IRES2013-008

IRES Working Paper Series

Credit Risk and Subordination Levels in Commercial Mortgage-backed Securities (CMBS)

Xudong An
Yongheng Deng
Joseph B. Nichols
Anthony B. Sanders

January, 2013

Credit Risk and Subordination Levels in Commercial Mortgage-backed Securities (CMBS)*

Xudong An
Department of Finance, San Diego State University
xan@mail.sdsu.edu

Yongheng Deng
Institute of Real Estate Studies, National University of Singapore
ydeng@nus.edu.sg

Joseph B. Nichols
Board of Governors of the Federal Reserve
joseph.b.nichols@frb.gov

Anthony B. Sanders
School of Management, George Mason University
asander7@gmu.edu

January, 2013

* We are grateful to Peter DeMarzo, Mark Flannery, Sally Gordon, Dwight Jaffee and Tim Riddiough for helpful comments. Special thanks are due to the Real Estate Research Institute (RERI) for its financial support. All remaining errors as well as the opinions expressed in this paper are our own responsibility. They do not represent the opinions of the Board of Governors of the Federal Reserve System or its staff.

Credit Risk and Subordinations Levels in Commercial Mortgage-backed Securities (CMBS)

1. Introduction

Structured finance products, such as CMBS, offer investors the advantages of a senior-subordinated debt structure where cash flows from underlying commercial mortgage pool are allocated to various tranches of securities (bonds) according to predetermined rules. Typically, repayments of principal are distributed first to the senior tranches while losses due to default are allocated first to the subordinated tranches. This allows for investors to buy the portion of the pool that provides the optimal combination of risk and return, with investors buying senior tranches expect to be well protected from credit risks while those holding subordinated tranches expect higher premium.

Subordination levels, which determine how much credit support the senior tranches obtain from the subordinated tranches, are critical in the senior-subordinated structure. For each CMBS deal, the issuer can improve the market value of the deal with the least amount of subordination in order to carve as many senior bonds as possible from the deal. But at the same time, he needs to convince the investors that the subordination is enough to insulate them from certain levels of credit risk. In this regard, credit rating agencies (CRAs) determine subordination levels for each tranche in order for these tranches to achieve a certain credit ratings, ranging from triple A (AAA) to single C[1].

The CRAs, however, have come under criticism for giving structured finance products including CMBS inflated credit ratings due to conflict of interest as the recent financial crisis unfolded (see, e.g., Bolton, Freixas and Shapiro, 2012; Stanton and

[1] Some unrated tranches are also issued in many CMBS deals.

Wallace, 2012)[2]. Worries about insufficient subordination protection had driven the spread of AAA CMBS bonds to over 200 bps during 2008. In this paper, we study CMBS subordination levels and credit risk. The main question is to what extent the subordination level operated as intended, reflecting the credit risk of the CMBS pool. We also test the alternative hypothesis, that the subordination levels were driven by non-credit risk factors, to partially address the doubt on CRAs' efficacy in subordination design and bond rating.

Given that the goal of subordination is to provide protection for senior tranches, there should be a positive relation between subordination level and credit risk: the higher the credit risk in a given pool, the higher the subordination level a tranche of a given credit quality should have. To test this relation, we look at both *ex post* and *ex ante* default losses of CMBS deals and link them to subordination levels.

We first regress the realized cumulative default loss of each CMBS deal on the subordination levels of its senior AAA, junior AAA and BBB tranches.[3] Interestingly, we find a significant negative, rather than positive, relation between senior AAA and junior AAA subordination levels and *ex post* default loss. For BBB tranches, the relation is positive but it is not as close as we thought, as reflected by the low model fit. What is really surprising is that we find a very simple default loss model based on a few underwriting variables dominates the subordination level in predicting tranche default loss, no matter whether the tranche is senior AAA, junior AAA or BBB.

[2] Credit ratings of most of the CRAs are paid by security issuers.
[3] We carefully match the time window on which we calculate deal loss with the duration of the tranche (senior AAA, junior AAA or BBB) that we analyze to make sure the cumulative default loss of the CMBS deal is in fact the risk bared by a particular tranche.

Proceeding to the *ex ante* measures of credit risk, we regress tranche credit spread on subordination level. The credit spread of a CMBS tranche reflects investors' perception of its credit risk. We find a negative, rather than positive, relation between credit spread and subordination level after 2003 for senior AAA tranches. For junior AAA tranches, the relation is insignificant. For BBB tranches, there is a statistically significant positive relation but again the relation is not as strong as we expect.

A caveat of looking at tranche spread is that subordination level may be endogenous.[4] Therefore, we assess *ex ante* credit risk with a second approach: based on loan level default risk hazard models, we obtain predicted default losses forecasted only with the information available at the time the deal was rated. This gives us a forward looking estimate of tranche credit risk. We then regress the predicted default loss on subordination level. We find that, for junior AAA tranches, there is no significant relation between subordination level and predicted default loss. For both senior AAA and BBB tranches, there is a significant negative, rather than positive, relation between subordination level and predicted default loss after 2004. For senior AAA prior to 2004 there does seem to be a positive correlation between expected losses and subordination rates. For all of these specifications the model fit is low, indicating a lack of close relation between subordination level and predicted default loss.

If subordination level is not a good predictor of CMBS credit risk, as shown in the previous analysis, then what is subordination about? What drives subordination levels? Are there identifiable non-credit risk factors that affect subordination design? If so, are those factors related to the conflict of interest of the CRAs, or there are other market

[4] Credit spread and subordination level may simultaneously be driven by credit risk.

forces that drive subordination design? Those are the questions we try to address in the remaining of this paper.

We test and confirm the importance of a number of non-credit risk factors in the next set of regression analysis. For example, we find that lagged credit spread slope, a potential barometer of relative popularity of different CMBS tranches, significantly affects subordination level. When the credit spread curve is steep, meaning that it is more profitable for issuers to carve out more senior tranches, AAA subordination levels decline. Similarly, we find that lagged average selling price of BBB tranches has a negative impact on subordination level.

Demand on certain CMBS tranches also affects subordination levels. For example, CDO issuance volume has a positive impact on senior AAA subordination level but it has a negative impact on junior AAA and BBB subordination levels. This is possibly due to the fact that junior AAA CMBS bonds and subordinated CMBS bonds can be sold to the CDO market to make CDOs, and thus development of the CDO market creates demand on relatively junior CMBS tranches.

We also find that rating shopping, here measured by the number of ratings a CMBS tranche has, is positively associated with senior AAA subordination level. This contradicts the common wisdom that rating shopping helps issuers obtain more favorable credit rating (subordination level), but it is consistent with our speculation that there is self-selection in rating solicitation – lower quality CMBS deals are sent out to more CRAs for rating.

We find that when CMBS issuers retain residual pieces (B-piece) of a CMBS issuance, the subordination levels of senior AAA, junior AAA and BBB tranches are all lower. This is consistent with an information asymmetry and adverse selection hypothesis: CMBS issuers choose to retain the residual pieces when the credit quality of the CMBS pool is high.

Findings in this paper contributes to the heated debate on the efficacy of CRA credit ratings and to our understanding of how the structured finance products are designed (see, e.g. Zhu and Riddiough, 2009; Sangiorgi, Sokobin and Spatt, 2011; Bolton, Freixas and Shapiro, 2012; Bongaerts, Cremers and Goetzmann, 2012; Stanton and Wallace, 2012; He, Qian and Strahan, 2012). In addition to credit risk, there are other market forces that affect subordination levels. So, subordination level is not just about credit risk as traditionally viewed. In some cases, it reflects the market need of a certain deal structure. This latter view is consistent with the view that clientele effect plays an important role in financial product design (see, e.g., Van Horne, 1985).

We hope our paper can also contribute to the credit risk literature that tries to understand determinants of credit spread. Credit spread is usually viewed as investors' perception of credit risk, although Longstaff, Mithal, and Neis (2005) find that liquidity plays an important role in corporate bond spread and Collin-Dufresne, Goldstein, and Martin (2001) find that a large portion of the variation in credit spread change is not explained by credit risk factors[5]. For CMBS, the traditional view is that subordination level is CRAs' perception of credit risk but we find that non-credit risk factors play important roles in forming subordination levels.

The rest of the paper is organized as follows: section 2 briefly summarizes the mechanism of CMBS structuring and subordination in order to set up the stage; section 3

[5] See Titman, Tompaidis, and Tsyplakov (2004), Chen, Lesmond and Wei (2007) and Huang and Huang (2012) for more discussions about credit spread determinants.

describes our data; sections 4 explains our analysis of the relation between credit risk and subordination; section 5 explains our identification of the determinants of subordination levels; concluding remarks are in a final section.

