

# **Subordination Level as a Predictor of Credit Risk**

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## **Abstract**

It has been documented that rating agencies use loan-to-value ratio (LTV) and debt-service-coverage ratio (DSCR) as two key variables to determine CMBS subordination levels. However, recent research on commercial mortgage loan performance suggests little statistically significant relationship exists between original LTV, DSCR and commercial mortgage default risk. These facts imply a potential misspecification problem in subordination design. We test the implied association of the subordination level and credit risk of the CMBS pools specified by rating agencies.

Our empirical analysis rejects the null hypothesis. We find that cutoff LTV and DSCR are significant factors in CMBS subordination design provided by rating agencies, and that original LTV has no statistically significant relationship with commercial mortgage default. Further, our analysis shows that CMBS pool default risk has little explanatory power of the deal AAA subordination levels, which suggests the misspecification problem in CMBS subordination design. We conclude that there is potential room to improve rating efficiency in the CMBS market.

# Subordination Level as a Predictor of Credit Risk

## 1. Introduction

The commercial mortgage-backed securities (CMBS) market has grown rapidly during the past two decades<sup>1</sup>. Besides its relatively higher yield<sup>2</sup>, one important feature which makes CMBS attractive to investors is its senior-subordinated debt structure – cash flows from underlying commercial mortgages pools are allocated to various tranches of securities on a prior basis: return of principal is typically distributed first to the senior tranches while losses due to mortgage default are allocated first to the subordinated. Therefore, investors buying senior tranches are expected to be well protected from credit risk<sup>3</sup>, while those holding subordinated tranches will get extraordinary high return.

In forming the senior-subordinated CMBS structure, rating agencies play a key role by assigning credit ratings to various tranches and determining exactly how much subordination (or “credit support”) is required to obtain a particular rating. Subordination level is important because it determines how senior tranches are protected from default losses (realized losses are first absorbed by subordinated tranches).

Our research question comes out of the puzzle that, while it is has been documented that rating agencies use loan-to-value ratio (LTV) and debt-service-coverage ratio (DSCR) as two key variables to determine CMBS subordination levels (Sanders, 1999 and Riddiough and Chiang, 2004 among many others), research on commercial

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<sup>1</sup> CMBS annual issuance has grown from less than \$1 billion in 1985 to \$93 billion in 2004. CMBS outstanding in the first quarter of 2005 reached \$444 billion, which accounts for about 20 percent of \$2.35 trillion commercial mortgage outstanding.

<sup>2</sup> The high credit quality AAA tranches of CMBS usually have 50 to 150 bps spreads over comparable maturity treasuries, and BBB tranches usually have 200-250 bps spreads.

<sup>3</sup> Commercial mortgages have much higher default rates than residential mortgages, which makes credit risk a major concern in CMBS.

mortgage loan performance suggests little relationship between original LTV, DSCR and default, possibly because of the endogeneity of LTV and DSCR to default risk (Ambrose and Sanders, 2003 and Ciochetti et al., 2003 among others).

Therefore, there is a potential misspecification problem when rating agencies assign subordination, namely, they are potentially using mis-specified factors to infer credit risk of the CMBS pool and assign subordination. However, it is possible that rating agencies also use other factors to effectively measure credit risk of CMBS pools. The key research question in this study is how subordination is related to credit risk factors and CMBS pool credit risk.

We perform empirical analysis with a three stage modeling framework: first, we regress subordination levels of AAA tranches of CMBS deals on cutoff LTV, DSCR and other credit risk characteristics of the deals to verify the association of LTV and DSCR and CMBS subordination; second, we use proportional hazard model to analyze risk factors for commercial mortgages default, particularly to test whether original LTV and DSCR are correlated with default risk; and finally we predict CMBS pool default risk based on information of loans underlying each pool and directly relate subordination levels to default risk of the CMBS pools to determine the misspecification problem.

A rich dataset containing information on about 200 CMBS conduit deals and 30,000 commercial mortgage loans underlying those deals makes our empirical analysis feasible. Our results show: 1) cutoff LTV and DSCR, especially the former, are highly correlated with CMBS subordination levels, which suggests these two factors play significant roles in specifying credit risk and subordination level by the rating agencies; 2) original LTV has no statistically significant relationship with commercial mortgage

default; 3) the predicted CMBS pool default risk has little explanatory power of subordination levels, which suggests that there is a misspecification problem in CMBS subordination design. We conclude that there is potential room for rating agencies to improve its rating efficiency and that investors should be skeptical on subordination, especially when rating agencies are implementing a less stringent subordination standards in recent years.

To our best knowledge, this study is the first empirical effort to integrate secondary mortgage market functionality and primary market performance to investigate credit rating efficiency in CMBS market. In addition to its exploring of the misspecification problem in CMBS subordination, the study builds a comprehensive commercial mortgage default model, which could be used by rating agencies, commercial mortgage lenders and CMBS investors.

The next section briefly summarizes the mechanism of CMBS product design and subordination; section 3 explains our research hypothesis and empirical approach; sections 4 and 5 describe the data and model results; concluding remarks are in a final section.

## **2. CMBS Product Design and Subordination**

### **2.1 CMBS structure**

The flourish of the CMBS market well reflects the success of structured finance: a number of commercial mortgages (sometimes only one) are pooled together by CMBS issuers and several tranches of securities are carved out of the pool and sold to investors, which increases liquidity, diversification and risk management in the commercial mortgage market. Lump sum investments go from investors to CMBS issuers, then

commercial mortgage lenders and then borrowers. Monthly mortgage payments come from borrowers to servicers and then to investors. This greatly enlarges the investor base and facilitates capital flow in commercial mortgage market. Several groups of people with special expertise, like commercial mortgage underwriter, CMBS issuer, master servicer, special servicer and rating agency are involved in the process to achieve better risk management.

A typical CMBS is formed when an issuer deposits commercial loans into a trust<sup>4</sup>. The issuer then creates a series of tranches (bonds) backed by the commercial loans and formed the so-called senior-subordinated debt structure. The tranches have varying credit qualities from AAA, AA (senior trache), to BB, B (subordinated) and to unrated (first loss)<sup>5</sup> given that any return of principal caused by amortization, prepayment and default is allocated to the highest-rated trache 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). Any interest received from outstanding principal is paid to all tranches<sup>6</sup>.

Since commercial mortgages are mostly restricted from prepayment by lockout, yield maintenance, defeasance and/or prepayment penalty, and commercial mortgages have much higher default rates than residential mortgages; default risk is the major concern of CMBS investors. Investors of subordinated tranches can get a as high as 500

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<sup>4</sup> The loans could be bought from traditional lenders, portfolio holders or from conduit loan originators.

<sup>5</sup> Many CMBS deals also have an interest only (IO) tranche which absorbs excess interest payment.

<sup>6</sup> It is noteworthy that many CMBS deals vary from this simple structure. For more information, see Sanders (1999) and Darrell (2001). Also see Sanders (1999), Geltner and Miller (2001), Wheeler (2001) for other issues like commercial mortgage underwriting, form of the trust, servicing, commercial loan evaluation, etc.

bps spread over comparable maturity treasuries, while those invest in AAA tranches get much lower spread since they are expected to be protected by the subordinated.

## **2.2 Subordination**

For each tranche, subordination level is simply proportion of principal outstanding in tranches with lower rating. It reflects “credit support” of that tranche. Rating agencies play a key role in determining subordination levels at deal cutoff. Typically, the CMBS issuer proposes a debt structure, and the rating agencies work independently to examine whether the proposed structure can assure the tranches to reach certain ratings. The rating agencies can require the issuer to remove certain loans from the pool or change the amount of tranches in order to assign specific ratings to the tranches<sup>7</sup>.

