Title

CMBS Subordination, Ratings Inflation, and Regulatory-Capital Arbitrage

Authors

Stanton, Richard
Wallace, Nancy

Publication Date

2012-12-14

CMBS Subordination, Ratings Inflation, and Regulatory-Capital Arbitrage

Richard Stanton* and Nancy Wallace†

December 14, 2012

Abstract

Using detailed origination and performance data on a comprehensive sample of CMBS deals, along with their underlying loans and a set of similarly rated residential MBS, we apply reduced-form and structural modeling strategies to test for regulatory-capital arbitrage and ratings inflation in the CMBS market. We find that the spread between CMBS and corporate-bond yields fell significantly for ratings AA and AAA after a loosening of capital requirements for highly rated CMBS in 2002, while no comparable drop occurred for lower-rated bonds (which experienced no similar regulatory change). We also find that CMBS rated below AA upgraded to AA or AAA significantly faster than comparable residential RMBS (for which there was no change in risk-based capital requirements). We use a structural model to investigate these results in more detail, and find that little else changed in the CMBS market over this period except for the rating agencies' persistent reductions in subordination levels between 1997 and late 2007. Indeed, had the 2005 vintage CMBS used the subordination levels from 2000, there would have been no losses to the senior bonds in most CMBS structures. Our conclusions have recently been accepted by the rating agency Standard & Poors (S&P), and are now a component of the proposed benchmark for S&P's new "Diversified Credit Enhancement Levels" (see Eastham, Digney, Hoeltz, Pollem, and Carrington, 2012).

*Haas School of Business, U.C. Berkeley, stanton@haas.berkeley.edu.

†Haas School of Business, U.C. Berkeley, wallace@haas.berkeley.edu.

1 Introduction

The rating agencies have taken a large share of the blame for the recent financial crisis.[1] For example, Tomlinson and Evans (2007), in a Bloomberg report on the subprime crisis, quote Satyajit Das, a former banker at Citigroup:

> "The models are fine. But they have an input problem. It becomes a number we pluck out of the air. They could be wrong, and the ratings could be misleading."

The same report quotes Brian McManus, head of CDO Research at Wachovia:

> "With CDOs, they underestimated the volatility of the subprime asset class in determining how much leverage was OK."

Before concluding that the rating agencies were to blame, however, it is important to control for the many other factors affecting these markets. For example, it is well documented that there was a significant drop in the quality of residential mortgages in the years preceding the financial crisis, especially in the subprime sector, fueled both by lower underwriting standards and by dishonesty on the part of borrowers and lenders.[2] Many have also blamed problems in the credit default swap (CDS) market.[3] Given all of these confounding factors,

[1]For discussion, see Bank for International Settlements (2008).

[2]See, for example, Demyanyk and Van Hemert (2011). On April 12, 2010, Senator Carl Levin, D-Mich., chair of the U.S. Senate Permanent Subcommittee on Investigations, issued a statement prior to beginning a series of hearings on the Financial Crisis. In the statement, he addressed some of the lending practices of Washington Mutual, the largest thrift in the U.S. until it was seized by the government and sold to J.P. Morgan Chase in 2008 (see U.S. Senate Press Release, "Senate Subcommittee Launches Series of Hearings on Wall Street And The Financial Crisis," April 12, 2010). Among other allegations, the statement claims:

> "One FDIC review of 4,000 Long Beach loans in 2003, found that less than a quarter could be properly sold to investors. A 2005 review of loans from two of Washington Mutual's top producing retail loan officers found fraud in 58% of the loans coming from one loan officer's operations and 83% from the other. Yet those two loan officers continued working for the bank for three years, receiving prizes for their loan production. A 2008 review found that staff in another top loan producer's office had been literally manufacturing borrower information to speed up production."

> "Documents obtained by the Subcommittee also show that, at a critical time, Washington Mutual selected loans for its securities because they were likely to default, and failed to disclose that fact to investors. It also included loans that had been identified as containing fraudulent borrower information, again without alerting investors when the fraud was discovered. An internal 2008 report found that lax controls had allowed loans that had been identified as fraudulent to be sold to investors."

[3]See Stulz (2010) for a detailed discussion. Stanton and Wallace (2011) show, for example, that during the crisis, prices for ABX.HE indexed CDS, backed by pools of residential MBS, implied default rates over 100% on the underlying loans, and were uncorrelated with the credit performance of the underlying loans. Many institutions incurred large losses through using ABX.HE prices to mark their MBS holdings to market.

it has proved hard to extract the separate role of the rating agencies in the recent crisis, despite the wealth of anecdotal evidence, and there has so far been little empirical work on this question in the academic literature.[4] Another, related, factor often blamed for the financial crisis is regulatory-capital arbitrage (RCA), defined by the Basel Committee on Banking Supervision (1999) as "the ability of banks to arbitrage their regulatory capital requirement and exploit divergences between true economic risk and risk measured under the [Basel Capital] Accord."[5] For example, Acharya and Richardson (2010, p. 197) state, "But especially from 2003 to 2007, the main purpose of securitization was not to share risks with investors, but to make an end run around capital-adequacy regulations. The net result was to keep the risk concentrated in the financial institutions—and, indeed, to keep the risk at a greatly magnified level, because of the overleveraging that it allowed."[6] Opp, Opp, and Harris (2012) argue that, especially for complex securities, regulatory distortions like this can reduce or eliminate the incentive for rating agencies to acquire information, in turn leading to rating inflation.

In this paper, we shed new light on the role of the rating agencies and regulatory-capital arbitrage in the crisis by focusing on the commercial mortgage-backed security (CMBS) market.[7] There are several reasons why the CMBS market is ideal for this purpose. First, we have access to large amounts of detailed origination and performance data on the CMBS tranches and the loans underlying them. Second, unlike the residential mortgage-backed security (RMBS) market, all agents in the CMBS market can reasonably be viewed as sophisticated, informed investors;[8] as a result, we need to look for explanations other than investor naïveté

[4]Notable exceptions include Ashcraft, Goldsmith-Pinkham, and Vickery (2009), who study credit ratings in the residential mortgage-backed security market, and Griffin and Tang (2009), who look at CDO ratings.

[5]For detailed discussions of regulatory-capital arbitrage, see, for example, Jones (2000), Basel Committee on Banking Supervision (1999), Altman and Saunders (2001), Alexander and Baptista (2006), Kashyap, Rajan, and Stein (2008), Acharya and Richardson (2010), and Acharya, Cooley, Richardson, and Walter (2010).

[6]The International Monetary Fund (2008, p. 31) reported that aggregate assets held by the ten largest publicly traded banks in the United States and Europe grew between Q2:2004 and Q2:2007 from about 8.7 to 15 trillion euros. Over the same period risk-weighted assets, which determine the capital requirements of these institutions, grew significantly less, from 3.9 to about 5 trillion euros.

[7]Prior to the recent financial crisis, the U.S. CMBS market had expanded rapidly, with an average annual growth rate of 18% from 1997 to 2007, at which point it stood second only to commercial banks as a source of credit to the commercial real estate sector. By the end of the third quarter of 2007, outstanding CMBS funded $637.2 billion, commercial banks $1,186.2 billion, and insurance companies $246.2 billion of the total $2.41 trillion of outstanding commercial mortgages [see Federal Reserve Z.1 Release (Flow of Funds), Third Quarter 2007].

[8]By 2007 more than 90% of all outstanding CMBS were held by insurance companies (50.1%), mutual funds (25.3%), commercial banks (8.5%), and the GSEs (6%). Over 90% of all commercial-bank holdings of CMBS were concentrated on the balance sheets of twelve banks who received TARP funds, including: Citigroup; J.P. Morgan; Bank of America; Metropolitan Bank Group; Wells Fargo Bank; US Bankcorp; Bank of New York Mellon; Citizens Bancshares Co.; BB&T; Fifth Third Bancorp; and the American subsidiaries of HSBC and RBS (see Inside Mortgage Finance Bank Mortgage Database).

or irrationality. Third, consistent with the findings of Driessen and Van Hemert (2011) and unlike the RMBS market, we shall show that there were no major changes in the underlying market for commercial loans over this period. Finally, in the years prior to the crisis there were significant regulatory changes in the CMBS market, which greatly increased incentives for institutions to hold highly rated CMBS; this provides a perfect experimental setting in which to test for the effects of regulatory-capital arbitrage.

In our analysis, we use both reduced-form and structural modeling approaches. The reduced-form approach (see, for example, Mian and Sufi, 2009) is a natural way to analyze the effects of recent changes in regulations that affected highly rated CMBS securities, but not lower-rated CMBS (or other defaultable securities of any rating). We find that the spread between CMBS and corporate-bond yields for ratings AA and AAA fell significantly after 2002, when risk-based capital requirements for highly rated CMBS were greatly lowered. No comparable drop in yield spread occurred for lower-rated bonds, which experienced no similar regulatory change. In addition, in the years prior to the crisis, the rate at which below-AA-rated CMBS upgraded to AA or AAA was significantly higher than the rate observed in a comparable sample of residential mortgage-backed securities (RMBS), for which there was no change in risk-based capital requirements in 2002.

Because many of the contract terms are endogenous, we need to be careful in interpreting the results of any analysis that focuses only on a single contract feature. We therefore complement our reduced-form analysis with a structural model that examines all of the loan features at once. We find that in the period leading up to the crisis, the rating agencies allowed subordination levels to fall to levels that provided insufficient protection to supposedly "safe" tranches.[9] While we shall be studying this in more detail later, prima facie evidence is provided by Figure 1, which shows how subordination levels fell between 1996 and 2007 (with a slight rise in 2008) for all classes of CMBS bonds.

Of course, there are many possible interpretations of this result. Perhaps (as commonly asserted prior to 2007), in the early days of CMBS issuance, the rating agencies were too conservative and they updated their views as they saw realized losses.[10] Or perhaps the loans themselves were changing over time in a way that made the CMBS bonds safer for a given subordination level. To conclude that subordination levels were too low by the beginning of the crisis, we need to rule out such alternative explanations. To do so, we perform a comprehensive analysis of the CMBS market both before and after the crisis, using a number of different data sets. We use the Trepp LLC loan-level, bond-level, and

[9]The subordination level is the maximum amount of principal loss on the underlying mortgage that can occur without a given security suffering any loss.

[10]See, for example, Wheeler (2001).