2. CMBS Product Design and Subordination

2.1 CMBS structure

Commercial mortgage-backed security (CMBS) issuers create CMBS by pooling commercial mortgages and carving out tranches (bonds) out of the commercial mortgage pool. CMBS is an example of a structured finance product where assets are pooled and tranched. A number of studies have shown that this pooling and tranching mechanism helps mitigate market imperfections and creates value (Riddiough 1997, DeMarzo and Duffie 1998, DeMarzo 2005 and Gaur, Seshadri and Subrahmanyam 2005). Intuitively, the pooling and tranching process enhances liquidity, diversification and risk management: by selling relatively "standard" and low-risk CMBS bonds (cash flows) rather than heterogeneous loans, the process greatly enlarges the investor base and facilitates capital flow in commercial mortgage market; in many cases, a large number of loans are pooled together to create diversification effect; finally, several entities with special expertise, such as commercial mortgage underwriter, CMBS issuer, master servicer, special servicer and rating agency are involved in the process to help achieve better risk management.

A typical CMBS is formed when an issuer deposits commercial mortgage loans into a trust[6]. The issuer then pass information of those loans into credit rating agencies (CRAs), and CRAs create a series of tranches (bonds) backed by the loans, which form

[6] The loans could be bought from traditional lenders, portfolio holders or from conduit loan originators.

the senior-subordinated debt structure. The tranches have varying credit qualities from AAA, AA (senior tranche), to BB, B (subordinated) and to unrated (first loss)[7] given that any return of principal generated by amortization, prepayment and default is allocated to the highest-rated tranche first and then the lower-rated tranches, while any losses that arise from a loan default is charged against the principal balance of the lowest-rated tranche that is outstanding (first loss piece).[8] Any interest received from outstanding principal is paid to all tranches[9].

Credit risk is the major concern of CMBS mainly because of two reasons: 1) commercial mortgages underlying CMBS deals are mostly restricted or deterred from prepayment by lockout, yield maintenance, defeasance and/or prepayment penalties; 2) commercial mortgages have substantially higher default rates than residential mortgages. Investors in subordinated tranches can get a as high as 500 bps spread over comparable maturity treasuries (depending on market conditions), while those who invest in AAA tranches get much lower spread since they are expected to be protected by the subordinated tranches of credit risk.

2.2 Subordination

For each CMBS tranche, subordination level is defined as the proportion of principal outstanding of other tranches with lower rating. It reflects “credit support” of that tranche. Credit rating agencies (CRAs) determine subordination levels at deal cutoff [10]. Typically, the CMBS issuer assembles a pool of loans and passes the

---

[7] Many CMBS deals also have an interest only (IO) tranche which absorbs excess interest payment.
[8] This type of structure is often referred to as the “reverse waterfall” structure.
[9] It is noteworthy that many CMBS deals vary from this simple structure. For more information, see Sanders (1999). Also see Sanders (1999) and Geltner and Miller (2001) for other issues such as commercial mortgage underwriting, form of the trust, servicing, commercial loan evaluation, etc.
[10] Moody’s, Standard and Poor’s and Fitch are currently three major CMBS rating agencies. There are other smaller credit rating agencies such as Duff & Phelps, Kroll Bond Ratings, and Realpoint that rate CMBS.

information of these loans to CRAs. CRAs then work independently to examine how much subordination is needed for the tranches to reach certain ratings, such as AAA, AA, A, BBB, etc[11]. This forms the perspective debt structure. In most cases, this debt structure is the final deal structure accepted by the issuer and provided to the investors. However, in case the issuer is not satisfied with the deal structure designed by the CRAs, he (she) may choose to remove certain loans from the pool and ask the CRAs to re-design the structure. Usually two or more rating agencies are invited to CMBS rating and the proposing-revision process for subordination goes recursively. Once the deal structure is finalized, rating agencies provide their credit risk assessment – bond ratings for each CMBS tranche. CMBS investors typically rely on the quality certification given by rating agencies and tell credit quality differences between different tranches mainly by their ratings[12].

In assessing subordination, CRAs gather CMBS deal and underlying loan information and use models to estimate subordination levels needed for each CMBS deal. In fact, each CRA has its own internal model. However, the general framework is approximately the same. CRAs perform typically three levels of analysis: 1) on the property level, based on commercial mortgage loan underwriters' cash flow report, rating agencies adjust property net operating income (NOI) based on their own judgments of whether the number in underwriting report is sustainable given the current market condition and deduct capital items such as capital reserves, tenant improvement and

[11] Throughout the paper, we use the S&P and Fitch rating scale (e.g., AAA). Moody's ratings (e.g., Aaa) are mapped into their S&P/Fitch equivalents.
[12] CRAs also provide surveillance services, i.e., they monitor each CMBS bond after its issuance, and like in corporate bond market, they upgrade and downgrade some bonds according to the change in the CMBS pool performance.

leasing commissions to form the so called net-cash flow (NCF)[13]. CRAs then calculate property value using their own capitalization rates, which could be different from the current market capitalization rate[14]. CRAs may also calculate their "stressed" LTV and DSCR for each loan and feed their stressed LTVs and DSCRs into a loss matrix to form the basic credit support assessments. 2) On the loan level, CRAs look at borrower quality, amortization, cash management, cross- and over-collateralization to make adjustment to their basic credit support assessments. After doing this, CRAs aggregate their analysis into the pool level and assign subordination to each proposed CMBS tranches[15]. 3) Finally rating agencies perform portfolio level analysis, which examines pool diversity (or concentration), information quality and legal and structural issues, and makes final adjustment to subordination levels for each CMBS bond.

It is noteworthy that there is no industry standard for subordination design. Each of the CRAs uses a different quantitative model to determine subordination levels, and they can apply out-of-model adjustments to the subordination levels to account for risks that they believe were not captured by the model[16].

3. Data

[13] CRAs usually apply "haircuts" to loan underwriting NOI.
[14] For example, Moody's uses a stabilized cap rate to try to achieve a "through-the-cycle" property value.
[15] Although rating agencies perform property and loan analysis mainly on individual basis, they sometimes only review a random sample (40-60%) of the loans when number of mortgages in the pool is large, the pool was originated with uniform underwriting standards and the distribution of the loan balance is not widely skewed.
[16] The models used by rating agencies are also evolving over time. For example, in early years, CRAs rely on the static stressed LTV and DSCR and other information at deal cutoff for subordination design. Later, some CRAs employ a dynamic approach which incorporates a default probability model and loss severity model to predict commercial mortgage and CMBS pool expected loss over a relatively long horizon. Moody's Commercial Mortgage Metrics (CMM) is one example of the dynamic models.

Our data on CMBS deals come from CMAlert. CMAlert monitors CMBS issuance worldwide, and thus it provides cutoff information about each CMBS deal[17]. The CMAlert data are at both the deal and tranche (bond) levels. At the deal level, CMAlert reports CMBS deal issuance (closing) date, deal name (name of the trust), total deal amount, denominator (US dollar or other foreign currency), region of distribution, type of deal (conduit, portfolio, fusion, etc.), offering type (rule 144A, private placement, SEC-registered, etc.), names of the issuer, trustee, book runner, seller, master servicer and special servicer, weighted average coupon (WAC), weighted average maturity (WAM), total number of loans and properties underlying the pool, weighted average loan-to-value (LTV) ratio, weighted average debt-service coverage ratio (DSCR), composition of loan types (e.g. percentage of office loans, percentage of hotel loans, etc.), the main location (state) of underlying loans, etc.

At the tranche (bond) level, CMAlert provides information on the name of the tranche, the issuance amount, denominator, ratings (name of the credit rating agencies and ratings assigned by the corresponding CRAs), subordination level, coupon, interest rate benchmark, spread, maturity date, expected life, selling price, etc. The tranche data is linked to the deal data through a unique deal ID for each CMBS deal.

In this paper, we focus on CMBS deals issued and sold within the U.S. Over $1 trillion of CMBS was issued from 1999 to 2012, accounting for about a quarter of all U.S. commercial real estate (CRE) lending. The total number of deals is 902, and there are a total of 15,208 tranches contained in these CMBS deals[18]. Among the CMBS tranches, 4,676 are rated AAA, 1,592 are rated AA, 1,844 are A, 2,988 are BBB, 1,681 are BB,

[17] CMAlert does not provide on-time CMBS performance data.
[18] We exclude government agency deals and deals backed by commercial real estate leases.