Rating agencies use two approaches in determining subordination levels: the actuarial approach and the property specific approach. 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, rating agencies will use the actuarial approach, which looks at the pool credit quality through aggregate loan characteristics. Otherwise, rating agencies would rely more on a loan-by-loan analysis. However, in either case, LTV and DSCR are two key factors in subordination design. Usually rating agencies review a sample (40-60%) or full number of individual loans in each pool to determine the LTV and DSCR of the pool. Then they produce a default frequency and loss potential of the pool by feeding the LTV and DSCR into a loss matrix and assign subordination to each tranche. Pools with higher LTV are seen as bearing

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<sup>7</sup> Usually two or more rating agencies are invited to CMBS rating and the proposing-revision process for subordination goes recursively. Moody’s, Standard and Poor’s and Fitch are currently three major CMBS rating agencies.

higher risk, and thus require more subordination, while those with higher DSCR will have less subordination requirements.

Rating agencies also look at other variables for subordination design, e.g. potential liquidation/workout costs, geographic and property diversification, the relative size of the larger loans as percentage of the pool, etc. It is also noteworthy that rating agencies tend to be very conservative at the beginning of the CMBS market development, and when they get more and more familiar with the product and the market, they are applying less stringent subordination criteria (Sanders, 1999, Geltner and Miller, 2001 and Wheeler, 2001).

### **3. Research Hypothesis and Empirical Approach**

While it has been documented that cutoff LTV and DSCR are the two key variables rating agencies use in determining subordination level (Sanders, 1999, Fishman, 2001, Geltner and Miller, 2001, Wheeler, 2001), recent research confirms that CMBS subordination level is highly correlated with LTV and DSCR (Polleys, 1998 and Riddiough and Chiang, 2004).

However, one important feature of commercial mortgage makes this problematic – original LTV and DSCR might be endogenous to commercial mortgage default risk (Archer et al, 2001, Ambrose and Sanders, 2003), and thus their relationship with default risk might be different from what people usually think. Since default risk is so much a concern of commercial mortgages, lenders/originators make due diligence in assessing credit quality of the borrower and the property. When a lender/originator perceives that a commercial mortgage has higher risk than usual, one important instrument he would use

is to adjust the amount of loan he issues, which results in a lower LTV and higher DSCR<sup>8</sup>. And in many circumstances, commercial mortgage originators are “conservative” so that they might “overreact” to the credit information, which results in over-damped LTV. This makes the usually perceived positive relationships between LTV and default risk and negative relationship between DSCR and default risk not necessarily to be true.

In fact, Vandell et al (1993), Archer et al (2001), Ambrose and Sanders (2003) and Ciochetti et al (2003) provide direct evidence that original LTV and DSCR have little explanatory power of commercial mortgage default. Others like Ciochetti et al (2002) and Chen and Deng (2003) also acknowledge the problem of using original LTV and DSCR as explanatory variables for commercial mortgage default and they instead use estimated contemporaneous LTV and DSCR in their models. Recently, research based on mortgages underlying CMBS pools also verify that original LTV has no relationship with loan default probability (Deng, Quigley and Sanders, 2005).

Therefore, we test whether cutoff LTV and DSCR are playing significant roles in subordination design by rating agencies, whether these two factors are statistically significant in explaining commercial mortgage default<sup>9</sup>, and whether CMBS subordination levels is closely related to pool credit risk. With these tests, we can infer whether there is misspecification problem in CMBS subordination design.

We perform empirical analysis by looking at subordination of specific CMBS deals and default risk of commercial mortgages underlying those deals. We analyze the

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<sup>8</sup> This is legitimate given that, during commercial mortgage origination, borrower and lender usually negotiate loan terms, and loan originator usually possesses good information about both the borrower and the collateralized property (Riddiough, 2000).

<sup>9</sup> For many CMBS deals, especially for conduit deals, commercial mortgages enter the CMBS pool after a short period of warehousing, and thus the cutoff LTV and DSCR are weighted average of original LTV and DSCR of mortgages in the pool.

relationship between CMBS deal subordination levels and default risk of the pools in a three stage framework.

First, we examine how subordination is associated with cutoff LTV and DSCR. Each CMBS deal has cutoff information for AAA subordination, LTV, DSCR. Other information like cutoff year, number of loans, geographic mix, property type mix and over-collateralization are also recorded. Therefore, we can infer the relationship between subordination and LTV and DSCR using multivariate analysis.

Second, we identify all commercial mortgage loans underlying the deals we analyzed in the first stage. Based on loan level information, we use a proportional hazard model to 1) test the endogeneity of original LTV and DSCR with respect to mortgage default risk; and 2) construct a prediction model in order to estimate default risk of CMBS pools. Proportional hazard model has been widely adopted in the literature to analyze commercial mortgage default (Vandell, 1993, Huang and Ondrich, 2002, Ciochetti et al, 2002, 2003, Chen and Deng, 2003). However, the frequently used estimation technique – Cox partial likelihood (CPL) estimation, is not appropriate for prediction purposes because CPL does not estimated the baseline of the hazard function. Therefore, in this study, we adopt the recent development – the Deng, Quigley and Van Order (2000) full maximum likelihood estimation approach to estimate a flexible baseline commercial mortgage default model.

Third, we use the estimated default model from the second stage to predict the cumulative default rates of all mortgage loans. Then we calculate a simple CMBS pool default risk measure – default rates of each CMBS pool as weighted average of loan default rates in that pool using original loan amounts as weights. Finally, we examine

whether the cross deal variation in potential credit risk matches well with subordination levels assigned by rating agencies by simply regressing CMBS deal subordination level on cumulative default rates of the CMBS pool.

#### **4. Data**

We construct a dataset with both CMBS deal information and commercial mortgage loan information by matching a CMBS deal database with a large commercial mortgage loan performance database.

We downloaded 718 CMBS deals from CMBS.COM. CMBS.COM is the most comprehensive database for CMBS, which covers almost all CMBS deals during the period and contains detailed information on cutoff date, cutoff balance, cutoff LTV and DSCR, cutoff AAA and BBB subordination, as well as current values for these variables. It also has detailed information on geographic and property type distributions of properties underlying the loans. Deals were cutoff during 1989-2005. The downloading date of the deal information is April 1, 2005.

We focus on conduit deals and those with all fixed rate loans underlying the pools. Conduit deal is becoming the dominant CMBS deal type. Commercial mortgage loans underlying conduit deals are intended to be put into CMBS pools at origination, and they usually go into the pools after a short warehousing period<sup>10</sup>. Conduit deals has cutoff LTV and DSCR very close to weighted average of original LTV and DSCR of underlying loans, and they are more opaque to public than other type of deals. Therefore, they are the

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<sup>10</sup> Another important deal type is portfolio deal, which has underlying loans originally held in whole loan form by lenders or other investors and then sold to CMBS issuers.

best suitable for our analysis. We end up with 311 conduit deals cutoff during 1995-2005<sup>11</sup>.

We have a large dataset of commercial mortgage loan performance from a major commercial mortgage data corporation<sup>12</sup> with about 50,000 loans originated during 1992-2003. The dataset contains detailed loan level information on origination date, original balance, original LTV and DSCR, mortgage rate, term, type and location of the property, paid off date, delinquency status, etc. The data report date is June 1, 2003.