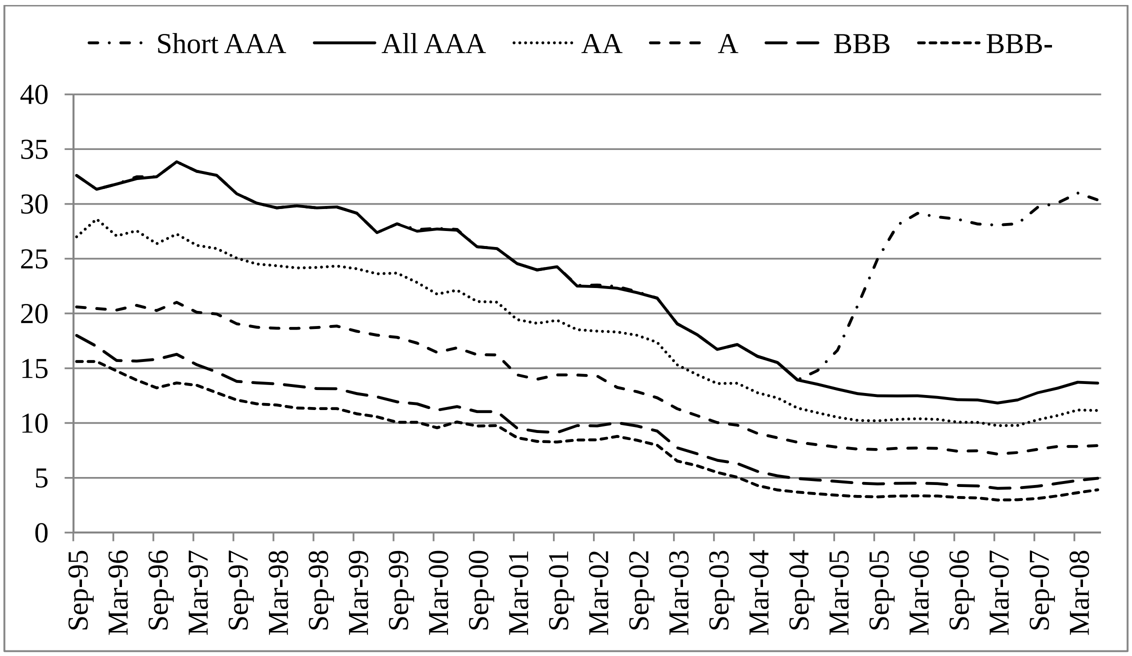


Figure 1: **CMBS Weighted Average Subordination Levels.** This figure plots the annual average percentage of subordination by bond class for the universe of 582 CMBS deals originated in the United States from 1995 to 2008. Starting in 2004, it became standard practice to re-tranche the overall principal balance of the AAA securities into senior and junior AAA-rated bonds. This caused an apparent increase in the subordination levels of the most senior (and usually shortest duration) of the AAA bonds (labeled "Short AAA"), because their reported subordination included the balances of the subordinate AAA bonds. However, this reported subordination level is not comparable to the AAA support in prior periods. The series labeled "All AAA," showing the subordination underlying the first dollar of AAA bonds, is consistent with the pre-2004 definition. The data were obtained from Trepp LLC.

pool-level performance data from 1995–2010. We also use bond-level performance data for residential mortgage-backed securities (RMBS), obtained from Lewtan ABSNet. The bond-level performance was used to track the relative upgrade history of RMBS bonds compared with the upgrade history of CMBS bonds. Overall, our study accounts for the performance of 582 CMBS pools and 9,732 RMBS pools.

We find that, unlike the RMBS market (see, Demyanyk and Van Hemert, 2011), CMBS loans did not significantly change their characteristics during this period. Moreover, although there is evidence that CMBS lenders did reduce their pricing for the late 2005 and 2006 vintage loans compared to average pricing levels between 1995 and 2007, these changes were insignificant relative to the persistent reductions in CMBS subordination levels over the same period. Indeed, had the 2005 vintage CMBS used the subordination levels from 2000, there would have been no losses to the senior bonds in most CMBS structures. Our conclusions have recently been corroborated by the rating agency Standard & Poors (S&P), and are now a component of the proposed benchmark for S&P's new "Diversified Credit Enhancement Levels" (see Eastham et al., 2012).

The decreases in CMBS subordination levels (with corresponding increases in the proportions of AA- and AAA-rated CMBS), unaccompanied by commensurate changes in the quality of the underlying loans, is consistent with the theoretical predictions of Opp, Opp, and Harris (2012). They argue that, especially for complex securities, regulatory distortions (in this case, the reduction in risk-based capital weights for AA- and AAA-rated CMBS compared with lower-rated whole loans) can reduce or eliminate the incentive for rating agencies to acquire information, in turn leading to rating inflation. These incentives were particularly strong in the CMBS market because of explicit regulatory changes in the years leading up to the crisis. Specifically, on January 2, 2002, the risk-based capital weights for AA and AAA CMBS were reduced by 80%. We show that this dramatic regulatory shift was associated with a substantial decrease in the yields of AA and AAA CMBS relative to yields of AA and AAA corporate bonds (with no similar change for lower-rated bonds), and a large increase in the overall proportion of CMBS rated AA or above—by 2007, about 95% of all outstanding CMBS were rated AA or above, compared with 86% just nine years earlier. We also show that between 2000 (when the regulatory shift in CMBS ratings was formulated and approved by the Financial Accounting Standards Board (FASB), the Federal Reserve Board, the Securities and Exchange Commission (SEC), and the U.S. Congress (see Federal Reserve and SEC, 1998)) and 2006, the rate at which below-AA rated CMBS bonds were upgraded to AA or AAA far exceeded the corresponding upgrade rates for RMBS.

These significant upgrade and pricing differentials of CMBS bonds compared with similarly rated corporate and RMBS bonds are difficult to explain based on market-wide shifts in risk perceptions. They are, however, entirely consistent with the increased risk-based capital savings to regulated institutions (the primary investors in CMBS bonds) leading to significant distortions in the stock of these bonds, the capital support underlying them, and the prices that regulated institutions were willing to pay.

2 Related literature

The empirical papers most closely related to ours are Griffin and Tang (2009), Ashcraft et al. (2009), and Benmelech and Dlugosz (2009). Griffin and Tang (2009) analyze the outputs of a rating agency's credit model for a sample of CDOs between 1997 and 2007. They find that the actual size of the AAA tranche in each deal was almost always larger than the model suggested, by an average of over 12% but in many cases much more. They are unable to explain these adjustments using variables related to default risk, and find that the average size of the adjustments increased in the years up to 2007. These results, using data from different (though related) markets, are a good complement to ours. In particular, while Griffin and Tang (2009) have direct access to a rating agency's model (which we do not), we have access to much more detailed information on the loans underlying our bonds. In both cases, the conclusion is the same: the only thing that materially changed over this period was the rating agencies' allowable subordination levels.

Ashcraft et al. (2009) analyze the validity of agencies' ratings of sub-prime and Alt-A residential mortgage backed securities (RMBS) between 2001 and 2007. They find important declines in risk-adjusted RMBS subordination between 2005 and mid-2007, and show that observably riskier deals significantly under-performed relative to their initial subordination levels. Ashcraft et al. (2009) conclude that their findings are consistent with two theoretical predictions found in the literature: i. ratings inflation could be associated with increased security opacity (proxied by the degree of no-documentation loans in pools) and ii. the benefits of a fee-based revenue model and high rates of security issuance could swamp the reputational costs of erroneous ratings (see Skreta and Veldkamp, 2009 for the first prediction, and Bolton, Freixas, and Shapiro, 2012; Mathis, McAndrews, and Rochet, 2009 for the second). The use of both loan-level and bond-level data in our study is similar to the strategy implemented by Ashcraft et al. (2009). However, an important difference between the two studies is that we find no evidence that the CMBS market was exposed to the confounding effects of significantly deteriorating and/or fraudulent mortgage underwriting practices that affected the RMBS market over the same period.

Benmelech and Dlugosz (2009) find that 70.7% of the dollar amount of CDOs received a AAA rating, whereas the collateral that supported these issues had average credit ratings of

B+. They hypothesize, but do not empirically test, that the CDO subordination structure was driven by rating-dependent regulation and asymmetric information. Similar to these findings, we find that the commercial real-estate loans in the CMBS pools would typically have received a credit rating of BBB or below, while the level of AAA CMBS bond issuance reached 88% in 2006.[11]

Many recent theoretical treatments of ratings shopping (see, for example, Skreta and Veldkamp, 2009; Bolton et al., 2012) assume that investors are naive or easily fooled by the rating agencies' practices of revealing only the highest ratings. The greater sophistication of CMBS investors makes this assumption less tenable. Instead, the CMBS market appears to fit more naturally into informed rational expectations frameworks with regulatory distortions (see, for example, Opp, Opp, and Harris, 2012; Coval, Jurek, and Stafford, 2009a; Merton and Perold, 1993; Sangiorgi, Sokobin, and Spatt, 2009).

3 CMBS ratings and regulatory-capital arbitrage

In their fully rational model, Opp, Opp, and Harris (2012) show that large regulatory benefits of high ratings may serve to eliminate delegated information acquisition by rating agencies, in turn leading to significant rating inflation. This outcome is more likely with more complex securities. The CMBS market is a useful place to examine this idea, because a significant regulatory shift occurred in 2002. Since that time, very generous risk-based capital weights have applied to AA and AAA CMBS, compared with the weights that apply to the underlying whole loans and to lower-rated CMBS.

Table 1 reports the risk-based capital (RBC) requirements for CMBS held by Federal Deposit Insurance Corporation (FDIC)-regulated financial institutions. Prior to January 2, 2002 (as shown in the bottom-left panel of the table), all investment-grade CMBS and most commercial real estate mortgages received a risk weight of 100%, implying that a $1 investment in CMBS required the institution to hold $.08 of capital ($\$1 \times 100\% \times 8\%$). After 2001 (as shown in the upper-left panel), whole commercial real estate mortgages and BBB-rated CMBS retained a 100% risk weight, whereas all AAA and AA-rated CMBS fell to a 20% risk-weight, requiring only 1.6 cents of capital per dollar of investment. An A-rated CMBS received a 50% risk-weight, requiring 4 cents of capital per dollar of investment, and BBB-rated CMBS received a 100% risk weight. Although not shown in the table, BB-rated CMBS carried a risk-weight of 200%, or 16 cents of capital for every dollar of investment. B-rated and unrated CMBS bonds required the financial institution to hold capital equal to

[11]See *The Structured Credit Handbook*, New York, John Wiley, 2007. This information was also obtained from discussions with CMBS servicers.

100% of the face amount of the bond.

The right-hand side of Table 1 shows life-insurance company capital requirements for all bonds, including CMBS, over the period 1997–2008. As shown, AAA, AA, and A bonds used a constant factor of 0.3%, requiring $0.003 of capital per $1 of Adjusted Carrying Value (ACV) of the investment, whereas BBB-rated bonds required $0.01 per $1 of the ACV of the investment.[12] Non-investment-grade BB-rated bonds had a factor of 4.0%. There were very modest changes in the factor for commercial real-estate loans between the two periods. From 1997 to 2000, commercial real-estate mortgages were required, on average, to use a factor of 2.25% or $0.0225 per $1 of ACV. After 2001, commercial real estate mortgages were required, on average, to use a factor of 2.6%.

The numerical differences in the risk-based capital percentages of the banks and the factors for the insurance companies are hard to compare directly, because there are important differences between the regulatory and accounting oversight of these institutions.[13] Nevertheless, we can conclude from Table 1, that that the RBC requirements for holding unsecuritized investment-grade commercial real estate mortgages on bank balance sheets were 5 times as high as for AA- and AAA-rated CMBS after 2001, and were 6.5 times as high for insurance companies after 2000. Prior to the regulatory change in 2001, banks would have been indifferent between holding whole commercial loans or investment grade CMBS, whereas after the regulatory shift, investment-grade CMBS required significantly less capital. Insurance companies also faced strong incentives to hold CMBS in preference to unsecuritized commercial real estate mortgages given the important differentials in risk-based capital requirements between CMBS and loans.