1,506 are B. There are also 53 CCC, 48 tranches with junk ratings and 820 unrated tranches. We report the number of CMBS deals and the total issuance amount in each year in Table 1. We also show the average number of tranches in those CMBS deals by cutoff year. As we can see as the overall activity in the market, measured both by the number and the size of deals we also saw the complexity of the deals increase, with the average number of tranches per deal peaking at 25 in 2007.

Table 2 contains descriptive statistics of the CMBS deals in our sample The deals on average were backed by approximately 120 loans which were in turn backed by 150 properties, Office (35%) and retail (38%) accounted for the most common property types, The five largest loans accounted for 44% of the balance of the average deal and te weighted average LTV is 63%. We find that for 38% of the deals the master servicer has chosen itself as the special servicer and most of the deals. Table 3, we provide descriptive statistics of the CMBS tranches. The average subordination rates ranges from 27 percent for the senior AAA, to 15 percent for the junior AAA, to 5 percent for the BBB. The spreads at origination also follow the same path, from 47 basis points for the senior AAA, to 65 basis points for the junior AAA, to 230 basis points for the BBB, The average subordination levels of the senior AAA, junior AAA and BBB tranches by cutoff year and plot them in Figure 1. While the subordination for the senior AAA tranches has been fairly consistent across time, those for junior AAA fell from 30 to 15 and BBB from 12 to 5.

Each CMBS deal is backed by commercial mortgage loans that provide financing for established income-generating properties (multifamily, office, retail, industrial, hotel, healthcare, etc.). Depending on the type of the deal, there are typically 50-400 loans underlying a CMBS deal from different borrowers. However, there are deals that contain only one large loan (large-loan deals)[19], and deals that contain loans from a single borrower (single-borrower deals). CMBS loans generally have a principal balance between $2 million and $15 million; and they usually have a 30-year amortization term with a balloon payment due within 5 to 10 years (interest-only loans became more prevalent by 2006 and 2007). Individual mortgages are usually non-recourse; and, in the event of default, the mortgage is turned over to a CMBS special servicer for workout with the borrower or liquidation. As discussed previously, there is virtually no prepayment risk associated with mortgages that back a CMBS: borrowers that wish to pre-pay are typically constrained to do so through some form of prepayment constraint such as lock-out, prepayment penalty, yield maintenance and defeasance[20].

Our data on CMBS loans is from Morningstar's subsidiary Realpoint. For each loan, Realpoint provides detailed information such as the name of the CMBS deal that the loan is from, loan origination date, original amount, LTV, DSCR, lender, and collateral information including property type, location, etc. In addition, Realpoint monitors the status of each loan so that we can identify whether a CMBS loan is defaulted, prepaid, matured, or current in each month.

We match the Realpoint loan data with the CMAlert deal data through deal information to identify loans underlying each CMBS deal[21].

---

[19] Fusion deals usually contain

[20] For example, defeasance, the more popular form of prepayment constraint in recent years, requires the borrower to deposit treasuries into the trust that mimic the terms of the underlying mortgage in order to prepay the loan.

[21] Since the deal IDs from the two databases do not match, we have to manually build a crosswalk between the two databases based on deal issuance information.

We report the number and amount of CMBS loans used to generate the loan level loss model identified in our sample in each year in Table 4. This dataset runs from 1999 to 2011. We provide summary statistics of the CMBS loans in Table 5. While it does somewhat differ from the characteristics in the same we match with the CMAlert data, it is largely similar in composition. It also includes important contemporaneous loan level variables such as current occupancy rates and current DSCR.

Other data we used in the analysis include: interest rates from the Federal Reserve; commercial property indices from the National Council of Real Estate Investment Fiduciaries (NCREIF), the National Association of Real Estate Investment Trusts (NAREIT) and CBRE; and state level unemployment rates from the Bureau of Labor Statistics (BLS).

4. Credit Risk and Subordination Level

From CMBS issuers' perspective, the least subordination for a given rating structure is desirable because the issuers can sell the senior tranches with a premium but the subordinated tranches with a discount. On the other hand, investors buying senior tranches always demand as much subordination as possible to protect them from default risk of the CMBS pool. Therefore, the optimal subordination design requires a fair coverage of CMBS credit risk. In other words, if a CMBS pool contains higher default risk, then higher subordination level should be provided to its senior tranches.

In order to test the positive relation between subordination level and credit risk, we conduct the following predictive regression analysis:

$$Credit\ risk = f(\text{subordination level}). \quad (1)$$

Measuring the credit risk of a CMBS tranche is challenging. We take several different approaches. The first approach we adopt is to look at the realized default loss of each CMBS deal and calculate the cumulative default loss of the deal during the life of each tranche. This *ex post* measure of credit risk is model independent. We then regress the *ex post* credit risk of the *tranche* on tranche subordination level. The regression takes the following form:

$$C_i = \alpha + \beta_1 b_i + \beta_2 b_i \cdot yr2004 + \varepsilon_i \quad (2)$$

Here C_i is the *ex post* credit risk, b_i is the tranche subordination level, and $yr2004$ is a dummy variable indicating that the CMBS is issued after 2003. We include the interaction of b_i and $yr2004$ dummy to account for any structural break in the CMBS market after 2003. The structured finance markets in general and the CMBS market in particular have experienced significant changes after 2003. For example, the asset-backed securities (ABS) market (especially the subprime ABS market) has exploded and the collateralized debt obligations (CDO) market has developed rapidly; conduit lending, where commercial mortgage loans are originated for the sole purpose of securitization, has become the dominant source of CMBS loans; and defeasance has become a popular means of prepayment constraint.

We run the regressions separately for senior AAA, junior AAA and BBB tranches. Given that even the shortest maturity AAA tranches of the CMBS deals issued after 2009 have not matured, and thus we cannot calculate the cumulative default loss during the full life of those tranches, we exclude all the deals issued after 2009 in this set of analysis. Coincidentally, none of the deals issued after 2009 in our sample has experienced any default loss.

We report the regression results in Table 6. Surprisingly, we see that for senior AAA tranches, subordination level has no significant relation with *ex post* credit risk before 2004 and it has a significant *negative* relation with ex post credit risk. This finding contradicts the expected positive relation between subordination level and credit risk. For junior AAA tranches, there is a significant negative relation between subordination and *ex post* credit risk and this negative relation has not changed after 2003. For BBB tranches, subordination level has a significant positive relation with *ex post* credit risk and this relation becomes more enhanced after 2003. The R-Squares show that the model fits are low suggesting that subordination levels do not predict *ex post* credit risk well. The R-Square of the senior AAA tranches regression is only 2 percent and that of the BBB tranches is only 6 percent.

Is the low predicting power of subordination levels due to the unpredictability of *ex post* credit risk of CMBS tranches? We try to address this question by running some additional regressions on *ex post* credit risk. We add a few underwriting variables to equation (2) and run the following regression:

$$C_i = \alpha + \beta_1 b_i + \beta_2 b_i \cdot yr2004 + \beta_3 NumProps_i + \beta_4 WLTV_i + \beta_5 Top5Loan_i + \beta_6 LogAmt_i + \varepsilon_i \quad (3)$$

Here $NumProps_i$ represents the number of properties in the CMBS loan collateral, $WLTV_i$ represents the weighted LTV of the CMBS deal, $Top5Loan_i$ represents the share of the largest 5 loans in the CMBS pool, and $LogAmt_i$ represents the log of the tranche dollar amount.

We provide the regression results in Table 7. Model 1 represents the aforementioned regression (equation 3). Interestingly, we can see that three of the added underwriting variables, weighted LTV, share of the largest 5 loans and log tranche amount are significant in the senior AAA regression and now subordination level becomes insignificant in the model. The model fit is significantly increased from 2 percent to 12 percent. For junior AAA tranches, model 1 results show that two of the added underwriting variables, weighted LTV and share of the largest 5 loans, are significant although subordination level is still negative and significant. Again, comparing to the model in equation (2) that contains only subordination level as regressor, the model fit is significantly increased from 24 percent to 36 percent. For BBB tranches, weighted LTV and share of the largest 5 loans are also significant, but subordination level becomes insignificant. The model fit also increased significantly from 6 percent to 23 percent.

Next, we leave out subordination level from equation (3) and keep only the underwriting variables in the *ex post* credit risk regression. The regression becomes:

$$C_i = \alpha + \beta_3 NumProps_i + \beta_4 WLTV_i + \beta_5 Top5Loan_i + \beta_6 LogAmt_i + \varepsilon_i \tag{4}$$

This is model 2 in Table 7. We can see that those significant underwriting variables in model 1 remain significant, and the model fits are almost unchanged from model 1, which are significantly higher than those of the regressions where subordination level is used to predict *ex post* credit risk.