We match the deal dataset and the loan dataset by deal name. We also verify whether every loan supposed to be in the deal (from number of loans recorded in the deal information) is in our sample, and excludes several deals with over 2 percent of loans missing from them. Finally we end up with 193 conduit deals associated with 30,049 loans. Table 1 lists the deals in our sample. Number of loans underlying each deal varies from 28 to 421, with an average of 156. These deals are cutoff during 1995-2003 (Table 2), and the year distribution somehow reflects the increasing popularity of conduit deals.

We also use other data sources like the Federal Reserve, the National Association of Real Estate Investment Trusts (NAREIT), and the Bureau of Labor Statistics (BLS) for interest rate, commercial property index and unemployment rate.

## **5. Results**

### **5.1 Subordination Analysis**

Table 3 reports descriptive statistics of the 193 deals. Deals are huge with average cutoff balance of \$924 million. AAA subordination level ranges from 12% to 37%, and weighted average LTVs at cutoff are between 43% and 77%. The geographic

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<sup>11</sup> We lost some observations due to missing information on AAA subordination.

<sup>12</sup> The provider prefers to be anonymous.

concentration variable is an entropy measure calculated with the percentages of the largest 10 states in the deal. The higher the value, the more evenly distributed the loans are in geography. The property concentration variable is also an entropy measure, which is calculated with the percentages of the 10 property types such as multifamily, anchored retail, unanchored retail, office, industrial, full service hotel, etc. The variable over-collateralization is percentage of loans with over-collateralization, and the prepayment constraint variable measures the weighted average mortgage term (in months) covered by lockout, yield maintenance, defeasance or prepayment penalty.

Table 4 reports regression results of the subordination model. LTV at cut off has substantial explanatory power subordination. It is highly significant with positive sign and accounts 20 percent of the cross sectional variation in subordination levels. The two factors cutoff LTV and DSCR account for about 25 percent of subordination variation<sup>13</sup>. Model 3 in table 4 shows that subordination level contracts over time, which is consistent with the observation that rating agencies and CMBS issuers tend to be conservative in subordination design at early stage of CMBS market development, and become less stringent with subordination levels. Cutoff LTV and DSCR, together with the year dummies explain 80 percent of subordination level variation. Finally, we add geographic diversification, property type diversification and variables on specific property types in model 4 and 5. Deals with more underlying office and hotel properties require more subordination, and subordination levels tend to decrease with the increase of number of loans in the pools. LTV at maturity somehow measures balloon default risk, which tends to have a positive relation with subordination. It is surprising that some variables have

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<sup>13</sup> We show in appendix A that cutoff LTV and DSCR have 34% explanatory power on subordination levels when we use the 311 deals cutoff from 1995 to 2005.

counterintuitive signs, e.g. the coefficient of the geographic concentration variable suggests that more geographically diversified pools require more rather than less subordination, while the percentage of largest loan in the pool tends to have a negative effect on subordination level. However, no matter which specification we use, one thing is for sure – LTV at cutoff is highly significant and it explains substantial variation in subordination levels, which suggests that it plays a key role in rating agencies’ subordination design.

## **5.2 Loan Default Risk Model**

Moving to the loan level analysis, we lost a few observations due to missing values in LTV and other variables. Table 5 shows the origination year distribution of 28,124 loans left in our sample. Parallel to the year distribution of deals, we have fewer loans originated in 1994 and 1995. The 28,124 loans finance properties widely distributed among 10 regions (Table 6), with the highest share of Southern/Atlantic. Southern/West Coast, Western/Southern Pacific and Northeast/Mid-Atlantic also have over 10 percent loans populated. A further analysis show that these loans are originated in 54 US states, concentrating in California (17.81%), Texas (10.98%) and Florida (7.65%) and New York (6.04%). The loans are within 332 MSAs, with Los Angeles, CA, NewYork, NY, Dallas, TX accounting for over 3 percent each.

The most populated property type is multifamily, which has a share of near 1/3 (Table 7). Retail and office also have significant shares. Table 8 shows characteristics of loans at origination. Original LTVs vary from less than 1% to 113%. Unfortunately we do not have original DSCR in our data. As usually seen, most of these commercial

mortgage loans have prepayment constraint, and lockout covers nearly 50 percent of the maturity terms (Table 9).

We identify 912 defaults (defined as over 60 days of delinquency), which is 3.24% of the whole sample (Table 10). This is higher than residential default rate in a 10 year horizon. We have only 2.37% prepayments, which is much lower than prepayment rate in residential mortgages.

Figure 1 plots the empirical conditional default probabilities at various duration months, comparing to the residential default rate benchmark – the 100% SDA. The default probabilities in our sample in most duration months are two to three times of the 100% SDA, which demonstrates that commercial mortgages could be much riskier than residential mortgages.

Table 11 reports means and variances of time varying variables at origination and at termination. Basically call option and put option values are calculated following Deng, Quigley and Van Order (2000) and volatility of 10 year treasury security rate, credit spread and credit spread volatility are calculated following Ambrose and Sanders (2003). Specifically, call option value is calculated as the ratio of present values of remaining mortgage payment based on market mortgage rate and on coupon rate. For put option, we use the National Association of Real Estate Investment Trusts (NAREIT) REITs index by property type to proximate the property value process of each mortgage, and then calculate the ratio of present value of remaining mortgage payment based on market mortgage rate and property value. Put option value is just this ratio minus 1. Volatility of the 10 year treasury rate is defined as the standard deviation of the 10 year rate measured over the past 24 months. Figure 2 show the treasury rates and yield slope during our

study period, and figure 3 shows the volatility of the 10 year treasury rate. Credit spread is defined as the spread between AAA and Baa rated corporate bond yields, and credit spread volatility is calculated similar to the volatility of the 10 year treasury rate. Figure 4 and 5 plot the credit spread and credit spread volatility. We get monthly unemployment rate by state from the BLS and match into our data. The variable prepayment constraint is a dummy variable indicating, in one specific month, whether the mortgage is covered by any type of prepayment constraint – lock out, yield maintenance or prepayment penalty. We see that average put option value for defaulted loans is significantly higher than loans at large.

We estimate a flexible baseline proportional hazard model following the method in Deng, Quigley and Van Order (2000) for default risk. The reason why we only focus on default risk are two folds: first, prepayment is very rare in commercial mortgage as seen in our sample<sup>14</sup>; second, prepayment theoretically has little to do with subordination level. Table 12 presents the full maximum likelihood estimation results.

Put option value is significantly positively related to default, and its quadratic term is also significant and positive. Different from the competing risks story in residential mortgages, call option value is positively related to default. In fact, this is consistent with the observation that given prepayment constraint and common workout practice in commercial mortgages, borrowers could simply choose to default when it's optimal to refinance and they could get a new mortgage to pay off the principal when original lender/servicer come to “workout” the loan. Unemployment rate, which is a good proxy for local economic environment is significant and has a positive effect on default. For different property types, hotel loans have higher default rates as expected.

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<sup>14</sup> This could be mainly because of the prepayment constraint.

Multifamily and office loans tend to have lower default rates, although the coefficients are not significant at the 5% significance level. Loans in Midwest/Eastern and in Southern part of the country are riskier, while those in Western/Southern Pacific, including California have lower default risk. This is consistent with regional real estate market performance.

Our focus variable, the original LTV has no significant relationship with default risk, or it even tends to show some negative effect. We also analyze the correlations of original LTV and put option and call option values. We find that the correlations are very low, which exclude the possibility that put option and call option value capture the effect of original LTV on default risk. Therefore, the results support the argument that original LTV is endogenous to default risk, and it is not a good measure of default risk.

