
cutoffdscr_noi	1885	2.54	2.3	0.76	0.49	6.71
cutoffltv	2213	57.38	58.19	7.75	24.3	79.22
secwac	1786	4.37	4.4	0.51	2	6.5
deal2018	2266	0.4	0	0.49	0	1
horsizeofpar	1334	7.41	6.83	2.64	0.94	12.6
vertsize	1194	4.41	5	1.03	1.9	5
horsize_hrr	989	8.08	9.74	2.49	5	12.6
horsize_hyrr	339	5.47	6.3	2.06	0.94	8.34
vertsize_vrr	847	5	5	0	5	5
vertsize_hyrr	339	2.93	2.7	0.81	1.9	4.22

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: Summary Statistics—loan level

Panel A—2006-2008 vintages						
	N	mean	median	sd	min	max
lossrate_face	23325	0.09	0	0.22	0	1
face	23315	17.42	6.32	66.45	0.08	7407.65
securltv	23183	68.65	71.7	11.9	1.3	102
orig_dscrnoi	22158	1.67	1.49	2.47	-0.5	204.17
securwac	23225	6	5.95	0.39	1.21	11.81
securocc	22150	92.75	96.9	10.15	2.3	100
term_secur	23062	8.86	9.73	3.21	0.06	34.83
origyear	23325	2006.46	2006	0.51	2006	2008
anyloss	23325	0.19	0	0.39	0	1
lossoverten	23325	0.16	0	0.37	0	1

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

Notes: 1) Data is for all 2006, 2007, 2008, 2017, and Jan-Sept 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 4: Loan-level characteristics: t-tests

	2006-2008 vintage	2017-2018 vintage	t-stat	p-value
face	17.42	34.90	-8.00	0.00
securltv	68.65	58.97	34.04	0.00
orig_dscrnoi	1.67	2.39	-13.78	0.00
securwac	6.00	4.65	110.55	0.00
securocc	92.75	90.69	9.67	0.00
term_secur	8.86	9.17	-5.81	0.00
origyear	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 September 2018 (column 3). Data comes from Trepp. 2). All variables are defined in Table 1.

Table 5: Pre-crisis loan loss indicator regression: 2006-2008 vintages

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	anyloss	*anyloss*	*anyloss*	*anyloss*	*lossoverten*	*lossoverten*	*lossoverten*	*lossoverten*
face	0.000068	0.000070	0.00013	-0.00011				
	(0.00015)	(0.00015)	(0.00038)	(0.00044)				
securltv	0.028***	0.028***	0.029***	0.031***	0.030***	0.030***	0.032***	0.035***
	(0.0016)	(0.0016)	(0.0015)	(0.0016)	(0.0015)	(0.0015)	(0.0016)	(0.0017)
orig_dscrnoi	-0.014*	-0.014*	-0.010	-0.0075	-0.017	-0.018	-0.016	-0.014
	(0.0081)	(0.0082)	(0.012)	(0.010)	(0.011)	(0.011)	(0.014)	(0.013)
securwac			0.40***	0.44***			0.39***	0.42***
			(0.039)	(0.039)			(0.039)	(0.039)
securocc			-0.0080***	-0.012***			-0.0083***	-0.011***
			(0.0014)	(0.0017)			(0.0014)	(0.0017)
term_secur			-0.017**	-0.018**			-0.0016	-0.0024
			(0.0076)	(0.0076)			(0.0070)	(0.0068)
Constant	-2.79***	-2.78***	-5.11***	-6.29***	-3.11***	-3.11***	-5.33***	-10.1***
	(0.12)	(0.12)	(0.39)	(0.66)	(0.12)	(0.12)	(0.41)	(0.46)
Observations	22,140	22,140	20,879	20,835	22,148	22,148	20,887	20,811
Pseudo-R^2	0.0336	0.034	0.0455	0.0921	0.0383	0.0386	0.0483	0.1026
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	0.134	0.135	0.058	0.056	0.104	0.105	0.046	0.044
Actual prob: 2006-2008	0.192	0.192	0.192	0.192	0.16	0.16	0.16	0.16

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 6: Pre-crisis loan loss size regression: 2006-2008 vintages

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Censored	*Censored*	*Censored*	*Censored*	*OLS*	*OLS*	*OLS*	*OLS*
securltv	0.027***	0.027***	0.029***	0.031***	0.0029***	0.0029***	0.0033***	0.0032***
	(0.0013)	(0.0013)	(0.0013)	(0.0015)	(0.00017)	(0.00017)	(0.00016)	(0.00017)
orig_dscrnoi	-0.0083	-0.0084	-0.0038	-0.0031	0.000017	0.000011	0.0018	0.0022
	(0.0067)	(0.0067)	(0.012)	(0.011)	(0.00071)	(0.00071)	(0.0017)	(0.0017)
securwac			0.32***	0.35***			0.048***	0.048***
			(0.033)	(0.033)			(0.0058)	(0.0056)
securocc			-0.0065***	-0.0085***			-0.00093***	-0.0011***
			(0.0012)	(0.0014)			(0.00021)	(0.00024)
term_secur			-0.00073	-0.0012			-0.00023	-0.00020
			(0.0060)	(0.0058)			(0.00091)	(0.00084)
Constant	-3.27***	-3.27***	-5.05***	-7.36***	-0.11***	-0.11***	-0.38***	-0.45***
	(0.098)	(0.098)	(0.33)	(0.47)	(0.012)	(0.012)	(0.045)	(0.050)
Observations	22,148	22,148	20,887	20,859	22,148	22,148	20,887	20,859
Pseudo-R^2	0.0313	0.0316	0.0381	0.0855				
R^2					0.023	0.024	0.031	0.080
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
Predicted mean: 2017-2018	0.056	0.056	0.026	0.025	0.061	0.061	-0.008	-0.011
Actual mean: 2006-2008	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089