Taking the regression results in Tables 6 and 7 together, we find that subordination levels of senior AAA, junior AAA and BBB CMBS tranches do not predict *ex post* credit risk well. Moreover, a very simple regression model that uses only a few underwriting variables available at CMBS deal cutoff does a better job in predicting *ex post* credit risk.

Considering that subordination levels are determined at CMBS issuance, we seek some *ex ante* measures of credit risk in equation (1). The first *ex ante* credit risk measure we use is the credit spread of the CMBS tranche at issuance. We adjust the credit spread reported by CMAlert by tranche selling price since some tranches are not sold at par. The price-adjusted credit spread reflects investors' perception of the tranche credit risk within the same level of bond rating. For example, comparing two CMBS tranches with the same AAA credit rating, the one with higher credit risk will be priced with a higher credit spread. We run the following regression:

$$S_i = \alpha + \beta_1 b_i + \beta_2 b_i \cdot yr2004 + \varepsilon_i \qquad (5)$$

Here S_i is the price-adjusted credit spread of a CMBS tranche. Again we include the interaction term to account for potential structural change in the CMBS market after 2003.

We report our regression results in Table 8. For senior AAA tranches, we see a positive relation between subordination level and credit spread, our *ex ante* credit risk measure, before 2004. However, this relation becomes negative after 2003 (7.95-16.46= -8.51). For junior AAA tranches, there is no significant relation between subordination level and credit spread no matter before or after 2003. For BBB tranches, there is a positive relation between subordination level and credit spread. The model fits of the three regressions are only 9 percent, 0 percent, and 6 percent, respectively.

The second *ex ante* credit risk measure we use is the predicted default loss. In order to obtain the predicted default loss of each CMBS tranche, we build default risk models based on loan level data and use those models to predict CMBS default loss.

At the CMBS loan level, a state of the art default probability model coupled with loss severity assumptions provide us a tool to predict CMBS loan default loss. The default probability model we estimate is a standard Cox proportional hazard model that is widely used in the mortgage literature (see, e.g. Vandell, 1993; Seslen and Wheaton, 2010). The hazard model is convenient mainly because it allows us to work with our full sample of loans despite some observations being censored when we collect our data. Assume the hazard rate of default of a mortgage loan at period T since its origination follows the form

$$h_i\left(T;Z_i\left(t\right)\right)=h_0\left(T\right)\exp\left(Z_i\left(t\right)'\beta\right),i=1,\cdots n. \qquad (6)$$

Here $h_0\left(T\right)$ is the baseline hazard function, which only depends on the age (duration), T, of the loan and is an arbitrary function that allows for a flexible default pattern over time[22]; $Z_i\left(t\right)$ is a vector of covariates for individual loan *i* that include all the identifiable risk factors. In this proportional hazard model, changes in covariates shift the hazard rate proportionally without otherwise affecting the duration pattern of default. Some examples of the covariates include loan balance, the original loan-to-value (LTV) ratio and debt-service coverage ratio (DSCR), the contemporaneous LTV and DSCR, regional dummies, yield curve slope, credit spread, and MSA-level unemployment rate[23]. The model specification is similar to that in An, Deng, Nichols and Sanders (2011). The

[22] Notice that the loan duration time *T* is different from the natural time t, which allows identification of the model.

[23] The contemporaneous LTV and DSCR are from the Realpoint data. Given that commercial properties are not reappraised frequently, and thus the contemporaneous LTV reported by the borrower may not be up-to-date, we experimented with a mark-to-market LTV calculated using the original LTV and change in property value based on a commercial property rice index. We experimented with a number of price indices including the NCREIF NPI, and the CBRE commercial property price index. We also take into consideration loan amortization that affects the remaining loan balance in the mark-to-market LTV calculation.

hazard model is estimated with Maximum Likelihood Estimation (MLE) method using the event-history data of loans[24].

We present the maximum likelihood estimates in Table 9. Contemporaneous DSCR and the contemporaneous occupancy rate are both significant and negatively related to default probability, as we expect. Credit spread and unemployment rate, which are good proxies for overall and local economic environments respectively, are significant and have positive effect on default. For different property types, hotel loans have higher default rates, other things being equal. Loans in Midwest and in Southern part of the country are riskier, while those in Western/Southern Pacific, including California, have lower default risks. Consistent with the existing literature, original LTV is not significant[25].

We then use the default probability model estimated above to predict conditional default probabilities for each loan over its lifetime. We produce two alternative estimates of the probability of default. For our baseline forecast, we assume both the loan level (current DSCR and current occupancy rate) and the market (term spread, credit spread, and state unemployment rate) remain constant for the life of the loan. For our adverse case we assume that each of these measures worsen significantly over the first three years of the loan and then remain flat for the remainder of the loan.[26]

Next, we calculate expected losses of each loan over certain horizons based on loss severity assumptions documented in the Appendix table ($expected\ loss =$

[24] See Clapp, Deng and An (2006) for details about the MLE estimation of the hazard model.
[25] Please refer to An, Deng, Nichols and Sanders (2011) for more discussions about default probability model for CMBS loans.
[26] Under our alternative scenario we assume state unemployment rates increase 3 percentage points, credit spreads rise 30 basis points while the term spread falls by the same amount, occupancy rates fall by 15 percentage points and the DSCR falls by 0.15 over the first three years of the loan.

$loan\ amount \times default\ probability \times loss\ given\ default$). Then, we aggregate loan level expected losses into CMBS deal level to form our *ex ante* credit risk measure. The expected loss rates are reported at different horizons in Table 10. The average cumulative default loss under the baseline forecast reaches is 15.7 percent in the seventh year. It reaches 51.5 percent under the alternative forecast.

Based on these models, we obtain the predicted default loss of each CMBS deal at each point in time, $\widehat{C_{i,t}}$. Finally, we run the predictive model of equation (2) by replacing C_i by $\widehat{C_{i,t}}$, where N is the expected life of the CMBS tranche. So the regression is:

$$\widehat{C_{i,t}} = \alpha + \beta_1 b_i + \beta_2 b_i \cdot yr2004 + \varepsilon_i \qquad (7)$$

We report our regression results in Table 11. Interestingly, it is only for the senior AAA tranches, those whose subordination levels are set independently of credit rating agencies, where see the expected positive sign. Even under this specification, the sign on the subordination rate after 2004 is negative, as it is also negative for the BBB specification. None of these specifications have much explanatory power, suggesting that the subordination rates are not good predictors of *ex ante* credit risk.

To briefly summarize the findings in this section: we find that subordination levels of senior and junior AAA CMBS tranches are not positively related to the credit risk of the CMBS tranche, either using the *ex post* credit risk measure or the *ex ante* credit risk measures. Subordination level of BBB CMBS tranches is weakly related to the credit risk of the CMBS tranche.

5. Determinants of Subordination Levels: Credit Risk and Non-Credit Risk Factors

Our empirical analysis in section 4 shows that subordination levels do not have the close relation with credit risk as we expect. Then the question is what determines subordination levels. In order to answer this question, we run the following regression analysis.

First, we extend the work of An, Deng and Sanders (2007) to regress subordination levels senior AAA, junior AAA and BBB tranches of each CMBS deal on identifiable credit risk factors of the CMBS pool, including the weighted LTV, number of properties in the CMBS pool, pool composition in property type, prepayment constraint coverage, etc. We also include in the regression some tranche characteristics such as the log amount of the tranche and the expected life of the tranche. The regression takes the following form:

$$b_i = \alpha + \gamma_1 NumProps_i + \gamma_2 WLTV_i + \gamma_3 Off_i + \gamma_4 Hotel_i + \gamma_5 Apt_i + \gamma_6 Nurs_i + \gamma_7 Retail_i + \gamma_8 Top5Loan_i + \gamma_9 Lockout_i + \gamma_{10} Penalty_i + \gamma_{11} Yldmain_i + \gamma_{12} Defeas_i + \gamma_{13} LogAmt_i + \gamma_{14} Life_i + \eta_i. \quad (8)$$

We present the regression results in Table 12, model 1. For senior AAA tranches, surprisingly subordination level is not significantly related to the weighted LTV of the CMBS deal, which is usually seen as the most important credit risk factor. The expected life of the tranche also has a surprisingly significant and negative impact on subordination level. We would expect the longer the life of the tranche is, the higher the credit risk exposure it has.