### **5.3 Prediction and the Misspecification Problem of CMBS Subordination**

So far our results tend to suggest that there is a misspecification problem in subordination design. In the last stage of our analysis, we directly link subordination to CMBS pool default risk.

We use the default risk model estimated in our second stage to predict conditional default probabilities during first 65 duration months for each loan. We then calculate cumulative default probabilities at each point. Figure 6 plots the average predicted cumulative default rates of the 28,124 loans weighted by original loan balance. The cumulative default rate in the first year is about 0.1 percent and it grows to over 2 percent in year 3 and over 4 percent in year 5.

We then calculate the predicted cumulative default rate for each pool at each duration month by taking average of the cumulative default rate of each loan in the pool

weighted by original loan balance. Table 13 shows the average cumulative default rates of the 174 CMBS deals at 3 month, 6 month, 1 year, 2 year, 3 year and 5 year.

Finally, we regress AAA subordination levels of CMBS deals on the predicted 3 month, 6 month, 1 year, 2 year, 3 year and 5 year cumulative default rates respectively. If subordination well reflects credit risk of the CMBS pools, the cumulative default rates should have strong explanatory power for the AAA subordination levels. In table 14, we see that the 1 year, 2 year and 3 year cumulative default rates are not significant for subordination. One problem of this approach is that subordination reflects “current” credit support and it changes as pool amortizes. Therefore, one may argue that 1 year, 2 year and 3 year cumulative default rates are not significantly related to subordination because of these reasons. However, taking a look at the results on 3 month and 6 month cumulative default rates refutes this explanation. At first sight, we see 3 month and 6 month cumulative default rates are significantly related to subordination levels in the regressions. However, the extremely low adjusted R-square show that they really have no explanatory power on subordination levels. One surprise is that we find 5 year cumulative default rate has some explanatory power on subordination levels – since we know subordination levels change over time and it should reflect “current” credit support, this result provides further evidence that there exists a misspecification problem in the current subordination design provided by rating agencies.

## **6. Conclusion and Discussion**

It has been well documented that rating agencies use cutoff LTV and DSCR as two key variables to determine CMBS subordination levels. However, recent research based on commercial mortgage loan performance suggests that there is little statistically

significant relationship between original LTV, DSCR and default risk. Therefore, there is a potential misspecification problem in the current subordination design, namely rating agencies are using mis-specified factors to infer credit risk of the CMBS pool and assign subordination accordingly.

Our empirical analysis based on a rich data set containing both CMBS deal information and loan information suggests that this is really a problem. We verify that cutoff LTV and DSCR play significant roles in determining CMBS subordination levels, and that original LTV has no relationship with commercial mortgage default. Further, our analysis shows that CMBS pool default risk has little explanatory power of the deal AAA subordination levels, which confirms misspecification problem in subordination design. We conclude that there is potential room to improve rating efficiency in the CMBS market, and that investors should be skeptical on subordination.

In practice, subordination hasn't been a problem possibly because rating agencies and CMBS issuers have been very conservative in subordination design in the early stage of CMBS market development, and that subordination levels have been systematically higher than needed (Downing and Wallace, 2005). When rating agencies are applying less stringent subordination standards in the following years, the misspecification problem could be detrimental.

Our study is the first empirical effort to integrate secondary market functionality and primary market performance to investigate credit rating efficiency in CMBS market based on loan level data<sup>15</sup>. In addition to its exploring of the risk measurement error

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<sup>15</sup> To our knowledge, Riddiough and Chiang (2004) and Downing and Wallace (2005) are the only ones that study CMBS subordination. Both studies are based on CMBS deal level information.

problem, it builds a comprehensive commercial mortgage default model, which could be used by rating agencies, commercial mortgage lenders and CMBS investors.

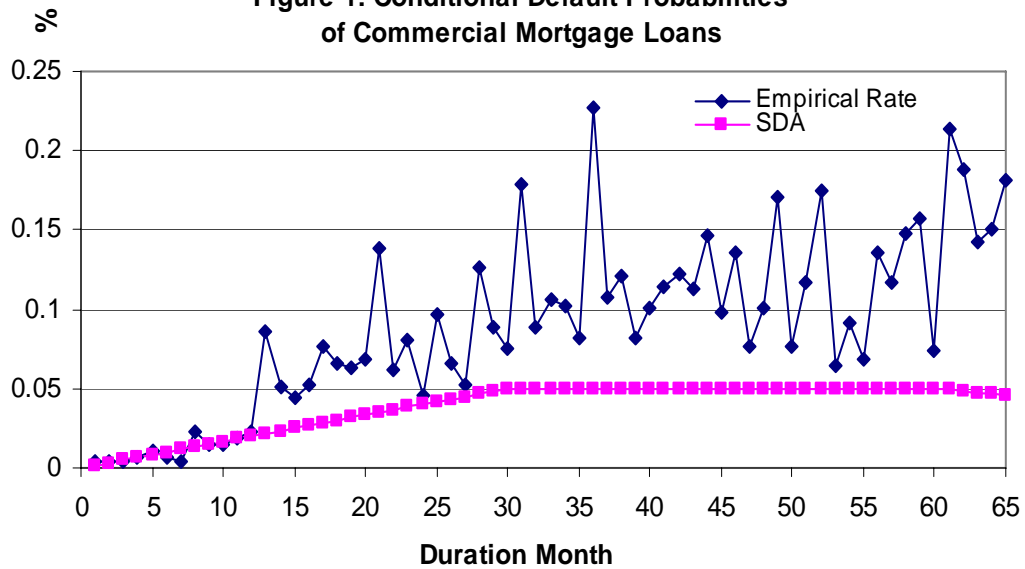
There are certain limitations of the current analysis. First, we could simulate cash flows of CMBS pools based on certain loss assumptions in our last stage of modeling to get a more accurate assessment of the CMBS pool default risk. Second, a full competing risks model including prepayment might be helpful to test the robustness of our results. Moreover, one could analyze subordination of other tranches than the AAA tranche to have a complete understanding of rating efficiency in the CMBS market.