Table 2 reports an estimate of the potential savings in risk-based capital from holding the equivalent of the book value of AA- or AAA-rated CMBS as commercial real estate mortgages. The AAA-CMBS holdings of the insurance companies were obtained from Alberto Manconi, Massimo Massa, and Ayako Yasuda, and the AAA-CMBS holdings of commercial banks were estimated using the proportional bank holdings of CMBS in 2009 combined with our estimate of the percentage of the stock of CMBS that was AAA in 2007 (93%). The actual insurance company holdings of AAA-CMBS in 2007 were $188.5 billion and the esti-

[12] The Adjusted Carrying Value (ACV) is a dynamic model-based determination of the default-risk-adjusted value of investments and their required reserves.

[13] Some of the major differences include: 1) The accounting basis for insurers is statutory accounting; 2) life insurers set up reserves that are separate from the risk-based minimum-capital requirements (such as Asset Valuation Reserves and reserves for asset/liability analysis); 3) tiering of capital is not done for insurers, as it is for banks, and some types of lower-tier capital are not allowed for insurers under statutory accounting rules; 4) the insurance factors are based on the default rates of all bonds of a given rating, not just CMBS; 5) insurance companies have a longer time horizon for holding investments than banks; and 6) there are numerous other differences related to the legal and regulatory environments of the two types of institution.

	Rating	Risk Weight[1]	Capital Requirement	Risk Based Capital Requirement per $1 of Book Value	Asset Class	Factor[2]	Risk Based Capital Requirement per $1 Adj. Carrying Value
		Commercial Banks			Life Insurance Companies		
		2002–2008			2001–2008		
CMBS Bonds							
a) Investment Grade							
	AAA	20%[3]	8%	$0.016	1	0.3%	$0.003
	AA	20%	8%	$0.016	1	0.3%	$0.003
	A	50%	8%	$0.040	1	0.3%	$0.003
	BBB	100%	8%	$0.080	2	1.0%	$0.010
b) Non-Investment Grade							
	BB	200%	8%	$0.160	3	4.0%	$0.040
Commercial Real Estate Mortgages	BBB	100%	8%	$0.080		2.60%	$0.0260
		1997–2001			1997–2000		
CMBS Bonds							
a) Investment Grade							
	AAA	100%	8%	$0.080	1	0.3%	$0.003
	AA	100%	8%	$0.080	1	0.3%	$0.003
	A	100%	8%	$0.080	1	0.3%	$0.003
	BBB	100%	8%	$0.080	2	1.0%	$0.010
b) Non-Investment Grade							
	BB	200%	8%	$0.160	3	4.0%	$0.040
Commercial Real Estate Mortgages	BBB	100%	8%	$0.080		2.25%	$0.0225

[1] Source: Rosenblatt (2001).
[2] Source: Discussion with NAIC staff and National Association of Insurance Commissioners (2009).
[3] IOs and POs are not eligible for less than 100% risk weighting.

Table 1: **Risk-based capital requirements for commercial banks and insurance companies.** The table presents the risk-based capital requirements for CMBS and Commercial Real Estate Mortgages held by commercial banks and insurance companies. The upper part of the table reports the risk-based capital requirements for the period 2002–2009. The lower part of the table reports the capital requirements during the period 1997–2001 where the risk-based capital weights for commercial banks holding investment grade CMBS were 100%.

	Bank RBC ($ billions)	Insurance RBC ($ billions)
AAA-CMBS Principal Balance Holdings in 2007	46.62	188.50
2007 Estimated Risk-Based Capital for AAA-CMBS	0.75	0.57
2007 Estimated Risk-Based Capital for Holding Equivalent as Commercial Real Estate Mortgages	3.73	4.90
Capital Savings	2.98	4.33

Table 2: **Approximate risk-based capital savings from holding AAA-CMBS instead of commercial real-estate mortgages in 2007.** The table presents the risk-based capital requirements for the actual AAA-CMBS holdings of the insurance companies and the estimated AAA-CMBS of commercial banks in 2007. We also report hypothetical risk-based capital requirements for the same book value of the AAA-CMBS holdings if the same position had been held as commercial real estate mortgages. The data for the insurance company holdings of AAA-CMBS was obtained from Manconi et al. (2010). The estimated value for the AAA-CMBS holdings of commercial banks was computed using the FDIC reported share of commercial bank holdings of CMBS to the stock of U.S. CMBS (an 8.5% share) to estimate the 2007 holdings and then multiplying this value by our estimate of the stock of AAA-CMBS in 2007 (93% of the outstanding stock). The basis used to compute the insurance company RBC was the full outstanding principal balance held by insurance companies instead of the (unknown) Adjusted Carrying Value.

mated aggregate holdings of the commercial banks were $46.62 billion. Using the 2007 RBC requirements, the RBC for the commercial banks is estimated to be $750 million and the RBC for the insurance companies is $570 million. If the banks and the insurance companies each held an amount equivalent to their AAA-CMBS investments as commercial real estate mortgages, their risk-based capital costs would have been $3.73 billion and $4.90 billion, respectively. This represents a $2.98 billion capital savings for the banks and a $4.33 billion savings for the insurance companies for the AAA-ratings label, providing a clear incentive for insurers and banks to hold AAA-rated CMBS.

4 Reduced-form tests for regulatory-capital arbitrage

If regulatory-capital arbitrage is an important force in the CMBS market, we should expect to see prices driven up (or equivalently, yields driven down) after the rule change in 2002, relative to other markets with no such change. However, we should expect only to see such a change for the higher rated CMBS securities, since they are the ones affected by the rule change. To investigate this, Figure 2 plots the difference (in basis points) between CMBS and

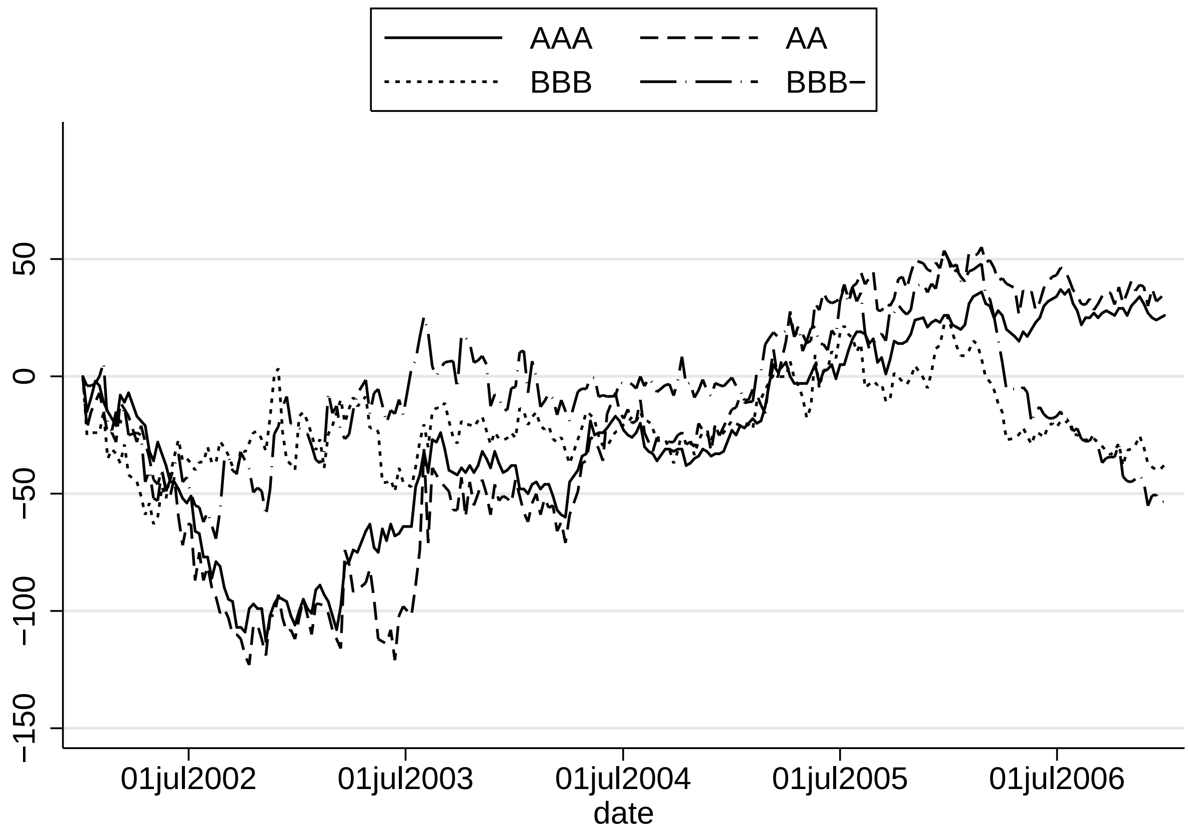


Figure 2: **CMBS versus corporate bond yields.** The figure plots the difference (in basis points) between CMBS and corporate-bond yields for ratings AAA, AA, BBB and BBB- from 2002 to 2006, indexed to zero at the start of the sample. The bond yields used are the Morgan Stanley U.S. Fixed-Rate CMBS yields for CMBS of each rating class. The corporate bond yields used are the Moody's AA and AAA Corporate Bond yield and the Bloomberg Fair Value (BFV) BBB and BBB- Corporate Bond yields.

corporate bond yields for ratings AAA, AA, BBB and BBB- from 2002 to 2006. Consistent with the implications of our regulatory-capital arbitrage explanation, it can clearly be seen that the relative spread for AA and AAA bonds fell substantially starting in 2002, compared with the relative spread for the lower rated bonds. This result also supports the conjecture of Coval, Jurek, and Stafford (2009b) that the observed yield spread advantage of AAA-rated CDOs relative to AAA-rated single-name corporate bonds arises from demand stimuli associated with minimum bank-capital requirements under Basel I and II.

Another important feature of the CMBS market was that in addition to the reductions in the principal support underlying the AA and AAA bonds at origination, there were also high rates of upgrading CMBS bonds with lower ratings to AA or AAA. By the fourth quarter of 2006, the combined effect of the low subordination rates at origination and the high rates of upgrading led to bonds rated AA or higher making up 95% of the overall stock of outstanding CMBS principal. This very high proportion persisted until the third quarter of 2009, when the rate of downgrades overtook the rate of upgrades.[14]

This increase in the outstanding stock of CMBS rated AA and above is consistent with an increase in regulatory-capital arbitrage induced by the RBC policy change. Of course, the raw increases do not rule out alternative explanations, such as a generally increased appetite for AA and AAA securities of all types, independent of the change in capital regulations. To investigate this further, we compare the CMBS upgrade behavior over time with the upgrade behavior for the RMBS market (which experienced no similar change in regulations) using a difference-in-difference regression approach, and tracking the monthly ratings status for all CMBS and RMBS bonds rated below AA from 1998 to 2010. The data for this analysis were the bond-level and ratings data from Trepp LLC for the CMBS bonds and the bond-level and ratings data from Lewtan ABSNet for all RMBS bonds.[15] Using a logit framework, we model the monthly probability that each bond rated below AA will be upgraded to AA or AAA. Over this period, 20.86% of CMBS bond-rating events for initially lower rated bonds were upgrades to AA or better, while only 11.88% of RMBS bond-rating events for initially lower-rated bonds were upgrades to AA or better.

Table 3 reports two alternative specifications, one in which we do not control for the origination vintage of each bond (shown in columns two and three), and a second (shown in columns four and five), in which we control for vintage fixed effects for the bonds to allow for possible changes in the credit quality of the bonds in the years preceding the financial crisis.