Estimates of other variables are generally conforming to the common wisdom. For example, the percentages of office, hotel and nursing/retirement properties have significant and positive impact on senior AAA subordination level, as office, hotel and nursing/retirement loans usually have higher default risk. The share of the largest 5 loans has a significant and positive impact on subordination level, consistent with the view that the CRAs consider concentration risk. Lockout and prepayment penalty coverage has positive impact on subordination level, which is also reasonable given that existing literatures find that prepayment constraint increases commercial mortgage loan default risk because borrowers can use default as a strategy to exit the mortgage obligation (see, e.g., Riddiough, 2004; An, Deng, Nichols and Sanders, 2011). Finally, the size of the tranche has a positive impact on senior AAA subordination level.

Results on junior AAA tranches are very similar to those of the senior AAA tranches, except that deal weighted LTV is significant for junior AAA subordination level and that tranche size has a negative impact on. For BBB subordination level, the number of properties has a significant negative impact, possibly due to the diversification effect. Deal weighted LTV is positive and significant, conforming to the common wisdom that higher LTV indicates higher credit risk. Surprisingly, the percentages of office and hotel loans are insignificant while the percentage of multifamily loans becomes significant and positive for BBB subordination level. Further, the percentage of retail loans has a negative impact. Contrary to the results for senior and junior AAA tranches, the share of the largest 5 loans has a negative impact on BBB subordination level. Lockout coverage remains positive and significant but prepayment penalty and defeasance coverage becomes significant and negative. Finally, tranche size and expected life both have significant and negative impacts on BBB subordination level.

The R-Squares are 33 percent, 48 percent and 29 percent for senior AAA, junior AAA and BBB regressions, respectively. The model fits are decent but there is apparently room for improvement.

Next, we explore the impact of a number of non-credit risk factors on subordination levels. Therefore, we add the following variables to equation (8).

First, we add a time trend to the regression. Sanders (1999), and Geltner and Miller (2001) document systematic decline in CMBS subordination levels over time. Riddiough (2004) argues that the CRAs follow a "learning by doing" approach in subordination design and they reduce their conservatism when they get familiar with CMBS as the market develops and more and more data become available. So we test whether this hypothesis is valid during the 1999-2012 periods.

Second, existing literature suggests "rating shopping" in the structured finance market, meaning that issuers choose the CRA that provides favorable ratings (see, e.g., Zhu and Riddiough, 2009; Bongaerts, Cremers and Goetzmann, 2012). To test this hypothesis, we include in our regression a dummy variable for tranches that are rated by more than two of the three major CRAs, Moody's, S & P, and Fitch. The rationale is that regulations require that CMBS be rated by at least two CRAs so if an issuer pays to obtain an additional rating it is likely he/she is not satisfied with the two ratings he/she obtained originally and thus seeks an additional more favorable rating.

Third, we consider the impact of institutional complexity. We include a dummy variable indicating that there are more than one book runners for the CMBS deal. We also include a dummy variable indicating whether the special servicer is the same as the master servicer. Increased institutional complexity can increase the difficulty in the resolution of financial distress while reduced institutional complexity can ease the resolution process and thus reduces default loss.

Next, we include a dummy variable indicating whether the issuer keep some residual pieces of the issuance (securitization program as the beneficiary). Information asymmetry may lead CMBS issuers to avoid being a stakeholder when the credit risk of the issuance if high.

The supply and demand of certain CMBS tranches (e.g., senior AAA) may affect the structure of a CMBS issuance. Therefore, we include the credit spread slope in our model. The variable is calculated as the difference between the average AAA CMBS spread and the average B CMBS spread in each quarter. We speculate that as the credit spread slope becomes steeper, issuers would like to issue more senior tranches such as AAA and AA tranches. We lag the variable by one quarter to avoid endogeneity problem. We also include lagged average tranche price as a regressor. When an issuer sees that the price of a certain tranche (e.g. BBB) was low in the last quarter, indicating that investors are less likely to be interested in such tranche, he/she may choose to issue smaller size of such tranche.

Starting from 2003, the collateralized debt obligations (CDO) market developed rapidly, which might have had an impact on the CMBS market. Usually senior AAA CMBS tranches are sold easily and quickly to investors. However, the less senior tranches, especially the mezzanine tranches such as AA, A, and BBB CMBS tranches are not sold easily and quickly in the CMBS market. Some of those CMBS tranches can be re-packaged and sold into CDO pools to make CDOs. From this perspective, the CDO market represents a source of demand on certain CMBS tranches. Therefore, we include CDO issuance as a regressor.

After adding those non-credit risk factors, our subordination regression takes the following form:

$$b_i = \alpha + \gamma_1 NumProps_i + \gamma_2 WLTV_i + \gamma_3 Off_i + \gamma_4 Hotel_i + \gamma_5 Apt_i + \gamma_6 Nurs_i + \gamma_7 Retail_i + \gamma_8 Top5Loan_i + \gamma_9 Lockout_i + \gamma_{10} Penalty_i + \gamma_{11} Yldmain_i + \gamma_{12} Defeas_i + \gamma_{13} LogAmt_i + \gamma_{14} Life_i + \gamma_{15} Bookrn2_i + \gamma_{16} Servsame_i + \gamma_{17} Secur_i + \gamma_{18} Shopping_i + \gamma_{19} LagCrdslope_i + \gamma_{20} LagPrice_i + \gamma_{21} TimeTrend_i + \gamma_{22} CDOIss_i + \eta_i. \quad (9)$$

We report our regression results in Table 12, model 2. Interestingly, we see that securitization program as beneficiary has a significant and negative impact on the subordinations levels of senior AAA, junior AAA and BBB tranches, consistent with the information asymmetry and adverse selection view of issuer's choice in retaining the residual pieces. Lagged credit spread slope has a negative impact on senior CMBS tranches, conforming to our expectation – the steeper the credit spread slope, the more issuance of senior rather than subordinated tranches. Consistent with our speculation of the impact from the CDO market, CDO issuance has a positive impact on senior AAA subordination level but a negative impact on junior AAA and BBB subordination levels – demand on the junior AAA and BBB tranches from the CDO market can drive the issuance of those tranches up. Regarding rating shopping, we do not find strong relation between the number of ratings and subordination levels. The dummy variable is only marginally significant in the senior AAA regression. Finally, the impact of institutional complexity is only significant in the senior AAA regression – when the special servicer is the same as the master service, senior AAA tranches have higher subordination, which contradicts our expectation.

By looking at the R-Squares, we do see significant improvement in model fits after we introduce those non-credit risk factors in our subordination models. The impacts are especially strong in the junior AAA and BBB regressions. This finding, together with the aforementioned coefficient estimates suggest that non-credit risk factors play important roles in determining CMBS subordination levels.

6. Conclusions

Subordination plays an important role in the senior-subordinated structure of securitized transactions. Typically, the structured finance issuer assembles a pool of loans and passes the information of these loans to credit rating agencies (CRAs). CRAs then work independently to examine how much subordination is needed for the tranches to reach certain ratings, such as AAA, AA, A, BBB, etc.

The recent crisis in the securitization markets has made the CRAs the subject of intense scrutiny. CRAs are alleged of poor subordination design and bond rating that give senior CMBS, ABS and CDO bonds insufficient credit risk protection. In this paper, we study the relation between subordination levels and credit risk of CMBS tranches (bonds). We examine to what extent the subordination level operated as intended, reflecting the credit risk of the CMBS pool.

Our analysis is based on deal, tranche (bond) and loan level data on US CMBS securities issued during 1999 and 2012. Results show that subordination levels of senior AAA, junior AAA and BBB CMBS tranches do not have a strong positive relation with tranche credit risk as expected. Further, we find that a number of non-credit risk factors drive subordination levels. Based on these results, we conclude that subordination level is not just about credit risk as traditionally viewed. It also reflects the market need of a certain deal structure. From this perspective, the CRAs may have played a passive role in some of the subordination designs.

The study fills the gap of existing studies and provides important information regarding structured finance vehicles. Rating agencies use their internal models to work with issuers on subordination design. Therefore, little is known to the public (including investors and financial economists) about how different credit risk and non-credit risk factors affect subordination. We identify those factors in our analysis. Further, our results show that even within the same credit rating bonds varies in credit risk. Therefore, investors should pay close attention to how CMBS credit risk impacts different bonds in order to differentiate “good” deals from “bad” deals.

References

An, Xudong, Yongheng Deng, Joseph B. Nichols, Anthony B. Sanders. 2012. Regional Variations in CMBS Loan Default Risk. Working paper.