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. 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 7: Yield spreads and the form of risk retention

	(1)	(2)	(3)	(4)	(5)
horizrr	-0.085**	-0.089***	-0.077**	-0.065**	-0.096**
	(0.033)	(0.033)	(0.035)	(0.028)	(0.037)
hybridrr	-0.015	-0.016	-0.0024	0.022	0.043
	(0.039)	(0.039)	(0.041)	(0.039)	(0.048)
AAA	-3.37***	-1.96***	-1.92***	-2.19***	-2.42***
	(0.29)	(0.12)	(0.11)	(0.099)	(0.11)
AA	-2.89***	-1.48***	-1.44***	-1.68***	-1.84***
	(0.26)	(0.089)	(0.084)	(0.087)	(0.095)
A	-2.49***	-1.09***	-1.05***	-1.22***	-1.33***
	(0.25)	(0.072)	(0.067)	(0.075)	(0.086)
BBB	-1.39***				
	(0.25)				
BB	-0.98***				
	(0.17)				
conduit	0.61***	0.59***	0.51***	0.50***	0.35***
	(0.089)	(0.092)	(0.078)	(0.10)	(0.11)
origsubpct	0.0048	0.0041	0.0046	0.0081***	0.015***
	(0.0038)	(0.0039)	(0.0037)	(0.0023)	(0.0029)
floater	0.0021	0.021	0.19	0.15	-0.22
	(0.18)	(0.19)	(0.12)	(0.11)	(0.19)
cutoffbalance	-0.065	-0.069	-0.038	-0.057	0.047
	(0.059)	(0.060)	(0.059)	(0.050)	(0.076)
leadmgrsize	-0.0077	-0.0082	-0.0014	0.00039	-0.0065
	(0.0053)	(0.0052)	(0.0095)	(0.0074)	(0.0081)
depository	-0.040	-0.041			
	(0.034)	(0.033)			
ntranches	-0.011**	-0.011*	-0.0045	-0.0027	-0.0056
	(0.0055)	(0.0055)	(0.0048)	(0.0048)	(0.0045)
mtg_orig_wal	0.10***	0.10***	0.10***	0.10***	0.11***
	(0.0049)	(0.0049)	(0.0041)	(0.0032)	(0.0029)
orig_wam	-0.0079***	-0.0076***	-0.0058***	-0.0059***	-0.0089***
	(0.0019)	(0.0020)	(0.0011)	(0.0011)	(0.0020)
deal2018	-0.13***	-0.12***	-0.086**	-0.14***	-0.076
	(0.040)	(0.040)	(0.037)	(0.039)	(0.048)
Observations	1,032	1,014	998	794	643
R-squared	0.806	0.788	0.802	0.866	0.891
Additional collat 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 8: Heterogeneous effects of risk retention on yield spreads

	(1)	(2)	(3)	(4)	(5)	(6)
horizrr	0.024	0.032	0.011	-0.013	-0.054	-0.083**
	(0.034)	(0.034)	(0.034)	(0.036)	(0.035)	(0.038)
hybridrr	-0.019	0.0024	-0.011	0.010	0.040	0.044
	(0.041)	(0.044)	(0.034)	(0.041)	(0.051)	(0.056)
nonAAAsr		0.76***		0.76***		0.64***
		(0.056)		(0.055)		(0.12)
nonAAAsr_h		-0.16**		-0.21***		-0.31***
		(0.064)		(0.065)		(0.077)
BBB	1.57***		1.77***		1.81***	
	(0.10)		(0.10)		(0.12)	
BBB_h	-0.60***		-0.83***		-0.97***	
	(0.16)		(0.16)		(0.19)	
conduit	0.074	0.029	-0.30***	-0.47***	-0.016	0.037
	(0.094)	(0.11)	(0.11)	(0.15)	(0.20)	(0.24)
origsubpct	-0.013***	-0.017***	-0.017***	-0.023***	-0.023***	-0.034***
	(0.0029)	(0.0035)	(0.0030)	(0.0040)	(0.0054)	(0.0090)
floater	-0.0022	0.064	0.17	0.23	0.28	0.55
	(0.20)	(0.25)	(0.13)	(0.15)	(0.27)	(0.36)
cutoffbalance	-0.092	-0.10	-0.045	0.0027	0.011	0.0076
	(0.073)	(0.081)	(0.069)	(0.087)	(0.076)	(0.095)
leadmgrsize	-0.0085	-0.011	-0.0085*	-0.011*	-0.0058	-0.0074
	(0.0058)	(0.0067)	(0.0049)	(0.0057)	(0.0079)	(0.0095)
depository	-0.055	-0.042	-0.014	0.0081		
	(0.034)	(0.035)	(0.030)	(0.033)		
ntranches	-0.0048	0.0014	0.0024	0.0078	0.0071	0.0097
	(0.0064)	(0.0068)	(0.0041)	(0.0047)	(0.0050)	(0.0065)
mtg_orig_wal	0.12***	0.095***	0.12***	0.094***	0.12***	0.091***
	(0.0060)	(0.0045)	(0.0057)	(0.0035)	(0.0089)	(0.0055)
orig_wam	-0.011***	-0.0079***	-0.0080***	-0.0059***	-0.0079***	-0.0046
	(0.0023)	(0.0028)	(0.0016)	(0.0019)	(0.0027)	(0.0035)
deal2018	-0.11**	-0.074*	-0.22***	-0.22***	-0.036	-0.0059
	(0.041)	(0.044)	(0.032)	(0.036)	(0.047)	(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 collat 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.

Appendix

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.

Table 9: 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 10: Summary Statistics—deal level

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

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

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