As shown in Table 3, there is little difference between the two specifications. The coefficient on the indicator variable for CMBS bonds prior to the change in RBC requirements is statistically significant and negative in both specifications since in this period there was no RBC advantage to the higher bond ratings. The sign changes to positive in 2001 and then grows to its highest level in 2002, implying that upgrades in 2002 greatly exceeded those in 2000. As shown in the table, from 2001 on—i.e., while the CMBS risk-based capital weight policy was vetted and approved by Congress (see Federal Reserve and SEC, 1998), and after its implementation in 2002—the CMBS bonds showed a significantly greater propensity to be upgraded than the corresponding RMBS bonds. This trend continued through 2006, although the effects in 2004 and 2005 are not statistically significant. In 2007 and the onset

[14]These calculations were carried out by the authors using bond-level data from Trepp LLC and bond ratings information from ABSNet Lewtan from 1996 to 2011.

[15]Overall, we analyze about 469,000 bond-months over the period.

Parameter	Coefficient Estimate	Standard Error	Coefficient Estimate	Standard Error
Intercept	-3.109***	0.023	-3.109***	0.023
Observation years 1998–2000	2.578***	0.053	2.601***	0.058
Observation year = 2001	3.052***	0.065	2.728***	0.090
Observation year = 2002	3.216***	0.043	2.798***	0.073
Observation year = 2003	2.343***	0.035	2.153***	0.056
Observation year = 2004	2.269***	0.034	2.098***	0.048
Observation year = 2005	2.482***	0.032	2.353***	0.041
Observation year = 2006	2.408***	0.030	2.456***	0.037
Observation year = 2007	1.704***	0.027	1.704***	0.027
Observation year = 2008	0.447***	0.028	0.447***	0.028
Observation year = 2009	-0.087***	0.031	-0.087***	0.031
CMBS × Observation Years 1998–2000	-1.549**	0.614	-1.508**	0.617
CMBS × Observation Year = 2001	1.596***	0.369	2.016***	0.392
CMBS × Observation Year = 2002	1.783***	0.206	2.046***	0.214
CMBS × Observation Year = 2003	0.259**	0.130	0.546***	0.138
CMBS × Observation Year = 2004	0.09	0.096	0.085	0.103
CMBS × Observation Year = 2005	0.024	0.071	0.173**	0.080
CMBS × Observation Year = 2006	0.429***	0.051	0.240***	0.063
CMBS × Observation Year = 2007	-1.298***	0.050	-1.298***	0.050
CMBS × Observation Year = 2008	-2.035***	0.047	-2.035***	0.047
CMBS × Observation Year = 2009	-0.412***	0.067	0.412***	0.067
Observation Year × Vintage Fixed Effects	No		Yes	
Likelihood	31,409.783***	20 df	32,196.55***	67 df
Number of Observations	234,902		234,902	

χ^2 tests of statistical significance: ** $p < 0.05$, *** $p < 0.01$

Table 3: **Logit analysis of the probability that a bond-rating event is associated with an upgrade of the bond to a rating of AA or better.** The table reports estimation results for a logit analysis of RMBS and CMBS bond-rating events for bonds with initial ratings below AA. A bond-rating event is measured as a one if the new bond rating is AA or better, and zero otherwise.

of the crisis, the signs switch and the probability of CMBS bonds being upgraded is now negative in 2007 through 2009. Otherwise the two specifications, one including and the other excluding vintage fixed effects, produce nearly identical results.

The results of this analysis strongly suggest that the elevated rates of upgrading below-AA rated CMBS bonds to AA or AAA cannot be solely explained by changes in perceptions of the overall risk for AA or AAA-rated bonds. Instead, there appears to be something unique to the likelihood of upgrading AA or AAA-rated CMBS over this period, despite the public knowledge that subordination levels were falling significantly. In addition, as we saw above, despite the large increase in the supply of CMBS rated AA or above, sophisticated investors were willing to pay high prices for these bonds relative to similarly rated bonds in other markets over this period, while this was not true for lower-rated CMBS. Taken together, these results strongly suggest that both pricing and ratings in the CMBS bond market were responding to the risk-based capital advantages of AA and AAA ratings provided by the ratings agencies starting in 2002.

5 Structural modeling evidence

We have shown that, consistent with a regulatory-capital arbitrage explanation, spreads between CMBS and corporate bonds rated AA and above decreased significantly starting in 2002, unlike yield spreads for lower-rated securities. We have also shown that the likelihood of an upgrade from AA to AAA was significantly higher in the CMBS market than in the RMBS market. While this is significant evidence for the importance of regulatory-capital arbitrage, in this section we analyze the CMBS market in more detail to see if there were some other CMBS-specific changes that could have accounted for these results.

5.1 Loan quality

It is well documented that there was a significant drop in quality in the residential mortgage market in the years preceding the financial crisis, especially in the subprime sector. Here we analyze whether a similar quality deterioration occurred in the commercial loan market (though, of course, a deterioration in commercial loan quality would suggest that subordination levels ought to have *increased*, rather than decreased, over time).

Table 4 shows summary statistics for the 516 CMBS deals originated in the United States between 1995 and 2008 for which we have information on the underlying loans. Overall, these CMBS pools were composed of 51,677 fixed-rate, fully amortizing, commercial real-estate loans at origination.[16] The data used to compute these summary statistics were obtained from Trepp LLC. As shown in Table 4, while there are differences in the loan characteristics from year to year, there are no strong trends over time. The Loan-to-Value Ratio (LTV) varies only very slightly during the sample, as does the Debt Service Coverage Ratio (DSCR).

From 2005 to 2007 the CMBS prospectuses explicitly allowed borrowers to add mezzanine debt on properties with existing securitized mortgages. We therefore include a measure for the degree of mezzanine debt—the ratio of the securitized loan to the total debt on the asset. When this ratio is one, the securitized lien is 100% of the debt and there is no mezzanine debt. As shown in the table, the average ratio is one for all of the origination vintages. The small standard deviations indicate that although some mortgages had mezzanine debt, those loans represented only a very small proportion of the CMBS collateral. The average original loan balances of the mortgages in these pools increased approximately four-fold from 1995 to 2008. The weighted average coupon on the mortgages fell over the period, following the decrease in interest rates, and, interestingly, the spread to 10 year Treasury notes decreased from 2002–2006 and then rose in 2007 and 2008. Overall there is little in these statistics to indicate significant changes (especially improvements) in credit quality over time that would justify the large observed reductions in subordination levels.

5.2 Pool composition

Even if the quality of individual loans of each type remains the same, it is still possible for the quality of CMBS mortgage pools to change over time if the mixture of loan types in each pool changes. To investigate this possibility, Figure 3 shows the mix of different property types underlying the same 516 CMBS deals. Again, we obtained the data from Trepp LLC. It can be seen that there was a substantial rebalancing of the loan composition of the pools away from multi-family loans and towards office loans. The share of hotel loans also increased over the period from about 10% to 15%. Hotel loans are usually considered riskier loans, due to the volatility of leisure/travel demand, while office are usually considered slightly less risky. Overall, the property concentration does not suggest any significant trends in CMBS default risk.

5.3 Loan pricing at origination

While measurable aspects of loan quality, such as LTV and DSCR, did not change materially in the years leading up to the crisis, it is possible that these measures do not fully capture all

[16]Most of the loans collateralizing CMBS are fixed rate. We exclude all floating-rate loans, which appeared primarily in the 1997 and 1998 vintages, eliminating about 2,700 loans from the sample.

Year	Number		Payoff Term (Months)	Amortization Term (Months)	Weighted Average Coupon (%)	Loan to Value Ratio (%)	Spread to Treasury (%)	Debt Service Coverage Ratio	Securitized Loan to Total Debt on Asset (%)	Original Loan Balance ($M)
1995	717	Mean	129.92	306.18	8.70	67.13	2.54	1.52	1.00	3.83
		Std. Dev.	50.45	48.68	0.72	3.21	0.50	0.16	0.00	3.45
1996	2193	Mean	132.10	304.73	8.84	68.16	2.42	1.49	1.00	4.18
		Std. Dev.	45.19	56.87	0.58	2.74	0.47	0.17	0.00	5.01
1997	4564	Mean	136.29	316.27	8.12	69.88	1.96	1.51	1.00	5.12
		Std. Dev.	44.05	54.39	0.70	3.73	0.51	0.20	0.00	7.15
1998	5296	Mean	137.88	317.65	7.34	68.52	1.94	1.53	1.00	4.91
		Std. Dev.	40.99	56.42	0.51	4.96	0.60	0.23	0.00	9.11
1999	3361	Mean	126.59	331.19	8.02	68.12	2.36	1.49	1.00	5.16
		Std. Dev.	32.25	51.10	0.55	5.17	0.50	0.23	0.03	7.83
2000	2391	Mean	129.90	335.96	8.30	67.17	2.37	1.47	1.00	6.50
		Std. Dev.	41.26	47.71	0.46	4.98	0.37	0.19	0.02	9.49
2001	3167	Mean	122.16	336.12	7.38	66.00	2.36	1.53	1.00	6.55
		Std. Dev.	26.48	56.25	0.40	5.89	0.41	0.23	0.02	9.44
2002	3233	Mean	121.81	334.52	6.73	65.95	2.25	1.84	1.00	7.79
		Std. Dev.	27.66	52.73	0.65	5.45	0.46	0.35	0.02	13.04
2003	4402	Mean	123.18	330.53	5.87	65.03	1.87	2.23	1.00	7.63
		Std. Dev.	29.94	57.39	0.45	4.85	0.46	0.33	0.04	11.93
2004	3889	Mean	123.55	335.80	5.82	65.83	1.56	2.04	1.00	7.37
		Std. Dev.	29.84	51.87	0.39	8.37	0.36	0.31	0.04	11.73
2005	5524	Mean	121.56	344.02	5.63	68.00	1.36	1.83	1.00	8.14
		Std. Dev.	24.44	48.46	0.32	5.76	0.29	0.31	0.01	13.13
2006	7668	Mean	118.10	365.54	6.09	68.15	1.35	1.67	1.00	8.94
		Std. Dev.	17.71	43.57	0.33	3.26	0.27	0.21	0.00	13.86
2007	5219	Mean	117.89	368.36	6.13	69.67	1.44	1.58	1.00	8.48
		Std. Dev.	15.94	43.66	0.36	3.58	0.40	0.16	0.00	14.93
2008	53	Mean	116.06	369.43	6.73	66.90	3.00	1.60	1.00	11.03
		Std. Dev.	17.78	25.37	0.54	2.85	0.58	0.00	0.00	13.75

Table 4: **Loan underwriting trends, 1995–2008.** The table presents summary statistics for the loan-underwriting characteristics for 51,677 loans that were securitized into the universe of 516 conduit CMBS pools in the United States from 1995 to 2008. The data were obtained from Trepp LLC.