An, Xudong, Yongheng Deng and Anthony B. Sanders. 2008. Subordination Levels in Structured Financing. In Arnoud Boot and Anjan Thakor (eds.) *Handbook of Financial Intermediation and Banking*, Elsevier. ISBN: 978-0-444-51558-2.

Ashcraft, Adam, Paul Goldsmith-Pinkham, and James Vickery. 2010. MBS Ratings and the Mortgage Credit Boom. FRB of New York Staff Report No. 449.

Bolton, Patrick, Xavier Freixas and Joel Shapiro. 2012. The Credit Rating Game. *Journal of Finance* 67(1): 85-111.

Bongaerts, Dion, K. J. Martijn Cremers and William N. Goetzmann. 2012. Tiebreaker: Certification and Multiple Credit Ratings. *Journal of Finance* 67(1): 113-152.

Chen, L., D. A. Lesmond, and J. Wei, 2007. Corporate Yield Spreads and Bond Liquidity. *Journal of Finance* 62(1), 119-149.

Clapp, John M., Yongheng Deng and Xudong An. 2006. Unobserved Heterogeneity in Models of Competing Mortgage Termination Risks. *Real Estate Economics*, 34(2): 243-273.

Collin-Dufresne, P., R. S. Goldstein, and S. Martin, 2001. The Determinants of Credit Spread Changes. *Journal of Finance* 56(6), 2177-2207.

DeMarzo, Peter. 2005. The Pooling and Tranching of Securities: A Model of Informed Intermediation. *Review of Financial Studies* 18: 1-35.

DeMarzo, Peter. and Darrell Duffie. 1999 A Liquidity-Based Model of Security Design. *Econometrica* 67: 65-99.

Gaur, Vishal, Sridhar Seshadri and Marti G. Subrahmanyam. 2005. Intermediation and Value Creation in an Incomplete Market. FMA European Conference 2005 working paper.

Geltner, David, Norman G. Miller. 2001. *Commercial Real Estate Analysis and Investment*, Mason, OH: South-Western Publishing.

Griffin, John M. and Dragon Yongjun Tang. 2012. Did Subjectivity Play a Role in CDO Credit Ratings? *Journal of Finance*. 67(4): 1293-1328.

He, Jie, Jun Qian and Philip E. Strahan. 2012. Are All Ratings Created Equal? The Impact of Issuer Size on the Pricing of Mortgage-Backed Securities. *Journal of Finance* 67(6): 2097-2138.

Huang, Jingzhi and Ming Huang. 2012. How Much of the Corporate-Treasury Yield Spread Is Due to Credit Risk? *Review of Asset Pricing Studies* 2: 153-202.

Longstaff, F. A., S. Mithal, and E. Neis, 2005. Corporate Yield Spreads: Default Risk or Liquidity? New Evidence from the Credit Default Swap Market. *Journal of Finance* 60 (5), 2213-2253.

Opp, Christian C., Marcus M. Opp, and Milton Harris. 2012. Rating Agencies in the Face of Regulation. *Journal of Financial Economics*. forthcoming (http://dx.doi.org/10.1016/j.jfineco.2012.10.011)

Rajan, Uday, Amit Seru, and Vikrant Vig. 2012. The Failure of Models That Predict Failure: Distance, Incentives and Defaults. *Journal of Financial Economics*. forthcoming.

Riddiough, Timothy J. 1997. Optimal Design and Governance of Asset-Backed Securities. *Journal of Financial Intermediation* 6: 121-152.

Riddiough, Timothy J. 2004. Commercial Mortgage-Backed Securities: An Exploration into Agency, Innovation, Information, and Learning in Financial Markets. University of Wisconsin, Madison, Mimeo.

Riddiough, Timothy J. and Jun Zhu. 2009. Shopping, Relationships, and Influence In the Market for Credit Ratings. Working paper.

Sanders, Anthony B. 1999. Commercial Mortgage-Backed Securities. In *The Handbook of Fixed-Income Securities*, edited by Frank J. Fabozzi. McGraw-Hill Co., 2000.

Sangiorgi, Francesco and Chester Spatt. 2011. Opacity, Credit Rating Shopping, and Bias. Working paper.

Seslen, T. and W. Wheaton. 2010. Contemporaneous Loan Stress and Termination Risk in the CMBS Pool: How "Ruthless" is Default? *Real Estate Economics* 38(2): 225-255.

Stanton, Richard and Nancy Wallace. 2012. CMBS Subordination, Ratings Inflation, and Regulatory Capital Arbitrage. Working Paper.

Titman, S., S. Tompaidis, and S. Tsyplakov, 2004. Market Imperfections, Investment Flexibility, and Default Spreads. *Journal of Finance* 59(1), 165-205.

Van Horne, James C. 1985. Of Financial Innovations and Excesses. *Journal of Finance* 40(3): 621–631.

Vandell, Kerry, Walter Barnes, David Hartzell, Dennis Kraft, and William Wendt. 1993. Commercial Mortgage Defaults: Proportional Hazards Estimations Using Individual

Loan Histories. *Journal of the American Real Estate and Urban Economics Association* 21 (4): 451-480.

Figure 1: Average Senior AAA, Junior AAA and BBB Subordination Levels by Cutoff Year

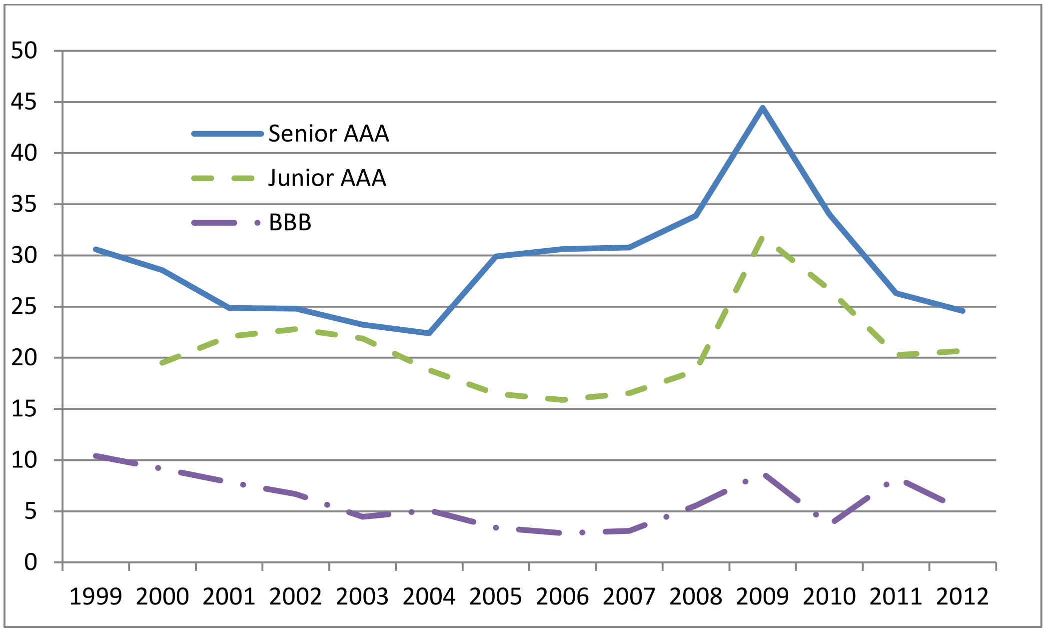

Figure 2: AAA, BBB, B Spread and Credit Spread Slope

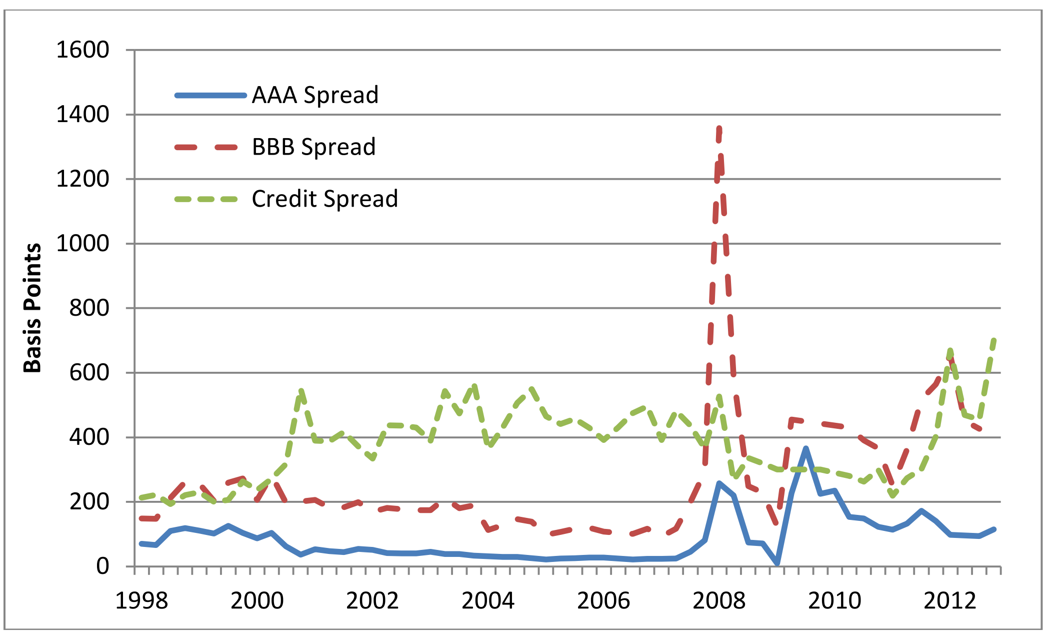

Figure 3: CMBS and Commercial Real Estate CDO Issuance ($Million)