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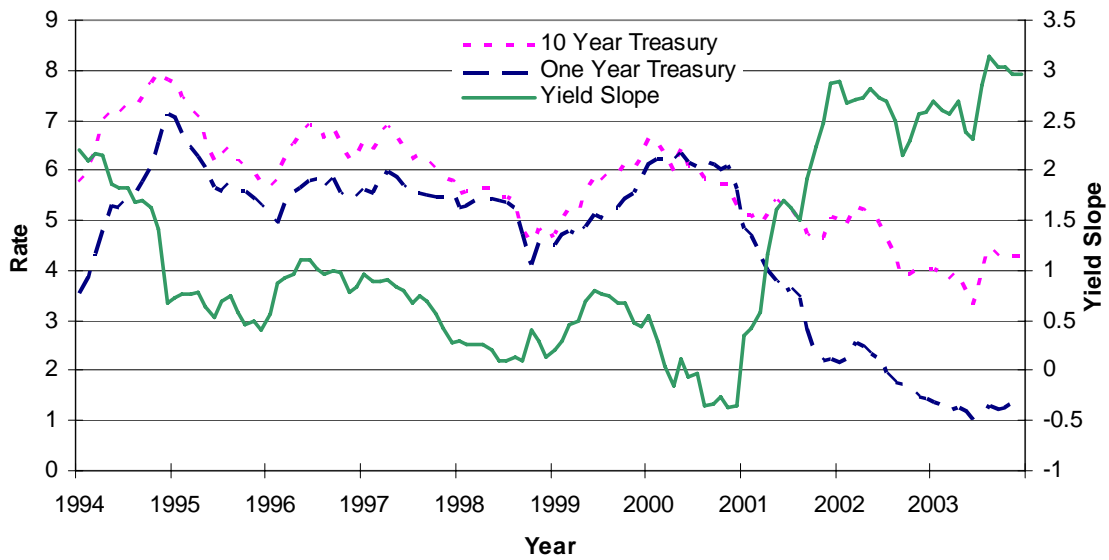
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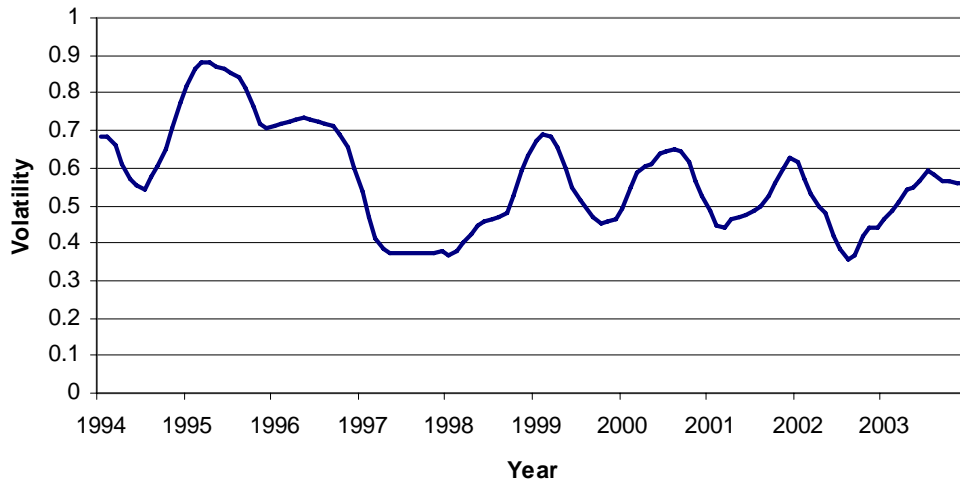
**Figure 1: Conditional Default Probabilities of Commercial Mortgage Loans**



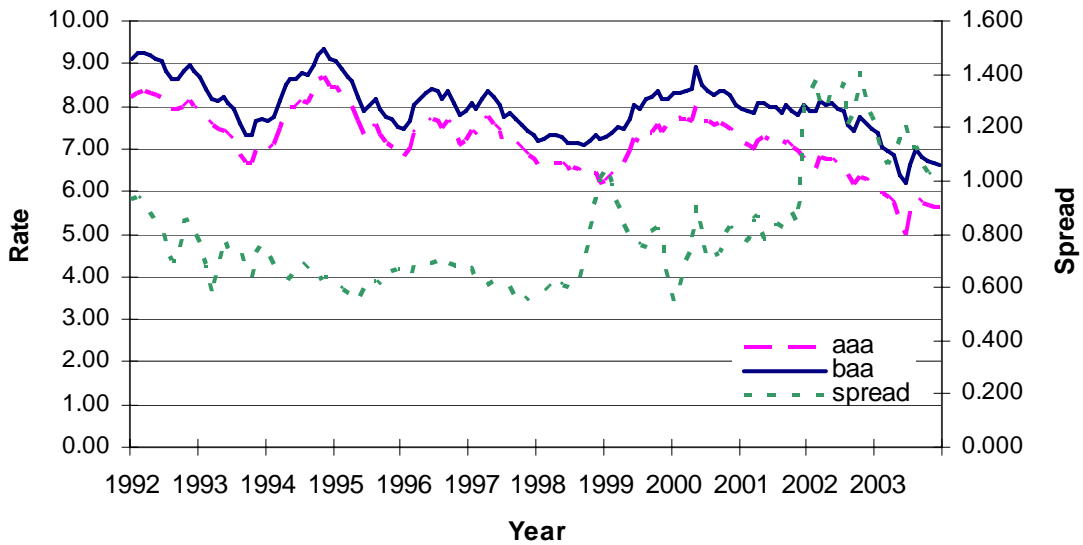
**Figure 2: Interest Rates and Yield Slope**



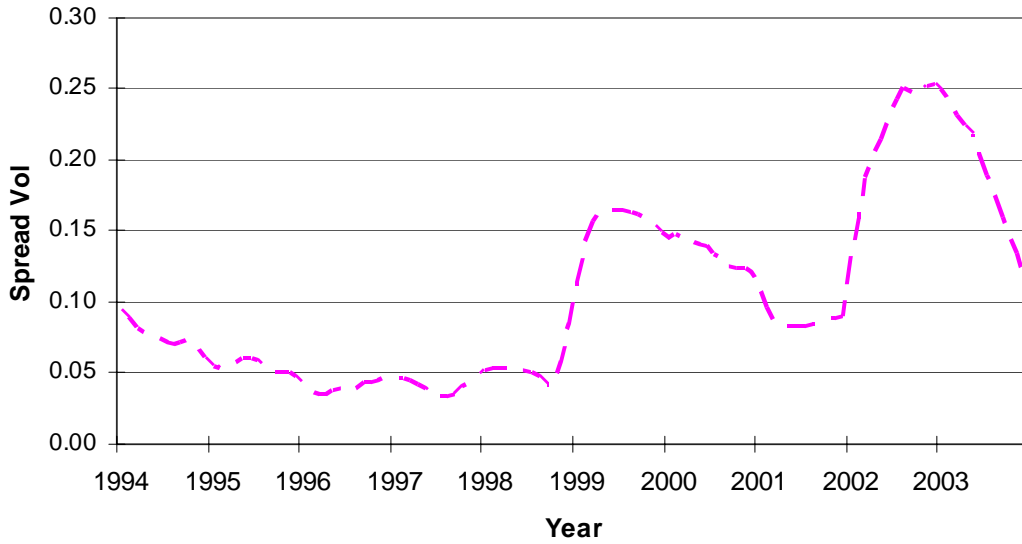
**Figure 3: Volatility of 10 Year Treasury Rate**



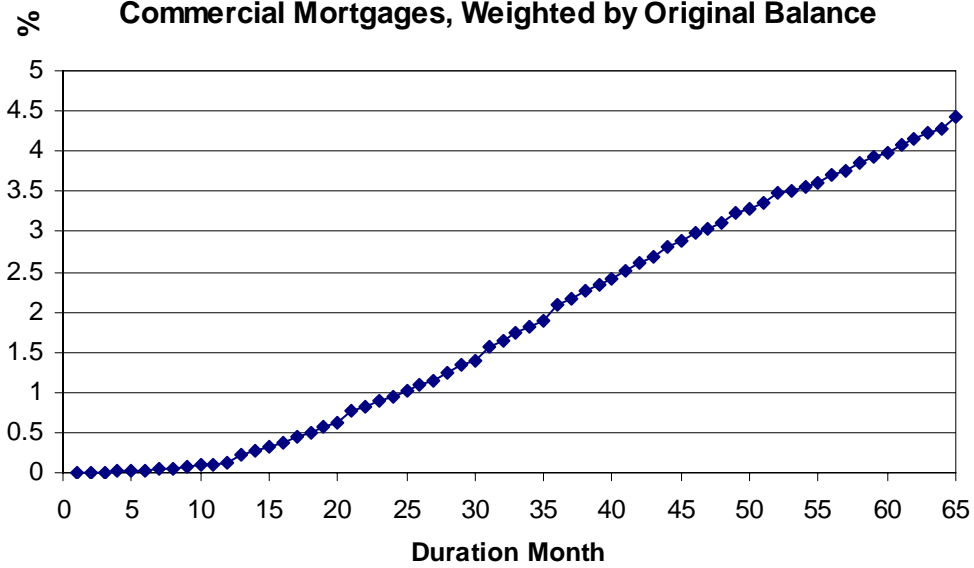
**Figure 4: Bond Rates and Credit Spread**