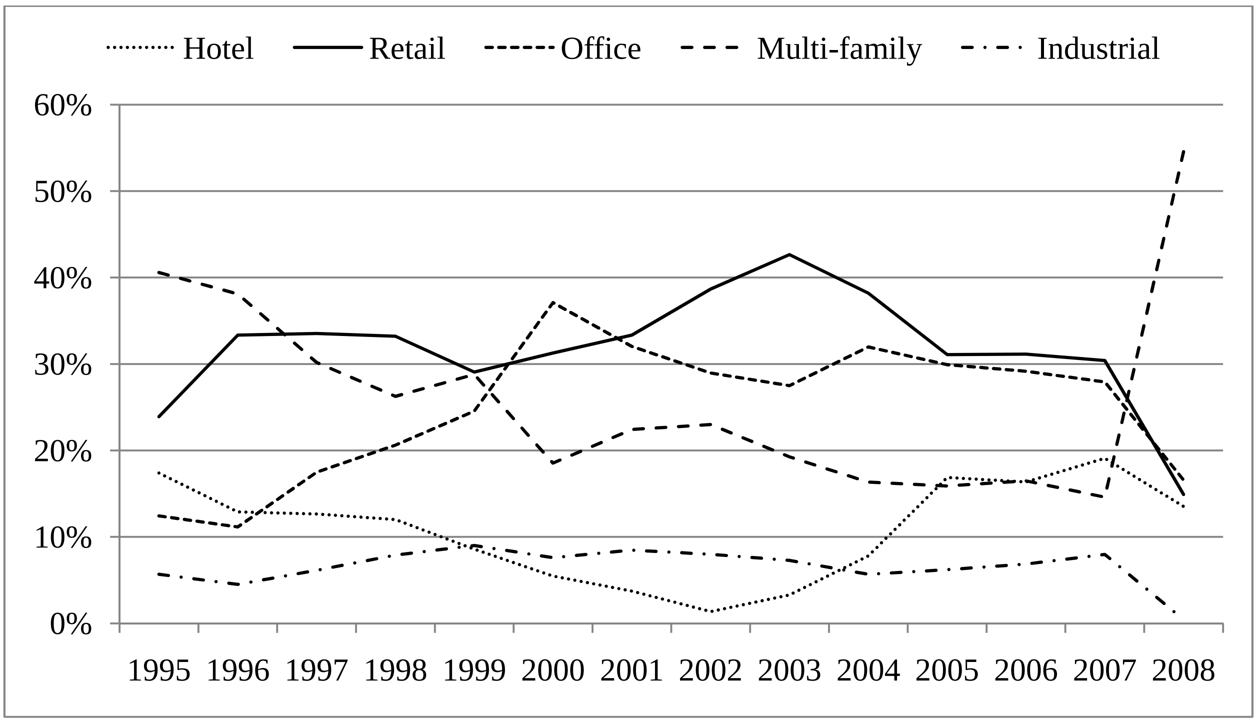


Figure 3: **CMBS pool composition, 1995–2008.** This figure shows the property-type composition of the universe of 516 CMBS pools that were originated from 1995 to 2008. These pools are composed of 51,677 non-seasoned fixed rate mortgages. The data were obtained from Trepp LLC

aspects of the perceived riskiness of the loans. In particular, it is possible that the market's estimates of default probabilities for a given loan changed over the period in a manner that was uncorrelated with LTV and DSCR. This would justify changing subordination levels, but would not necessarily show up as a change in LTV or DSCR values. However, it *would* show up as a change in pricing (or equivalently, the coupon rate) over time for a loan with given characteristics.

We here perform two different analyses to investigate whether commercial real estate loan underwriting standards changed over the pre-crisis period. First, we analyze the composition of the spread between the loan contract rates and the 10-year constant-maturity Treasury rates for a large sample of securitized commercial mortgages over this period. Then, since commercial mortgage loan underwriting characteristics are determined jointly, we carry out a second structural modeling analysis, which accounts for the true nonlinear relationship between commercial mortgage contract variables and the embedded options in these contracts. In this analysis, we use the Titman and Torous (1989) two-factor mortgage valuation model to estimate loan-by-loan implied volatilities at origination for the commercial real estate loans in our sample. In this analysis, we would expect that any change in default expectations should translate into an increase or decrease in the embedded implied volatilities in these contracts over time.

5.3.1 Regression analysis

For our empirical analysis of the pre-crisis trends in loan underwriting, we again use the loan-level sample obtained from Trepp LLC. Our pre-crisis sampling period corresponds to a time period over which CMBS subordination levels experienced dramatic declines, as shown in Figure 1, and yet it precedes by at least two years generally acknowledged market indicators of the financial crisis (see Tong and Wei, 2008).

Table 5 reports our regression analysis of the pre-crisis components of commercial mortgage contract rate spreads to the ten-year constant-maturity Treasury rates at the origination date of each loan. Although all mortgage terms are jointly determined, we find that the loan-to-value ratio and the debt-service coverage ratios are highly correlated, so we report two sets of regressions.[17] One set is for spread as a function of loan characteristics, excluding DSCR, but including property type and loan-origination year dummies for 1996–2008. As shown, relative to the omitted property type (hotels), the loans on industrial, multifamily, office, and retail property types all have a smaller spread to Treasuries. Although all of the year dummies are different from zero, there is no obvious trend in the dummies, though spreads to Treasuries were narrowest in 2005 and 2006. Together, these results suggest that although

[17] A regression of LTV on DSCR and no intercept has an R^2 of .80.

subordination levels were persistently falling over this period, lenders did not significantly alter their pricing of the underlying loans over the same period.

5.3.2 Implied volatilities

In the model of Titman and Torous (1989), the value of a mortgage, M, is a function of interest rates, r, and property prices, p, which evolve together as:

$$dr_t = \kappa(\theta_r - r_t)\, dt + \phi_r \sqrt{r_t}\, dW_{r,t}, \tag{1}$$

$$dp_t = (\theta_{p,t} - q_p)p_t\, dt + \phi_p p_t\, dW_{p,t}. \tag{2}$$

The implied volatility of a newly issued mortgage is defined as the volatility which sets the value of a newly issued mortgage equal to par. Details of the estimation procedure and of the loan characteristics are provided in Appendix A. Table 6 reports summary statistics for the time series of estimated loan-level implied volatilities. Office and industrial properties exhibit the highest implied volatilities, at 21.48% and 20.62%, respectively. For retail properties, the average implied volatility is 18.84%, and for multifamily properties it is 17.05%. Although these volatilities are higher than the values that appeared in the early literature, they are consistent with some more recent estimates, including Stanton and Wallace (2009) and Korteweg and Sørensen (2011).[18]

Figure 4 shows the estimated implied volatilities by property type between 1995 and 2008. Despite some variation, implied volatilities showed no major trends prior to May 2003. After that date, although there was continued variability, average implied volatilities trended downward until 2006, However, this downward trend reversed in 2007. These results suggest that lenders' pricing strategies for the 2005 and 2006 vintage loans were anomalous relative to longer term trends. However, they do not support the substantial decreases in CMBS subordination levels from 1997 through 2007.

5.4 Ex ante default expectations

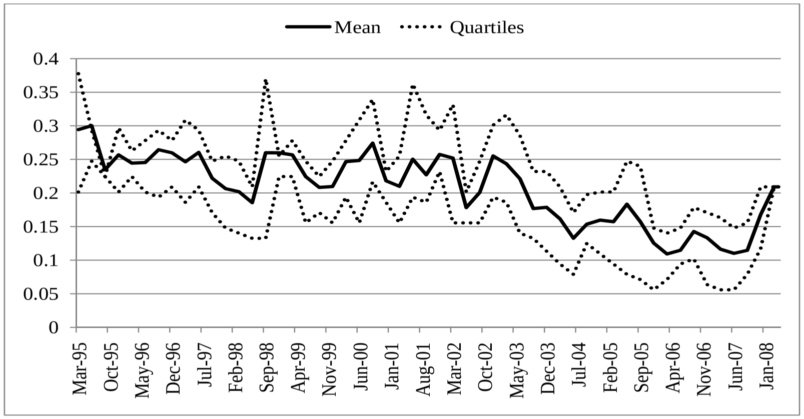
Despite observable loan characteristics remaining roughly constant, implied volatilities on newly issued commercial loans did show some decline during the period 1995–2008, indicating some improvement in credit quality. Directionally, at least, this is consistent with a

[18]Much of the early literature predates the development of the modern CMBS market. Titman and Torous (1989) apply a two factor model using quoted mortgage contract rates (as opposed to transaction rates) from 1985–1987. Ciochetti and Vandell (1999) and Holland, Ott, and Riddiough (2000) both calculate implied volatilities from one-factor mortgage valuation models, using mortgage origination data from the mid 1970s to the early 1990s.

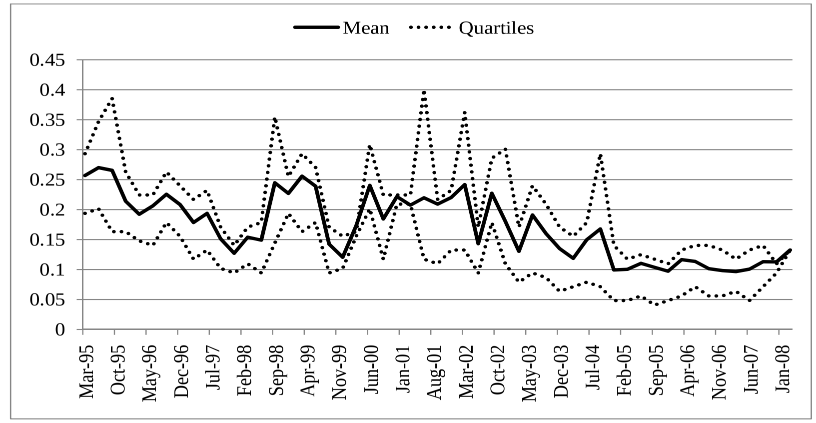
	Spread		Spread	
	Coefficient Estimate	Standard Error	Coefficient Estimate	Standard Error
Origination Principal ($M)	-0.003***	0.000	-0.003***	0.000
Amortization Term	-0.0003***	0.000	-0.001***	0.000
Payout Term	0.001***	0.000	0.001***	0.000
Loan-to-Value Ratio at Origination	0.001***	0.0004		
Debt Service Coverage Ratio on NOI			-0.0361***	0.009
Ratio of Securitized Loan to Total Debt	-0.594***	0.087	-0.612***	0.082
Industrial Property	-0.245***	0.009	-0.220***	0.010
MultiFamily Property	-0.398***	0.008	-0.326***	0.008
Retail Property	-0.262***	0.008	-0.225***	0.008
Office Property	-0.251***	0.008	-0.224***	0.009
Origination year 1996	-0.152***	0.018	-0.189***	0.028
Origination year 1997	-0.617***	0.017	-0.647***	0.026
Origination year 1998	-0.882***	0.017	-0.736***	0.026
Origination year 1999	-0.201***	0.017	-0.258***	0.027
Origination year 2000	-0.201***	0.018	-0.187***	0.028
Origination year 2001	-0.201***	0.017	-0.215***	0.026
Origination year 2002	-0.321***	0.017	-0.318***	0.026
Origination year 2003	-0.686***	0.017	-0.681***	0.026
Origination year 2004	-1.015***	0.017	-1.008***	0.026
Origination year 2005	-1.230***	0.017	-1.219***	0.026
Origination year 2006	-1.242***	0.018	-1.225***	0.026
Origination year 2007	-1.160***	0.018	-1.142***	0.026
Constant	3.411***	0.092	3.649***	0.089
Observations	51,677		51,677	
R^2	0.517		0.5038	

t tests of statistical significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

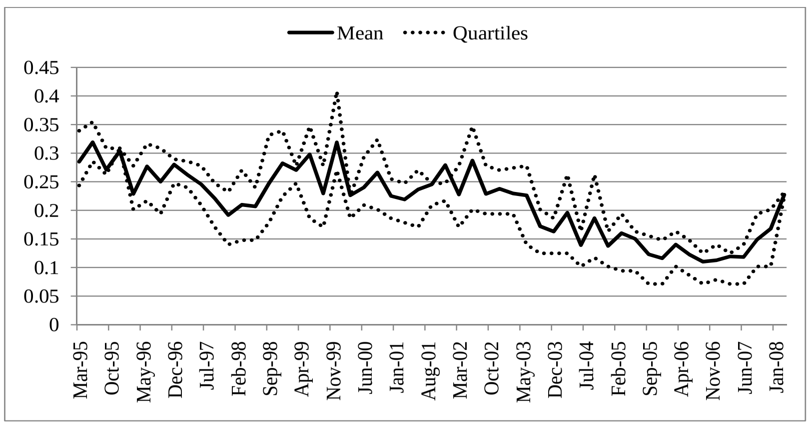
Table 5: **Regression of Contract Rate Spread on Loan Characteristics.** The table presents regression results for the contract rate spread, measured as the difference between the loan contract rate at origination and the ten-year constant-maturity Treasury rate on the origination date. The data for the analysis include 51,677 loans that were securitized in 516 CMBS pools from 1995–2008. The loan-level data were obtained from from the Trepp LLC.