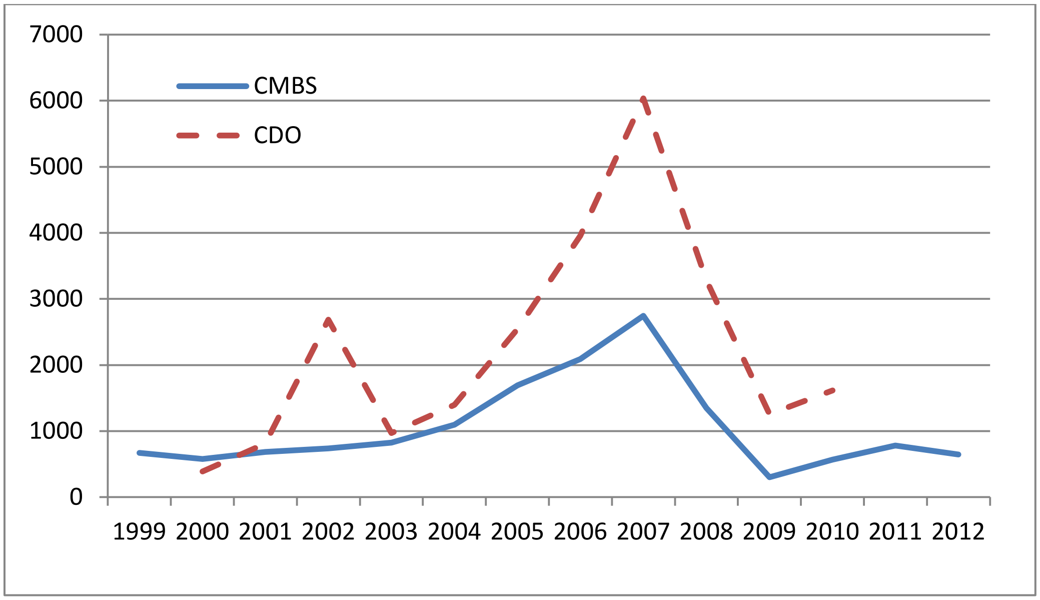

Table 1: Cutoff Year Distribution of the CMBS Deals in Our Sample

Year	# of Deals	$ Amount (billions)	# Tranches	Avg. Tranches per deal
1999	80	695	816	10
2000	80	685	910	12
2001	97	1,166	1,361	14
2002	71	990	1,170	16
2003	94	1,524	1,522	16
2004	85	2,019	1,743	21
2005	100	4,167	2,209	22
2006	94	5,287	2,275	24
2007	83	6,021	2,081	25
2008	9	283	210	23
2009	5	7	19	4
2010	19	94	129	7
2011	41	401	377	9
2012	44	337	386	9

Table 2: Descriptive Statistics of the CMBS Deals

	Average or Percent
Total Deal Amount (millions)	1,184 (1,057)
Number of Underlying Properties	148.6 (165.2)
Number of Underlying Loans	121.7 (356.8)
Deal weighted average LTV	63.4 (9.4)
% of office mortgages	34.5%
% of hotel mortgages	17.5%
% of multi-family mortgages	24.0%
% of nursing/retirement mortgages	16.2%
% of retail mortgages	37.5%
Share of the largest 5 loans	44.4 (28.5)
Lock out coverage	14.8%
Yield maintenance coverage	33.7%
Prepayment penalty coverage	35.9%
Defeasance coverage	27.1%
More than one book runners	35.4%
Special servicer = servicer	38.2%
Securitization program as beneficiary	71.0%

NOTE: Standard deviations for continuous variables are included in parentheses.

Table 3: Descriptive Statistics of the CMBS Tranches (Bonds)

	Senior AAAA	Junior AAA	BBB
Subordination Rate	26.9	15.4	5.1
Spread	47	65	230
Rating shopping	11.5%	18.9%	10.7%
Expected life of the tranche	3.6	8.4	9.4
Ex Post Pool Losses	0.3%	1.8%	1.7%

Table 4: Cutoff Year Distribution of the CMBS Loans in Our Sample

Year	Number of Loans
1999	828
2000	398
2001	271
2002	343
2003	2,049
2004	3,928
2005	4,538
2006	7,734
2007	8,125
2008	6,397
2009	3
2010	393
2011	232

Table 5: Descriptive Statistics of the CMBS Loans

Variables	Average or Percent
Pacific	20.2%
Mountain	9.1%
West North Central	3.9%
West South Central	12.3%
East North Central	11.7%
East South Central	4.3%
South Atlantic	22.4%
New England	3.5%
Balance (millions)	9.717
Underwritten LTV	69.1%
Underwritten DSCR	1.50
Current DSCR	1.49
Current Occupancy Rate	92.5
Yield Curve Slope	0.80
Credit Spread	0.89
Lock-Out Coverage	0.92
Yield maintenance coverage	0.50
Months to complete initial action of Foreclosure	4.3

NOTE: Standard deviations for continuous variables are included in parentheses.

Table 6: OLS Estimates of the *Ex Post* Default Loss Regression
Dependent variable: Realized CMBS deal loss during the life of the tranche

	Senior AAA	Junior AAA	BBB
Intercept	0.003***	0.019***	0.019***
	(0)	(0.001)	(0.001)
Subordination level	0	-0.009***	0.003***
	(0)	(0.001)	(0.001)
Subordination level * issuance year ≥ 2004	-0.001***	0.001	0.004***
	(0)	(0.001)	(0.001)
N	434	211	397
Adjusted R-Square	0.0242	0.2411	0.0631

NOTE: Standard errors are in parentheses. * for p<1%, ** for p<0.1% and *** for p<0.001%.

Table 7: OLS Estimates of the Ex Post Default Loss Regression: Alternative Specifications

Dependent variable: Realized CMBS deal loss during the life of the tranche

	Senior AAA		Junior AAA		BBB	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Intercept	0.003***	0.003***	0.019***	0.019***	0.019***	0.019***
	(0)	(0)	(0.001)	(0.001)	(0.001)	(0.001)
Subordination level	0		-0.004*		-0.002	
	(0)		(0.002)		(0.001)	
Subordination level * issuance year ≥ 2004	0		0.002		0.001	
	(0)		(0.001)		(0.001)	
Number of underlying properties	-0.001	0	0	0	-0.001	0
	(0)	(0)	(0.001)	(0.001)	(0.001)	(0.001)
Deal weighted average LTV	0.002***	0.002***	0.006***	0.006**	0.005***	0.004***
	(0)	(0)	(0.002)	(0.002)	(0.001)	(0.001)
Share of the largest 5 loans	-0.001*	-0.001*	-0.003	-0.004**	-0.005***	-0.004***
	(0)	(0)	(0.002)	(0.002)	(0.001)	(0.001)
Log of tranche amount	0.002***	0.002***	0	0.001	0.001	0.002
	(0)	(0)	(0.001)	(0.001)	(0.001)	(0.001)
N	434	434	211	211	397	397
Adjusted R-Square	0.1186	0.1204	0.3572	0.3453	0.2252	0.2195

NOTE: Standard errors are in parentheses. * for p<1%, ** for p<0.1% and *** for p<0.001%.

Table 8: OLS Estimates of the Tranche Spread Regression

Dependent variable: Price-adjusted credit spread of the CMBS tranche

	Senior AAA	Junior AAA	BBB
Intercept	39.27***	58.058***	201.581***
	(2.092)	(6.203)	(6.662)
Subordination level	7.949**	-2.65	26.202***
	(2.431)	(7.301)	(7.117)
Subordination level * issuance year ≥ 2004	-16.455***	-3.195	-8.367
	(2.466)	(7.284)	(7.052)
N	412	208	311
Adjusted R-Square	0.0940	-0.0064	0.0564

NOTE: Standard errors are in parentheses. * for p<1%, ** for p<0.1% and *** for p<0.001%.