**Figure 5: Bond Rates and Credit Spread**



**Figure 6: Average Predicted Cumulative Default Rate of Commercial Mortgages, Weighted by Original Balance**



**Table 1: CMBS Conduit Deals in Our Sample**

Deal Name	Loan Number	Percent	Deal Name	Loan Number	Percent
AMRESKO 1997-C1	96	0.32	JPMCC 2001-CIBC3	125	0.42
ASC 1995-D1	61	0.20	JPMCC 2002-C1	129	0.43
ASC 1996-D2	124	0.41	JPMCC 2002-C2	108	0.36
ASC 1996-D3	114	0.38	JPMCC 2002-C3	87	0.29
BACM 2000-2	128	0.43	JPMCC 2002-CIBC4	121	0.40
BACM 2001-PB1	134	0.45	JPMCC 2002-CIBC5	116	0.39
BACM 2002-PB2	118	0.39	JPMCC 2003-C1	103	0.34
BACM 2003-1	112	0.37	JPMCC 2003-ML1	122	0.41
BSCMS 2000-WF1	181	0.60	JPMC 2000-C10	168	0.56
BSCMS 2000-WF2	145	0.48	JPMCC 2001-CIBC1	165	0.55
BSCMS 2001-TOP2	140	0.47	JPMCC 2001-CIBC2	143	0.48
BSCMS 2001-TOP4	152	0.51	JPMC 2000-C9	140	0.47
BSCMS 2002-PBW1	126	0.42	JPM 1997-C5	269	0.90
BSCMS 2002-TOP6	150	0.50	JPM 1999-C7	145	0.48
BSCMS 2002-TOP8	120	0.40	JPM 1999-C8	128	0.43
BSCMSI 1998-C1	146	0.49	JPMC 1999-PLS1	65	0.22
BSCMSI 1999-C1	114	0.38	LBCC 1996-C2	109	0.36
BSCMSI 1999-WF2	285	0.95	LBCMT 1998-C1	259	0.86
CASC 1998-D7	199	0.66	LBUBS 2000-C3	173	0.58
CCA1-2	92	0.31	LBUBS 2000-C4	167	0.56
CCA1-3	108	0.36	LBUBS 2000-C5	110	0.37
CCIC 2002-CCL1	53	0.18	LBUBS 2001-C2	141	0.47
CCMSC 2000-1	91	0.30	LBUBS 2001-C3	134	0.45
CCMSC 2000-2	81	0.27	LBUBS 2001-C7	114	0.38
CCMSC 2000-3	95	0.32	LBUBS 2002-C1	142	0.47
CCMSC 1999-2	92	0.31	LBUBS 2002-C2	111	0.37
CDCMT 2002-FX1	58	0.19	LBUBS 2002-C4	114	0.38
CMAC 1998-C1	312	1.04	LBUBS 2003-C3	110	0.37
CMAC 1999-C1	242	0.81	MCFI 1996-MC1	162	0.54
CMAT 1999-C1	230	0.77	MCFI 1997-MC1	158	0.53
CMAT 1999-C2	81	0.27	MCFI 1997-MC2	181	0.60
CMB-FUNB 1999-1	205	0.68	MCFI 1998-MC1	249	0.83
CMLBC 2001-CMLB-1	120	0.40	MCFI 1998-MC3	232	0.77
COMM 2003-LNB1	92	0.31	MLFA 2002-CAN7	49	0.16
COMM 2000-C1	112	0.37	MLFA 2002-CAN8	66	0.22
COMM 1999-1	221	0.74	MLFA 2003-CAN9	63	0.21
CSFB 2000-C1	211	0.70	MLFA 2003-CAN10	55	0.18
CSFB 2001-CF2	182	0.61	MLFA 2000-CAN3	53	0.18
CSFB 2001-CK1	142	0.47	MLFA 2000-CAN4	63	0.21
CSFB 2001-CK3	169	0.56	MLFA 2001-CAN5	55	0.18
CSFB 2001-CKN5	195	0.65	MLFA 2001-CAN6	40	0.13
CSFB 2001-CK6	240	0.80	MLMI 1996-C2	300	1.00
CSFB 2001-CP4	130	0.43	MLMI 1997-C1	219	0.73
CSFB 2002-CKP1	156	0.52	MLMI 1997-C2	147	0.49
CSFB 2002-CKN2	204	0.68	MLMI 1998-C2	401	1.33
CSFB 2002-CKS4	156	0.52	MLMI 1998-C3	139	0.46
CSFB 2002-CP3	103	0.34	MLFA 1998-CAN1	32	0.11

CSFB 2002-CP5	141	0.47	MLMI 1999-C1	106	0.35
CSFB 2003-C3	249	0.83	MLFA 1999-CAN2	43	0.14
CSFB 2003-CK2	101	0.34	MLMT 2002-MW1	101	0.34
CSFB 1995-M1	28	0.09	MSCI 2003-IQ4	119	0.40
CSFB 1999-C1	152	0.51	MSCI 2000-LIFE1	131	0.44
DLJ 2000-CF1	128	0.43	MSCI 1996-WF1	148	0.49
DLJCMC 2000-CKP1	230	0.77	MSCI 1997-C1	160	0.53
DLJ 1997-CF1	118	0.39	MSCI 1997-HF1	169	0.56
DLJ 1997-CF2	126	0.42	MSCI 1997-WF1	126	0.42
DLJ 1998-CF2	302	1.01	MSCI 1998-CF1	323	1.07
DLJ 1998-CG1	301	1.00	MSCI 1998-HF2	262	0.87
DLJ 1999-CG2	343	1.14	MSCI 1998-HF1	351	1.17
DLJ 1999-CG3	160	0.53	MSCI 1998-WF1	299	1.00
FUBOA 2001-C1	182	0.61	MSCI 1998-WF2	218	0.73
FULB 1997-C1	283	0.94	MSCI 1999-FNV1	166	0.55
FULB 1997-C2	421	1.40	MSCI 1999-RM1	221	0.74
FUNB 2000-C1	143	0.48	MSCI 1999-WF1	266	0.89
FUNB 2000-C2	162	0.54	MSDWC 2001-PPM	84	0.28
FUNB 2001-C2	107	0.36	MSDWC 2001-TOP1	165	0.55
FUNB 2001-C3	125	0.42	MSDWC 2001-TOP3	158	0.53
FUNB 2001-C4	137	0.46	MSDWC 2001-TOP5	143	0.48
FUNB 2002-C1	106	0.35	NFC 1998-1	201	0.67
FUNB-CMB 1999-C2	223	0.74	NFC 1998-2	376	1.25
FUNB 1999-C4	156	0.52	NFC 1999-1	331	1.10
GCCFC 2002-C1	112	0.37	PCMT 2003-PWR1	100	0.33
GCCFC 2003-C1	72	0.24	PMAC 1999-C1	177	0.59
GECCMC 2000-1	102	0.34	PNCMA 2000-C1	209	0.70
GECCMC 2001-1	151	0.50	PNCMAC 2000-C2	185	0.62
GECCMC 2001-2	126	0.42	PNCMAC 1999-CM1	207	0.69
GECCMC 2001-3	133	0.44	PSSFC 1998-C1	254	0.85
GECCMC 2002-1	137	0.46	PSSFC 1999-C2	220	0.73
GECCMC 2002-2	111	0.37	PSSFC 1999-NRF1	257	0.86
GECCMC 2002-3	131	0.44	RMF 1997-1	48	0.16
GECCMC 2003-C1	134	0.45	SBM7 2002-KEY2	66	0.22
GMAC 2000-C1	136	0.45	SBMS 2000-C1	266	0.89
GMAC 2000-C2	129	0.43	SBMS 2000-C3	181	0.60
GMAC 2000-C3	174	0.58	SBMS 2001-C1	182	0.61
GMAC 2001-C1	101	0.34	SBMS 2001-C2	139	0.46
GMAC 2001-C2	96	0.32	SBM7 2002-KEY2	66	0.22
GMAC 2002-C1	108	0.36	SBMS 1999-C1	213	0.71
GMAC 2002-C2	109	0.36	Solar Trust 2001-1	47	0.16
GMAC 2002-C3	108	0.36	SOLAR 2003-CC1	77	0.26
GMAC 2003-C1	104	0.35	WBCMT 2002-C1	156	0.52
GMAC 1997-C1	355	1.18	WBCMT 2002-C2	104	0.35
GMAC 1999-C3	138	0.46	WBCMT 2003-C3	130	0.43
GSMSCII 2003-C1	74	0.25	WBCMT 2003-C4	140	0.47
GSMSCII 1999-C1	304	1.01	WBCMT 2003-C5	152	0.51
HMAC 2000-PH1	235	0.78	WBCMT 2003-C4	140	0.47
HMAC 1999-PH1	181	0.60	WMCM 2003-C1	212	0.71
JPMCC 2001-C1	169	0.56	<b>Total (193 deals)</b>	<b>30049</b>	<b>100.00</b>