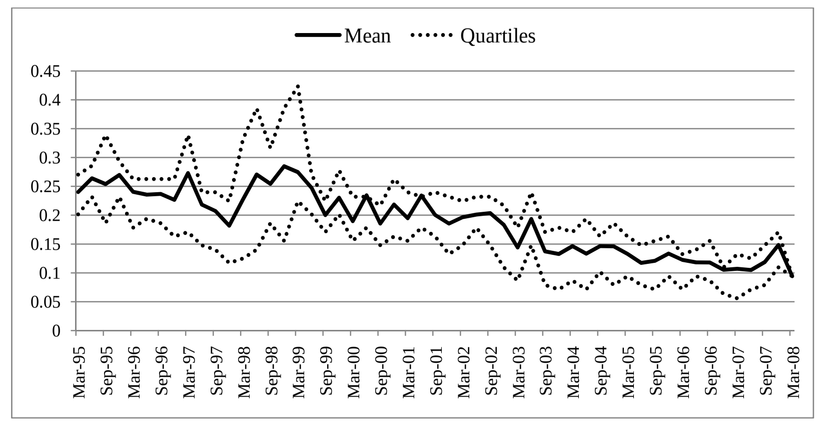
(a) Industrial



(b) Multifamily



(c) Office



(d) Retail

Figure 4: **Implied Volatilities by Property Type, 1995–2008.**This figure plots our calibrated implied volatilities by property type. The solid line plots the mean implied volatility for mortgage originated within a quarter. The bottom dashed line plots the 25$^{\text{th}}$ quartile and the top dashed line plots the 75$^{\text{th}}$ quartile of the quarterly implied volatility distributions.

	Number of Observations	Mean (%)	Standard Deviation (%)
Retail	18,399	18.842	5.526
Multifamily	15,129	17.051	5.392
Office	9,778	21.478	5.973
Industrial	4,675	20.619	5.250

Table 6: **Implied Volatilities by Property Type.** The table presents the computed implied volatilities for our sample of loans. The implied volatility is defined for each loan as the value of ϕ_p in Equation (5) that sets the initial value of the loan equal to par.

reduction in subordination levels over time. To understand whether the size of the reduction in subordination levels makes sense in light of the observed reduction in implied volatilities, we here combine the subordination levels with a statistical model for defaults over time to ask what future defaults could reasonably have been expected at the time the CMBS were issued. We model the distribution of defaults over time using the Titman and Torous (1989) model described above, inserting our property-specific implied volatilities from Section 5.3 into the property price evolution described by Equation (2). Details are provided in Appendix B.

Figure 5 shows the distribution of cumulative default rates, calculated using our implied volatility measures. The solid line indicates the median cumulative default rate across the simulations, the dashed lines show the approximate location of the 25^{th} and 75^{th} percentiles, and the dotted lines show the 5^{th} and 95^{th} percentiles, respectively. As can be seen, for approximately the first two years from origination, there are virtually no defaults, consistent with the fact that, by and large, the simulated loans carry low LTV levels. However, starting around year two, defaults begin to ramp up, and by the end of the 10-year horizon, the median cumulative default rate is 17%, with an interquartile range from 11% to 25%. An interesting feature of the cumulative default rates shown in Figure 5 is the up-tick in cumulative default at the maturity date of the loans. Since, on average, conduit loans amortize over a thirty horizon but are due at the end of ten years, there is usually a large remaining principal balance that is due at the maturity date. Thus, the amortization structure of these loans exposes investors to elevated risk of default that is concentrated at their maturity dates. Figure 6 shows the corresponding distribution of realized cumulative loss rates. The losses track the default rates closely. Again, there are almost no losses during the first two years, but then losses start to increase. By the end of the 10-year horizon, the median cumulative loss rate is 7.0%, with an interquartile range from 4% to 10.5%.

To assess the adequacy of CMBS subordination levels, we can compare our simulated

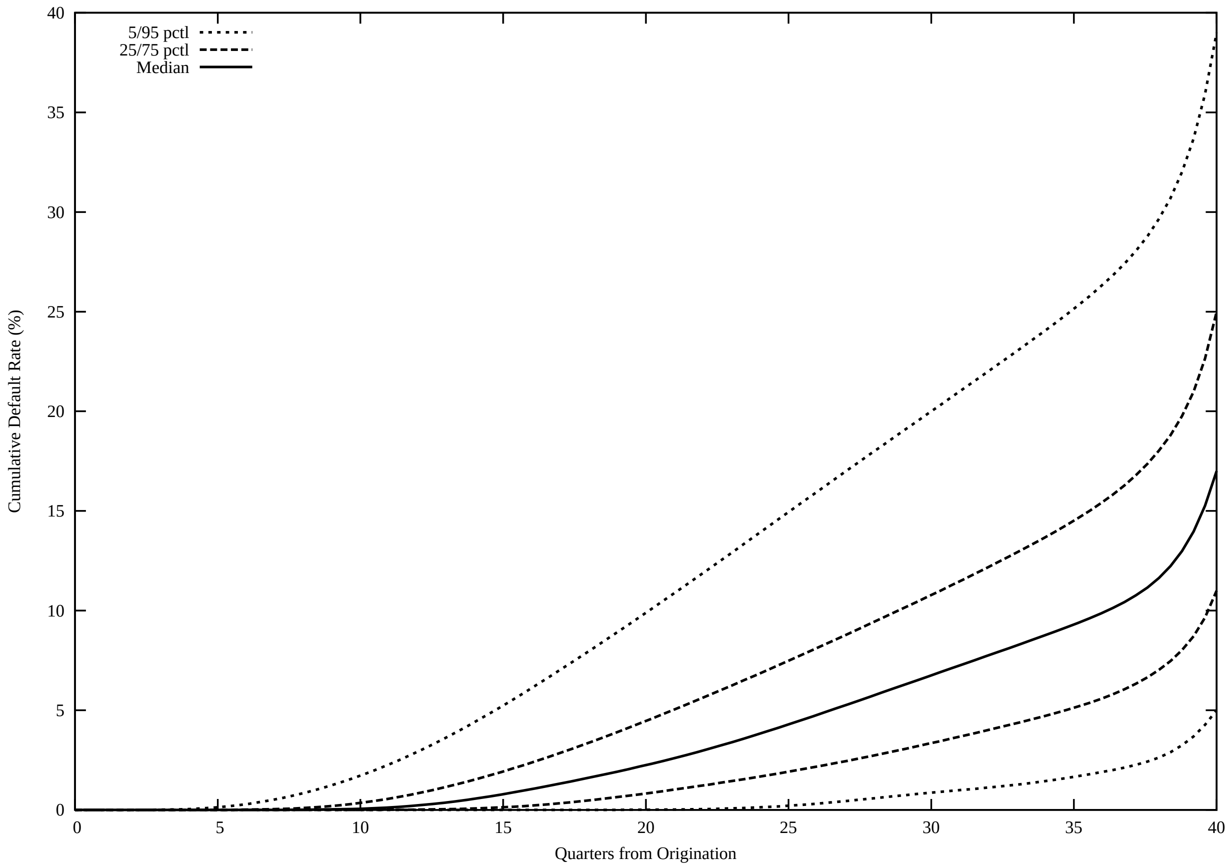


Figure 5: **Simulated Cumulative Default Rates.** This figures shows the distribution of cumulative default rates under our implied volatility measure. The solid line indicates the median cumulative default rate across the simulations, the dashed lines show the approximate location of the 25^{th} and 75^{th} percentiles, and the dotted lines show the 5^{th} and 95^{th} percentiles, respectively. We make 5,000 draws from the system of Equations (6) and (7), keeping track of the first time that each mortgage defaults along a simulated path of interest rates and property returns.

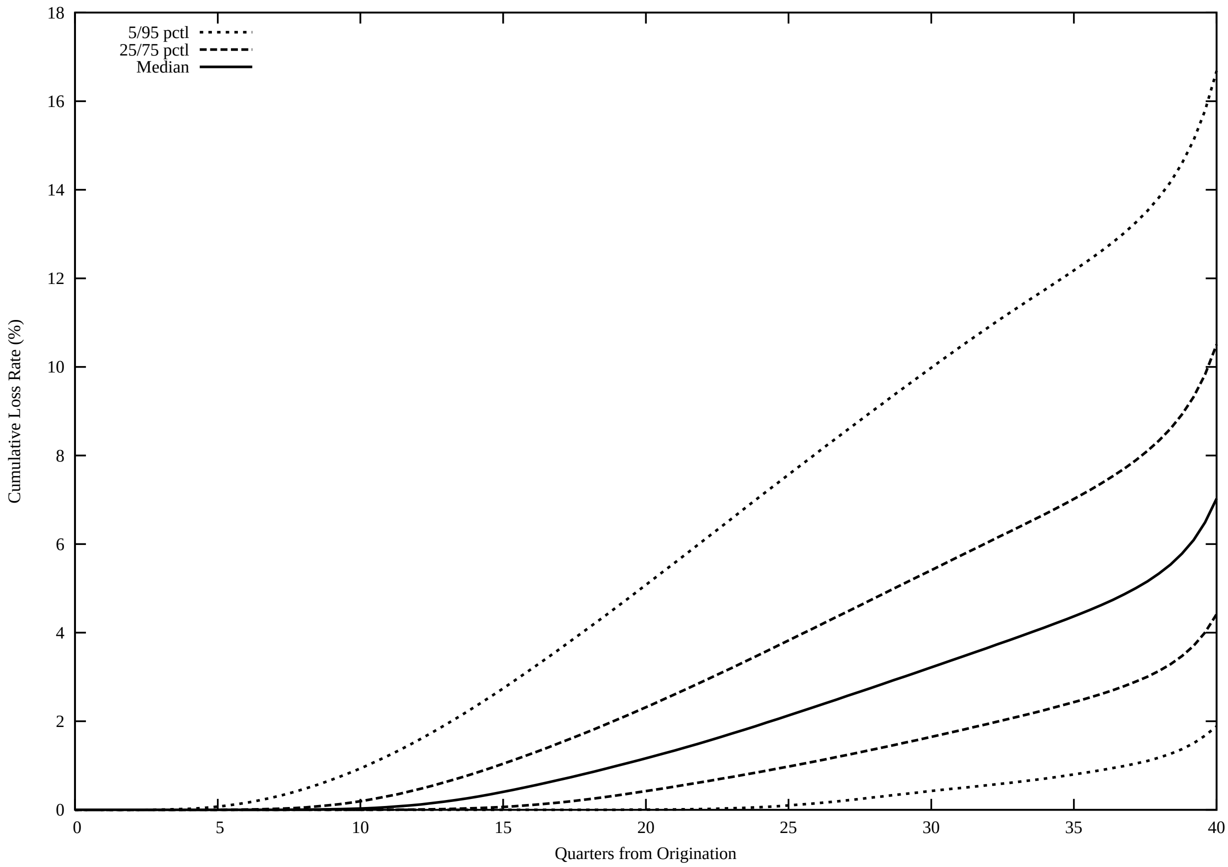


Figure 6: **Simulated Cumulative Loss Rates.** This figures shows the distribution of cumulative loss rates under our implied volatility measure. The solid line indicates the median cumulative loss rate across the simulations, the dashed lines show the approximate location of the 25^{th} and 75^{th} percentiles, and the dotted lines show the 5^{th} and 95^{th} percentiles, respectively. We make 5,000 draws from the system of Equations (6) and (7), keeping track of the first time that each mortgage defaults along a simulated path of interest rates and property returns.