Table 9: MLE Estimates of the Flexible Baseline Default Probability Model

Variables	**Coefficient**	**Standard Error**	**Odds Ratio**
Pacific	-0.463***	(0.119)	0.639
Mountain	0.215*	(0.117)	1.240
West North Central	0.489***	(0.161)	1.631
West South Central	0.559***	(0.127)	1.748
East North Central	0.0267	(0.109)	1.027
East South Central	0.349**	(0.139)	1.418
South Atlantic	0.202*	(0.107)	1.225
New England	-0.0305	(0.176)	0.970
Log Balance	0.292***	(0.0252)	1.340
Underwritten LTV	0.400***	(0.0420)	1.492
Underwritten DSCR	-0.0999***	(0.0350)	0.905
Current DSCR	-1,134***	(0.0428)	0.322
Current Occupancy Rate	-0.261***	(0.0178)	0.771
Yield Curve Slope	-0.138***	(0.0406)	0.871
Credit Spread	0.450***	(0.0237)	1.568
Lock-Out Coverage	-0.611***	(0.0803)	0.543
Yield maintenance coverage	-0.378***	(0.0538)	0.686
Months to complete initial action of Foreclosure	0.100***	(0.0315)	1.105
State Unemployment Rate	0.599***	(0.0352)	1.820

NOTE: Standard errors are in parentheses. * for p<1%, ** for p<0.1% and *** for p<0.001%. Continuous variables have been standardized.

Table 10: Predicted Cumulative Expected Loss Rate of CMBS Loans

	Mean	Std Dev.	Minimum	Maximum
Baseline				
1 year cum. loss rate	0.16	0.15	0.00	1.3
2 year cum. loss rate	0.67	0.62	0.00	5.79
3 year cum. loss rate	1.84	0.17	0.01	15.87
5 year cum. loss rate	6.98	6.42	0.02	59.91
7 year cum. loss rate	15.70	12.14	0.05	60.00
Adverse				
1 year cum. loss rate	0.24	0.22	0.00	2.05
2 year cum. loss rate	1.87	1.72	0.01	16.07
3 year cum. loss rate	9.20	7.95	0.03	60.00
5 year cum. loss rate	36.34	19.10	0.15	60.00
7 year cum. loss rate	51.47	14.78	0.35	60.00
Number of loans	24,169			
Number of deals	442			

NOTE: The numbers are in percent. We use the estimated model 2 in table 13 to predict the hazard rate in each of the 40 duration quarters for each loan. We then calculate the cumulative loss rates for each loan. Deal level cumulative loss rates are top coded at 60%.

Table 11: OLS Estimates of the *Ex Ante* Default Loss Regression, Based on Loan Level Model
Dependent variable: Expected CMBS deal loss during the life of the tranche based on loan level loss models

	Senior AAA	Junior AAA	BBB
Baseline Expected Cumulative Losses			
Intercept	0.041***	0.107***	0.175***
	(0.017)	(0.006)	(0.008)
Subordination level	0.017***	0.016	0.020*
	(0.006)	(0.011)	(0.011)
Subordination level * issuance year ≥ 2004	-0.025***	-0.002	-0.064***
	(0.005)	(0.011)	(0.009)
Adjusted R-Square	0.079	0.002	0.248
Alternative Expected Cumulative Losses			
Intercept	0.179***	0.528***	0.529***
	(0.010)	(0.0180)	(0.008)
Subordination level	0.0687***	0.0140	-0.00884
	(0.0174)	(0.0316)	(0.012)
Subordination level * issuance year ≥ 2004	-0.100***	0.0452	-0.020**
	(0.013)	(0.0325)	(0.009)
Adjusted R-Square	0.157	-0.000	0.0101
N	434	211	397

NOTE: Standard errors are in parentheses. * for p<1%, ** for p<0.1% and *** for p<0.001%.

Table 12: OLS Estimations of the Subordination Level Regression

Dependent variable: CMBS tranche subordination level

	Senior AAA		Junior AAA		BBB	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Intercept	27.721***	101.161	16.368***	-50.609	5.379***	17.652**
	(0.348)	(75.981)	(0.305)	(56.018)	(0.17)	(6.286)
Number of underlying properties	0.413	-0.443	-0.119	0.184	-0.661***	-0.719***
	(0.384)	(0.381)	(0.364)	(0.339)	(0.188)	(0.17)
Deal weighted average LTV	0.917	1.596**	1.628**	2.173***	2.001***	1.906***
	(0.524)	(0.526)	(0.582)	(0.55)	(0.239)	(0.22)
% of office mortgages	1.141**	0.391	0.784	0.586	0.064	-0.499**
	(0.417)	(0.409)	(0.4)	(0.369)	(0.203)	(0.184)
% of hotel mortgages	4.64***	3.86***	2.201***	1.974***	0.042	-0.465*
	(0.465)	(0.452)	(0.456)	(0.415)	(0.236)	(0.211)
% of multifamily mortgages	-0.282	-1.136**	0.479	-0.045	0.572**	-0.117
	(0.402)	(0.403)	(0.37)	(0.36)	(0.183)	(0.181)
% of nursing/retirement mortgages	1.098**	0.789*	1.198***	0.674*	0.46**	0.266
	(0.359)	(0.343)	(0.337)	(0.315)	(0.177)	(0.156)
% of retail mortgages	-0.173	-0.92*	0.559	0.18	-0.491*	-1.425***
	(0.435)	(0.453)	(0.411)	(0.369)	(0.208)	(0.201)
Share of the largest 5 loans	1.214*	0.746	0.967*	0.712	-0.823***	-0.707**
	(0.485)	(0.477)	(0.454)	(0.412)	(0.246)	(0.218)
Lock out coverage	1.121*	1.088*	0.123	0.17	0.681**	-0.24
	(0.434)	(0.449)	(0.375)	(0.34)	(0.208)	(0.201)
Yield maintenance coverage	-1.548	-2.019	1.498	2.014*	0.77	0.095
	(1.317)	(1.267)	(1.129)	(1.012)	(0.587)	(0.516)
Prepayment penalty coverage	2.734*	2.188	-0.738	-0.723	-1.006*	-0.398
	(1.162)	(1.118)	(0.916)	(0.818)	(0.512)	(0.45)
Defeasance coverage	-1.273	-0.32	-0.968	-0.837	-1.105**	0.117
	(0.709)	(0.702)	(0.652)	(0.593)	(0.345)	(0.312)
Log of tranche amount	1.382**	1.362**	-1.618***	-0.725*	-0.584**	-0.433*
	(0.459)	(0.456)	(0.342)	(0.341)	(0.192)	(0.186)
Expected life of the tranche	-1.612***	-1.834***	-3.689***	-4.553***	-1.096***	-1.072***

	(0.418)	(0.412)	(0.588)	(0.588)	(0.229)	(0.203)
More than one book runners		-0.046		-0.248		-0.217
		(0.351)		(0.301)		(0.157)
Special servicer = servicer		1.088**		0.246		0.029
		(0.401)		(0.388)		(0.178)
Securitization program as beneficiary		-2.665***		-1.746***		-1.768***
		(0.422)		(0.334)		(0.195)
Rating shopping		1.04**		0.036		0.146
		(0.378)		(0.324)		(0.166)
Lagged credit spread slope		-0.94*		-0.607*		-1.134***
		(0.378)		(0.292)		(0.174)
Lagged tranche price		-0.733		0.669		-0.124
		(0.758)		(0.559)		(0.064)
Time trend		-0.201		0.97**		-0.433
		(0.47)		(0.337)		(0.235)
CDO issuance		1.82***		-2.157***		-0.84***
		(0.434)		(0.354)		(0.191)
N	680	680	316	316	657	657
Adjusted R-Square	0.3295	0.4011	0.4794	0.5937	0.2907	0.4683

NOTE: Standard errors are in parentheses. * for p<1%, ** for p<0.1% and *** for p<0.001%.

Appendix Table: Loss Severity Assumptions Used in CMBS Pool Expected Loss Calculations

Property type	Loss ratio (%)
Multifamily	32.3
Retail	43.6
Office	38.1
Industrial	35.0
Hotel	52.5
Other	60.6

NOTE: This is based on Moody's study of historical loss ratios of commercial mortgages.