**Table 2: CMBS Conduit Deals by Cutoff Year**

Year	Frequency	Cumulative Frequency	Percent	Cumulative Percent
1995	2	2	1.04	1.04
1996	6	8	3.11	4.15
1997	16	24	8.29	12.44
1998	20	44	10.36	22.8
1999	30	74	15.54	38.34
2000	29	103	15.03	53.37
2001	35	138	18.13	71.50
2002	34	172	17.62	89.12
2003	21	193	10.88	100.00

**Table 3: Descriptive Statistics of CMBS Conduit Deals**

Variable	Mean	Std Dev.	Minimum	Maximum
Cutoff LTV	0.63	0.04	0.43	0.77
Cutoff DSCR	1.47	0.21	0.92	3.13
Estimated LTV at Maturity	0.58	0.10	0.22	1.54
AAA subordination	0.23	0.05	0.12	0.37
BBB subordination	0.09	0.03	0.00	0.17
Over-collateralization	0.00	0.03	0.00	0.33
Geographic concentration	0.87	0.07	0.36	0.97
Pct of amount in the most populated state	21.79	9.42	9.68	66.36
Property type concentration	0.03	0.00	0.02	0.04
Pct of amount of the largest loan	0.07	0.04	0.02	0.27
Percentage of Multifamily	0.24	0.12	0.00	1.00
Percentage of retail, anchored	0.24	0.13	0.00	0.56
Percentage of office	0.21	0.10	0.00	0.48
Percentage of industrial	0.07	0.05	0.00	0.25
Percentage of full service hotel	0.02	0.03	0.00	0.18
Cutoff balance (000s)	\$924,000	\$352,000	\$77,962	\$2,370,000
Number of assets at cutoff	156.32	75.06	28.00	422.00
Prepayment constraint	0.93	0.18	0.16	1.00
Number of deals			193	

**Table 4: Estimates of the Subordination Model**  
 Dependent variable: AAA subordination at cut off

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)
Intercept	-0.150** (0.054)	0.037 (0.078)	0.095* (0.042)	0.007 (0.048)	0.026 (0.063)
Cutoff LTV	0.563*** (0.079)	0.416*** (0.089)	0.356*** (0.048)	0.341*** (0.042)	0.326*** (0.044)
Cutoff DSCR		-0.059** (0.018)	-0.015 (0.010)	-0.019* (0.009)	-0.017 (0.009)
Estimated LTV at Maturity					0.013 (0.017)
Over-collateralization				0.081 (0.050)	0.105* (0.052)
Geographic concentration				0.094*** (0.020)	0.113** (0.032)
Pct of amount in the most populated state					0.000 (0.000)
Property type concentration				0.700 (0.880)	0.325 (0.950)
Pct of amount of the largest loan					-0.085 (0.046)
Log of loan number				-0.004 (0.003)	-0.006 (0.004)
Percentage of Multifamily				0.055** (0.016)	0.049** (0.016)
Percentage of retail, anchored				-0.032 (0.017)	-0.029 (0.018)
Percentage of office				0.050* (0.021)	0.048* (0.021)
Percentage of industrial				-0.066 (0.035)	-0.074* (0.036)
Percentage of full service hotel				0.115** (0.042)	0.110* (0.043)
Prepayment constraint					-0.011 (0.012)
YR 97			-0.022* (0.010)	-0.018* (0.009)	-0.020* (0.009)
YR 98			-0.037** (0.010)	-0.029** (0.009)	-0.029*** (0.009)
YR 99			-0.050*** (0.009)	-0.046*** (0.009)	-0.045*** (0.010)
YR 00			-0.089*** (0.009)	-0.084*** (0.009)	-0.084*** (0.011)
YR 01			-0.114*** (0.009)	-0.106*** (0.010)	-0.105*** (0.011)
YR 02			-0.118*** (0.009)	-0.106*** (0.010)	-0.104*** (0.011)

YR 03			-0.130***	-0.118***	-0.118***
			(0.010)	(0.010)	(0.011)
N	193	193	193	193	193
Adjusted R-Square	0.208	0.245	0.805	0.868	0.869

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Note: \*\*\* for  $p < 0.001$ ; \*\* for  $p < 0.01$ ; \* for  $p < 0.05$

**Table 5: Commercial Mortgage Loans Underlying CMBS Conduit Deals by Origination Year**

Type	Frequency	Cumulative Frequency	Percent	Cumulative Percent
1994	52	52	0.18	0.18
1995	269	321	0.96	1.14
1996	1,407	1,728	5.00	6.14
1997	4,025	5,753	14.31	20.46
1998	7,133	12,886	25.36	45.82
1999	4,027	16,913	14.32	60.14
2000	3,346	20,259	11.90	72.03
2001	4,151	24,410	14.76	86.79
2002	2,909	27,319	10.34	97.14
2003	805	28,124	2.86	100.00

**Table 6: Regional Distribution of the Commercial Mortgage Loans**

Region	Frequency	Cumulative Frequency	Percent	Cumulative Percent
Midwest/Eastern	2,708	2,708	9.63	9.63
Midwest/Western	1,056	3,764	3.75	13.38
Northeast/Mid-Atlantic	3,259	7,023	11.59	24.97
Northeast/New England	1,308	8,331	4.65	29.62
Southern/Atlantic	5,875	14,206	20.89	50.51
Southern/East Coast	916	15,122	3.26	53.77
Southern/West Coast	3,675	18,797	13.07	66.84
Western/Mountain	2,669	21,466	9.49	76.33
Western/Northern Pacific	2,353	23,819	8.37	84.7
Western/Southern Pacific	3,497	27,316	12.43	97.13
Missing	808	28,124	2.87	100