loss rates with the subordination levels observed in practice, which are shown in Table 7. Focusing in particular on the BBB tranche (the story is similar for other tranches), the loss levels required to generate losses to investors would be 5.5% for 2004 pools, 4.8% for 2005 pools, 4.6% for 2006 pools, and 4.7% for 2007 pools. Based upon the simulation results reported in Figure 5, all of these values are well below the median ten-year loss rate generated by our model.

5.5 Comparison with historical default experience

The results above strongly suggest that subordination levels in the years immediately prior to the recent crisis were too low (or equivalently, that they implied expected default levels on supposedly "safe" bonds that were too high). To confirm the reasonableness of the model's predictions, we compare them with historical CMBS default experience analyzed by Esaki (2002) using a panel of 116,595 commercial real estate loans held by major insurance companies. The default rate of these loans between 1972 and 1990 never fell below 10% and at times exceeded 30%. While default rates fell substantially between 1990 and 1996 (during the operation of the Resolution Trust Corporation and establishment of CMBS auctions to liquidate the holdings of failed S&L institutions), the long-run average default rate for these commercial loan portfolios from 1972 to 1996 was around 20%, very close to the model's predictions. In a subsequent extension of this study through 2002, Esaki and Goldman (2005) find a similar 19.6% average ten-year cumulative default rate for commercial real estate loans held by insurance companies. In another recent study, Wiggers and Ashcraft (2012) find that the ten-year cumulative default rate for a large sample of commercial real estate bonds was about 30% between 1920 and 1932. Although these results exceed our numbers, they correspond to the significantly worse real-estate market conditions of the Great Depression.

In sum, historical commercial-mortgage default evidence is largely supportive of the predictions from our structural model, supporting our conclusion that subordination levels of CMBS issued in the years immediately prior to the crisis were too low.

6 Conclusions

By studying the CMBS market, we shed new light on the role of the rating agencies and subordination levels in the financial crisis of 2007–2009. While the rating agencies have been blamed by many for over-optimistic ratings, it has been hard to pin down their role unambiguously due to the presence of many other confounding factors. We show that almost

Class	Percentage Subordination %
2004 CMBS Conduit Pools - Number of Pools = 62	
AAA	15.3
AA	11.8
A	8.8
BBB	5.5
BBB-	3.9
2005 CMBS Conduit Pools - Number of Pools = 64	
Short-Senior AAA	26.5
Long-Junior AAA	13.1
AA	10.8
A	8.1
BBB	4.8
BBB-	3.4
2006 CMBS Conduit Pools - Number of Pools = 70	
Short-Senior AAA	28.4
Long-Junior AAA	12.4
AA	10.4
A	7.8
BBB	4.6
BBB-	3.3
2007 CMBS Conduit Pools - Number of Pools = 65	
Short-Senior AAA	28.5
Long-Junior AAA	13.6
AA	10.5
A	8.0
BBB	4.7
BBB-	3.2

Table 7: **Subordination rates.** The table shows weighted-average subordination levels (equivalently, the maximum principal loss that can be sustained without affecting a given security) for the universe of CMBS securities with different ratings originated between 2004 and 2007. The subordination structure for these pools was obtained from CMAlert (`http://www.CMAlert.com/`).

all of these confounding factors are absent in the CMBS market. In particular, unlike with residential loans, commercial loans did not significantly change their characteristics during this period, and commercial lenders did not change the way they priced a loan with given characteristics (except perhaps for the 2005 and 2006 vintages). Moreover, during the crisis, expected cumulative default rates are in line with levels observed over almost the whole of the 40-year period before the crisis, excluding the most recent few years.

We find that both before and during the crisis, the primary shift in the market was the reduction in allowable subordination levels by the rating agencies. This is consistent with ratings-capital arbitrage, following the loosening of risk-based capital requirements for highly rated CMBS in 2002. This loosening introduced significant incentives for insurers and banks to hold AA and AAA-rated CMBS, providing an explanation for both the trends in subordination and for the patterns we uncovered in spreads and upgrade behavior in the CMBS market relative to other markets that did not experience a similar regulatory change, This is also consistent with general evidence provided in Acharya and Richardson (2010) and Acharya et al. (2010) that regulatory-capital arbitrage fundamentally drove bank and insurance company investment strategies prior to the financial crisis, and that these strategies served to greatly increase the leverage of these firms and their susceptibility to insolvency with even minor shocks to fundamentals.

A Calculating implied volatilities

As when using option prices to infer implied volatility for an equity option, calculating implied volatilities for commercial mortgages requires a mortgage pricing model. We use a two-factor model based on Titman and Torous (1989), in which the value of a mortgage, M, is a function of interest rates, r, property prices, p, and time, t.

Interest rates Interest rates are governed by the Cox, Ingersoll, and Ross (1985) model,

$$dr_t = \kappa(\theta_r - r_t)\, dt + \phi_r \sqrt{r_t}\, dW_{r,t}, \tag{3}$$

where κ is the rate of reversion to the long-run mean, θ_r, and ϕ_r governs interest rate volatility. The price of interest rate risk is determined by the product ηr_t. We estimate parameters for the interest rate process using the methodology of Pearson and Sun (1989) and daily data on constant-maturity 3-month and 10-year Treasury rates from 1968 to 2006:

$$\begin{aligned} \kappa &= 0.13131, \\ \theta_r &= 0.05740, \\ \phi_r &= 0.06035, \\ \eta &= -0.07577. \end{aligned}$$

Property prices Property prices follow the risk-neutral geometric Brownian motion process,

$$dp_t = (r_t - q_p)p_t\, dt + \phi_p p_t\, dW_{p,t}, \tag{4}$$

where q_p is the net income as a fraction of market value and ϕ_p is the volatility of the property's return. We estimate q_p using realized income returns, obtained from NCREIF, between the first quarter of 1978 and the first quarter of 2005, leading to estimates (close to those used in Titman and Torous, 1989) of:

$$q_p = \begin{cases} 7.90\% & \text{for office properties;} \\ 7.84\% & \text{for multifamily properties;} \\ 7.85\% & \text{for retail properties;} \\ 8.47\% & \text{for industrial properties} \\ 7.99\% & \text{for other properties.} \end{cases}$$

Pricing p.d.e. Given the above processes for interest rates and property prices, the value of a commercial mortgage $M(p_t, r_t, t)$ with maturity date $T > t$, paying coupon C, must satisfy the partial differential equation:

$$\frac{1}{2}\phi_r^2 r M_{rr} + \frac{1}{2}\phi_p^2 p^2 M_{pp} + \rho\phi_r\phi_p p\sqrt{r} M_{rp} + \left(\kappa(\theta_r - r) - \eta r\right) M_r + \left((r - q_p)p_t\right) M_p + M_t - rM + C = 0, \tag{5}$$

where $E\left[dW_r\, dW_p\right] = \rho\, dt$, subject to boundary conditions is similar to those described in detail in Titman and Torous (1989), though with one significant difference. Based on results from Brown, Ciochetti, and Riddiough (2006), we assume that, in the event of a default, the underlying real estate suffers an immediate additional drop in value of 24.4%. This does not affect the borrower's default decision, but does affect the lender's loss in the event of a default (and hence also affects implied volatilities).[19]

We assume that $\rho = 0$, and solve the model numerically, using a finite difference method to value the security, simultaneously determining the critical default boundary. The implied volatility for a given mortgage is then determined (also numerically) by finding the value of ϕ_p at which the model prices a newly issued mortgage (from the perspective of the lender) at par.

B Simulating defaults

To simulate defaults, we use the Titman and Torous (1989) model described above, inserting our property-specific implied volatilities from Section 5.3 into the property price evolution described by Equation (2). Before doing this, however, it is necessary to model the correlation between defaults on different loans in a pool.

Correlation between loans While the correlation between mortgages in a pool does not affect the total value of all CMBS tranches, it does affect the relative values of different tranches.[20] In general, more dispersion (more correlation) lowers the value of safer tranches,

[19]We could add other features to the model, such as borrower default costs or stochastic volatility. While this might change implied volatilities, the effect on default and loss rates would be small because we are using the same model to estimate both implied volatilities and default rates. With deadweight costs of default, for example, then at the previously estimated implied volatilities, the model would now yield initial mortgage values well above par (because default rates would now be lower than before). To bring prices back down to par again, implied volatilities would have to increase above their prior values, in turn resulting in an offsetting *increase* in default probabilities. This is very similar to a point noted by Huang and Huang (2003), who calibrated a variety of different credit-risk models to historical default rates and found that "[D]ifferent structural models . . . predict fairly similar credit spreads under empirically reasonable parameter choices." In both cases, prices are primarily driven by default rates, so even quite different-looking models will tend to agree on default (loss) rates if they agree on prices, and vice versa.

[20]Ignoring spreads and liquidity differences, the total CMBS cash flow equals the total mortgage cash flow, and the value of each mortgage does not depend on correlation. Thus, in particular, changes in correlation

and increases the value of extremely risky tranches.[21] The tranches most adversely affected by greater dispersion of mortgage default would be not the AAA securities (which are protected even if defaults are substantially higher than expected), but the securities slightly lower down in priority, such as BBB. In estimating default expectations, it is therefore important to take correlation between individual mortgages into account. To do this, we split the return shocks for each property into two components, a common component shared across all properties, and a property-specific component, whose volatility varies by property type. More precisely, we simulate draws from the following system:

$$dr_t = \kappa(\theta_r - r_t)\, dt + \phi_r \sqrt{r_t}\, dW_{r,t}, \tag{6}$$

$$dp^j_{i,t} = (\theta^j_{p,t} - q^j_p) p^j_{i,t}\, dt + \phi p^j_{i,t}\, dW_t + \phi^j_p p^j_{i,t}\, dW^i_t, \tag{7}$$

where $p^j_{i,t}$ is the price of property i, of type j (where $i = 1, 2, 3, 4, 5$ indexes apartment, office, retail, industrial, and all other properties, respectively), dW_t is common across all properties, and dW^i_t is an independent shock for each property. We use the total return volatility published by the National Council of Real Estate Investment Fiduciaries (NCREIF) as an estimate of the systematic component, 7.019%. We then set the idiosyncratic volatility for each property type to match the total volatilities given in Table 6. For example, the idiosyncratic volatility for office properties is set to ϕ_{p_i}=0.203, implying a total volatility for office properties of

$$\sqrt{0.07019^2 + 0.203^2} = 0.215,$$

the relevant value in Table 6.

Simulation Details To estimate the default behavior of pools of mortgages, we first create a simulated pool, containing 100 mortgages, with types chosen to match the average proportions seen in the data: 25 apartment, 20 office, 30 retail, 10 industrial, and 15 "other" (proxied by national averages). For each mortgage, we randomly draw an LTV so that we match the sample mean and standard deviation of the origination LTV ratios for the property's type. Within each property type, though the mortgages differ in their initial LTV

cannot cause subordination levels on all bonds to shrink at the same time.

[21] The dependence on dispersion (correlation) arises because tranching makes CMBS payoffs nonlinear in the default rates of the underlying mortgages. Hence, by Jensen's Inequality, the expected cash flow to a CMBS is not equal to its cash flow at the expected default rate on the underlying mortgages, the difference depending on the volatility of the cash flows. As an example, suppose that a CMBS structure protected against losses up to 10%, and the expected loss on the mortgages was 10%. If the default rate were certain, then the CMBS would experience a 0% default rate. If the default rate were uncertain, and, say, had a fifty percent chance of a 0% or 20% default realization, the CMBS would have an expected loss of 5% of underlying principal.

ratio, they share the sample average coupon level, term, and amortization schedule.

Given the composition of the pool, we now make 5,000 draws from the system of equations (6) and (7), keeping track of the frequency with which the joint interest rate and property price process moves into the region where each borrower optimally chooses to default both over the term of the mortgage and at maturity.[22] For the net drift of the house price process, we use the average inflation rate over the last 20 years, 2.5%, following a large literature that has found long-run real growth in land and real-estate prices to be approximately zero (see, for example, Hoyt, 1933; Mills, 1969; Edel and Sclar, 1975; Eicholtz, 1997; Wheaton, Baranski, and Templeton, 2009). In the event of a default, we also keep track of the realized loss to the lender.

[22]The default boundary for each loan is determined as part of the numerical solution of the pricing p.d.e.

References

Acharya, Viral, Thomas Cooley, Matthew Richardson, and Ingo Walter, 2010, Manufacturing tail risk: A perspective on the financial crisis of 2007–2009, in *Foundations and Trends in Finance*, chapter 1, 249–320 (NOW Essence of Knowledge, New York).

Acharya, Viral, and Matthew Richardson, 2010, Causes of the financial crisis, in *Critical Review*, volume 21, 195–210 (Routledge Publishers).

Alexander, Gordon J., and Alexandre M. Baptista, 2006, Does the Basle Capital Accord reduce bank fragility? An assessment of the value-at-risk approach, *Journal of Monetary Economics* 53, 1631–1660.

Altman, Edward I., and Anthony Saunders, 2001, An analysis and critique of the BIS proposal on capital adequacy and ratings, *Journal of Banking and Finance* 25, 25–46.

Ashcraft, Adam, Paul Goldsmith-Pinkham, and James Vickery, 2009, MBS ratings and the mortgage credit boom, Working paper, Federal Reserve Bank of New York.

Bank for International Settlements, 2008, Ratings in structured finance: What went wrong and what can be done to address shortcomings?

Basel Committee on Banking Supervision, 1999, A new capital adequacy framework.

Benmelech, Efraim, and Jennifer Dlugosz, 2009, The alchemy of CDO credit ratings, *Journal of Monetary Economics* 56, 617–634.

Board of Governers of the Federal Reserve System and U.S. Securities and Exchange Commission, 1998, Report to congress on markets for small businesses and commercial mortgage-related securities, Technical report: Regulator use, Submitted to the U.S. Congress.

Bolton, Patrick, Xavier Freixas, and Joel Shapiro, 2012, The credit ratings game, *Journal of Finance* 67, 85–112.

Brown, David T., Brian A. Ciochetti, and Timothy J. Riddiough, 2006, Theory and evidence on the resolution of financial distress, *Review of Financial Studies* 19, 1357–1397.

Ciochetti, Brian A., and Kerry D. Vandell, 1999, The performance of commercial mortgages, *Real Estate Economics* 27–61.

Coval, Joshua, Jakub Jurek, and Erik Stafford, 2009a, The economics of structured finance, *Journal of Economic Perspectives* 23, 3–25.

Coval, Joshua D., Jakub W. Jurek, and Erik Stafford, 2009b, Economic catastrophe bonds, *American Economic Review* 99, 628–666.

Cox, John C., Jonathan E. Ingersoll, Jr., and Stephen A. Ross, 1985, A theory of the term structure of interest rates, *Econometrica* 53, 385–407.

Demyanyk, Yuliya, and Otto Van Hemert, 2011, Understanding the subprime mortgage crisis, *Review of Financial Studies* 24, 1848–1880.

Driessen, Joost, and Otto Van Hemert, 2011, Pricing of commercial real estate securities during the 2007–2009 financial crisis, Working paper, NYU, forthcoming, *Journal of Financial Economics*.

Eastham, Peter, James C. Digney, Barbara Hoeltz, Kurt C. Pollem, and Gary T. Carrington, 2012, Request for comment: Rating methodology and assumptions for U.S. and Canadian CMBS, Technical report, Standard & Poor's.

Edel, Matthew, and Elliott Sclar, 1975, The distribution of residential value changes: Metro Boston, 1870–1970, *Journal of Urban Economics* 2, 366–387.

Eicholtz, Piet, 1997, A long run house price index: The Herengracht index, *Real Estate Economics* 25, 175–192.

Esaki, Howard, 2002, Commercial mortgage defaults: 1972–2000, *Real Estate Finance* 18, 43–53.

Esaki, Howard, and Masumi Goldman, 2005, Commercial mortgage defaults: 30 years of history, *CMBS World* Winter, 21–29.

Griffin, John M., and Dragon Yongjun Tang, 2009, Did subjectivity play a role in CDO credit ratings?, Working paper, U.T. Austin, forthcoming, *Journal of Finance*.

Holland, A. Steven, Steven H. Ott, and Timothy J. Riddiough, 2000, The role of uncertainty in investment: An examination of competing investment models using commercial real estate data, *Real Estate Economics* 28, 33–64.

Hoyt, Homer, 1933, *One Hundred Years of Land Value in Chicago* (University of Chicago Press, Chicago).

Huang, Jing-Zhi, and Ming Huang, 2003, How much of the corporate-Treasury yield spread is due to credit risk? A new calibration approach, Working paper, Stanford University.

International Monetary Fund, 2008, Global financial stability report: Containing systemic risks and restoring financial soundness.

Jones, David, 2000, Emerging problems with the Basel Capital Accord: Regulatory capital arbitrage and related issues, *Journal of Banking and Finance* 24, 35–58.

Kashyap, Anil K., Raghuram G. Rajan, and Jeremy C. Stein, 2008, Rethinking capital regulation, in *Maintaining Stability in a Changing Financial System*, 431–471 (Federal Reserve Bank of Kansas City).

Korteweg, Arthur, and Morten Sørensen, 2011, Estimating loan-to-value ratios and foreclosure behavior, Working paper, Columbia University.

Manconi, Alberto, Massimo Massa, and Ayako Yasuda, 2010, The role of institutional investors in propagating the crisis of 2007-2008, Working paper, INSEAD, forthcoming, *Journal of Financial Economics*.

Mathis, Jérôme, James McAndrews, and Jean-Charles Rochet, 2009, Rating the raters: Are reputation concerns powerful enough to discipline rating agencies?, *Journal of Monetary Economics* 56, 657–674.

Merton, Robert C., and André Perold, 1993, Theory of risk capital in financial firms, *Journal of Applied Corporate Finance* 6, 16–32.

Mian, Atif, and Amir Sufi, 2009, The consequences of mortgage credit expansion: Evidence from the U.S. mortgage default crisis, *Quarterly Journal of Economics* 124, 127–145.

Mills, Edwin S., 1969, The value of urban land, in Harvey Perloff, ed., *The Quality of the Urban Environment* (Johns Hopkins University Press, Baltimore).

National Association of Insurance Commissioners, 2009, Risk-based capital forecasting and instructions, Technical report: Regulator use, National Association of Insurance Commissioners.

Opp, Christian, Marcus Opp, and Milton Harris, 2012, Rating agencies in the face of regulation: Rating inflation and regulatory arbitrage, Working paper, U.C. Berkeley, forthcoming, *Journal of Financial Economics*.

Pearson, Neil D., and Tong-Sheng Sun, 1989, A test of the Cox, Ingersoll, Ross model of the term structure of interest rates using the method of maximum likelihood, Working paper, MIT.

Rosenblatt, Marty, 2001, U.S. banking agencies approve final rule on recourse and residuals, Deloitte & Touche.

Sangiorgi, Francesco, Jonathan Sokobin, and Chester Spatt, 2009, Credit-rating shopping, selection, and the equilibrium structure of ratings, Working paper, Carnegie Mellon University.

Skreta, Vasiliki, and Laura Veldkamp, 2009, Ratings shopping and asset complexity: A theory of ratings inflation, *Journal of Monetary Economics* 56, 678–695.

Stanton, Richard, and Nancy Wallace, 2009, Dynamic house price indices: Foundations for a new estimator, Working paper, U.C. Berkeley.

Stanton, Richard, and Nancy Wallace, 2011, The Bear's lair: Indexed credit default swaps and the subprime mortgage crisis, *Review of Financial Studies* 24, 3250–3280.

Stulz, René M., 2010, Credit default swaps and the credit crisis, *Journal of Economic Perspectives* 24, 73–92.

Titman, Sheridan, and Walter N. Torous, 1989, Valuing commercial mortgages: An empirical investigation of the contingent-claims approach to pricing risky debt, *Journal of Finance* 43, 345–374.

Tomlinson, Richard, and David Evans, 2007, CDO boom masks subprime losses, abetted by S&P, Moody's, Fitch, Bloomberg.com.

Tong, Hui, and Shang-Jin Wei, 2008, Real effects of the subprime mortgage crisis: Is it a demand or a finance shock?, Working paper, International Monetary Fund.

Wheaton, William C., Mark S. Baranski, and Cesarina A. Templeton, 2009, 100 years of commercial real estate prices in Manhattan, *Real Estate Economics* 37, 69–83.

Wheeler, Darrell, 2001, A guide to commercial mortgage-backed securities, in Lakhbir Hayre, ed., *Salomon Smith Barney Guide to Mortgage-Backed and Asset-Backed Securities*, chapter 16, 399–451 (John Wiley, New York).

Wiggers, Tyler, and Adam Ashcraft, 2012, Defaults and losses on commercial real estate bonds during the Great Depression, Working paper, Federal Reserve Bank of New York.