**Table 7: Property Type Composition of the Commercial Mortgage Loans**

Type	Frequency	Cumulative Frequency	Percent	Cumulative Percent
Multifamily	8,871	8,871	31.54	31.54
Retail	7,746	16,617	27.54	59.08
Office	4,186	20,803	14.88	73.96
Industrial	2,401	23,204	8.54	82.5
Hotel	1,495	24,699	5.32	87.82
Other	3,425	28,124	12.18	100

**Table 8: Characteristics of the Commercial Mortgage Loans at Origination**

Variable	Mean	Std Dev.	Minimum	Maximum
Original Balance (000s)	\$5,857.41	\$9,362.98	\$67.48	\$295,000.00
Original LTV (%)	69.02	11.54	0.66	112.50
Gross coupon rate (%)	7.76	0.86	4.35	12.88
Net coupon rate (%)	7.68	0.84	4.23	12.78
Amortization term (months)	324.54	52.34	33.00	720.00
Maturity term (months)	128.07	35.36	33.00	360.00
Number of loans	28124	28124	28124	28124

**Table 9: Prepayment Constraint Coverage**

Variable	Month	Coverage	Cumulative
Maturity Term	3,601,947		
Lockout	1,702,134	47.26	47.26
Yield Maintenance	692,094	19.21	66.47
Prepayment Penalty	70,458	1.96	68.43

**Table 10: Termination Status of the Commercial Mortgage Loans**

Type	Frequency	Cumulative Frequency	Percent	Cumulative Percent
Default	912	912	3.24	3.24
Prepay	667	1,579	2.37	5.61
Mature	51	1,630	0.18	5.80
Censor	26,494	28,124	94.20	100.00

**Table 11: Descriptive Statistics of Time Varying Variables**

Variable	At Origination				At Termination			
	All loans		Defaulted loans		All loans		Defaulted loans	
	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
Call option	0.024	0.002	0.047	0.002	0.153	0.003	0.111	0.005
Call option square	0.003	0.000	0.004	0.000	0.027	0.000	0.017	0.000
Put option	-0.551	3.123	-0.400	0.050	-1.083	4.481	-0.638	0.293
Put option square	3.427	21178	0.210	0.105	5.653	37240	0.699	1.135
Vol. of 10 year treasury	0.854	0.819	0.525	0.209	2.349	0.165	1.658	1.253
Credit spread	0.800	0.052	0.698	0.017	1.150	0.010	1.002	0.061
Vol. of credit spread	0.102	0.004	0.078	0.002	0.212	0.001	0.153	0.004
Unemployment rate	4.827	1.298	4.567	1.065	5.812	0.847	5.109	1.416
Prepayment constraint	0.994	0.007	0.997	0.003	0.843	0.132	0.907	0.085
Number of loans	28124		912		28124		912	

**Table 12: Maximum Likelihood Estimates of the Flexible Baseline Default Model**

Variable	Model 1	Model 2
	Estimate (S.E.)	Estimate (S.E.)
Original LTV	-0.002 (0.052)	-0.001 (0.053)
Call option	0.635*** (0.080)	0.631*** (0.084)
Call option square	-0.123* (0.058)	-0.110 (0.059)
Put option	0.370*** (0.088)	0.391*** (0.090)
Put option square	0.117* (0.049)	0.124* (0.049)
Vol. of 10 year treasury		0.310** (0.094)
Credit spread		0.133 (0.098)
Vol. of credit spread		-0.257*** (0.062)
Unemployment rate		0.213* (0.089)
Prepayment constraint		-0.261* (0.122)
Multifamily dummy	-0.208 (0.127)	-0.204 (0.127)
Retail dummy	0.143 (0.123)	0.147 (0.123)
Office dummy	-0.275 (0.154)	-0.259 (0.154)
Industrial dummy	0.272 (0.156)	0.288 (0.156)
Hotel dummy	1.010*** (0.148)	0.984*** (0.149)
REG 1	0.763** (0.243)	0.736** (0.243)
REG 2	0.450 (0.278)	0.506 (0.280)
REG 3	0.291 (0.249)	0.245 (0.249)
REG 4	0.172 (0.277)	0.234 (0.279)
REG 5	0.493* (0.243)	0.500* (0.234)
REG 6	0.911*** (0.262)	0.879*** (0.262)
REG 7	0.632** (0.240)	0.569* (0.241)

REG 8	0.310	0.291
	(0.250)	(0.250)
REG 9	0.045	-0.073
	(0.265)	(0.269)
REG 10	-0.658**	-0.761**
	(0.279)	(0.282)
Likelihood	662.845	706.694
SBC	17,223.035	17,213.265
AIC	17,126.722	17,092.874
N	28,124	28,124

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Note: \*\*\* for  $p < 0.001$ ; \*\* for  $p < 0.01$ ; \* for  $p < 0.05$

**Table 13: Predicted Cumulative Default Rate for CMBS pools**

Variable	Mean	Std Dev.	Minimum	Maximum
3 month cum. default rate	0.010	0.005	0.003	0.044
6 month cum. default rate	0.036	0.017	0.011	0.158
1 year cum. default rate	0.136	0.060	0.032	0.548
2 year cum. default rate	0.967	0.409	0.261	2.582
3 year cum. default rate	2.154	0.850	0.800	5.236
5 year cum. default rate	4.081	1.277	2.287	10.793
Number of deals	174			

**Table 14: Subordination – Predicted Cumulative Default Rate Regression**

Dependent variable: AAA subordination level of CMBS deal

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)
Intercept	0.220*** (0.008)	0.225*** (0.008)	0.231*** (0.009)	0.233*** (0.009)	0.229 (0.010)	0.181*** (0.011)
3 month cum. default rate	2.068** (0.694)					
6 month cum. default rate		0.483* (0.210)				
1 year cum. default rate			0.081 (0.061)			
2 year cum. default rate				0.009 (0.009)		
3 year cum. default rate					0.006 (0.004)	
5 year cum. default rate						0.015*** (0.003)
N	174	174	174	174	174	174
Adjusted R-Square	0.044	0.024	0.004	0.000	0.006	0.151

Note: \*\*\* for p&lt;0.001; \*\* for p&lt;0.01; \* for p&lt;0.05

**Appendix Table A: Estimates of the Subordination Model Based on Deals Cutoff during 1995-2005**

Dependent variable: AAA subordination at cut off

Variable	Model 1	Model 2	Model 3
	Estimate (S.E.)	Estimate (S.E.)	Estimate (S.E.)
Intercept	-0.172*** (0.029)	0.158* (0.072)	0.093** (0.031)
Cutoff LTV	0.358*** (0.043)	0.316*** (0.083)	0.335*** (0.035)
Cutoff DSCR		-0.106*** (0.0143)	-0.008 (0.007)
YR 97			-0.015 (0.008)
YR 98			-0.029*** (0.008)
YR 99			-0.043*** (0.007)
YR 00			-0.082*** (0.007)
YR 01			-0.107*** (0.007)
YR 02			-0.115*** (0.007)
YR 03			-0.135*** (0.007)
YR 04			-0.166*** (0.007)
YR 05			-0.180*** (0.008)
N	311	311	311
Adjusted R-Square	0.1830	0.3421	0.8922

Note: \*\*\* for p<0.001; \*\* for p<0.01; \* for p<0.05