CMBS Subordination, Ratings Inflation, and the Crisis of 2007-2009*

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June 8, 2010

Abstract

This paper analyzes the performance of the commercial mortgage-backed security (CMBS) market before and during the recent financial crisis. Using a comprehensive sample of CMBS deals from 1996 to 2008, we show that (unlike the residential mortgage market) the loans underlying CMBS did not significantly change their characteristics during this period, commercial lenders did not change the way they priced a given loan, defaults remained in line with their levels during the entire 1970s and 1980s and, overall, the CMBS and CMBX markets performed as normal during the financial crisis (at least by the standards of other recent market downturns). We show that the recent collapse of the CMBS market was caused primarily by the rating agencies allowing subordination levels to fall to levels that provided insufficient protection to supposedly "safe" tranches.

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*Financial support from the Fisher Center for Real Estate and Urban Economics is gratefully acknowledged.

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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 an early 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."

However, before concluding that the rating agencies were to blame, it is important to control for 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,

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[1] For further discussion, see Bank for International Settlements (2008). Theoretical models explaining ratings inflation over time include Opp, Opp, and Harris (2010) and Sangiorgi, Sokobin, and Spatt (2009).

[2] See, for example, Demyanyk and Van Hemert (2009). 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."
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> "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 (2009) for a detailed discussion. Stanton and Wallace (2009) show, for example, that during the crisis, prices for ABX.HE indexed CDS, backed by pools of residential MBS, implied default rates over

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]

In this paper, we shed new light on the role of the rating agencies in the crisis by focusing on the CMBS market. There are several reasons why this market is ideal for this purpose. First, we have access to large amounts of very detailed information on the loans underlying the securities. Second, unlike the residential MBS market, all agents in the CMBS market can reasonably be viewed as sophisticated, informed investors.[5] Third, as we shall show (and also unlike the RMBS market), there were no major changes in the underlying market for commercial loans over this period; and fourth, as we shall also show, unlike the ABX market (indexed credit default swaps written on pools of RMBS), the CMBX market functioned normally both before and during the crisis. As a result, we can rule out many of the confounding factors that make studying other markets so difficult, and focus more clearly just on the role played by the rating agencies.

Prior to the recent financial crisis, the U.S. commercial mortgage-backed security (CMBS) market had expanded rapidly, with an average annual growth rate of about 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.[6] Since 2007, however, there have been large write-downs on the CMBS holdings of financial institutions, followed by the virtual collapse of the CMBS market in the United States. This has led to a commercial mortgage funding shortfall of about $200 billion, and a growing problem with so called "maturity defaults," caused by the inability of current commercial real estate borrowers to refinance the outstanding balances on their maturing mortgages.

We find that while there are certainly some similarities to events in the RMBS market, the differences between the markets are more striking. In particular, while it is common to talk about events in the RMBS market as being a "hundred-year storm," we show that the CMBS market did not perform noticeably worse during the crisis of 2007–2009 than it had done numerous times in recent history, prompting the question: Why did this crisis cause

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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.

[4] There are some notable exceptions. In particular, Ashcraft, Goldsmith-Pinkham, and Vickery (2009) study credit ratings in the RMBS market, and Griffin and Tang (2009) look at CDO ratings.

[5] For example, the B-piece investors in CMBS hold dual roles as bond investors (if the assets remain current on their obligations) and controlling interests (if the loans default and go into special servicing). Thus, the below-investment-grade CMBS investor is usually a real estate specialist with extensive knowledge about the underlying assets and mortgages in the pools.

[6] 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].

the CMBS and commercial real estate loan markets to collapse, when the commercial loan market had survived many similar prior downturns?

The short answer is that the CMBS market collapsed because, in the period leading up to the latest crisis, the rating agencies allowed subordination levels to fall to levels that provided insufficient protection to supposedly "safe" tranches.[7] Prima facie evidence of this 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.[8]

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.[9] 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 2005, 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 to answer several related questions:

1. Did the quality of loans underlying CMBS change leading up to the crisis?
2. Did the pricing of the loans underlying CMBS change?
3. How did default expectations prior to the crisis compare with the protection provided by the then-current subordination levels?
4. How did realized defaults during the crisis compare with those in recent prior downturns?
5. What default rates would we have seen using today's subordination levels in earlier downturns?
6. What default rates would we have seen using 1996's (say) subordination levels in 2008?
7. Did related markets, such as the CMBX indexed CDS market, lose touch with fundamentals during the crisis, as happened with the ABX.HE?

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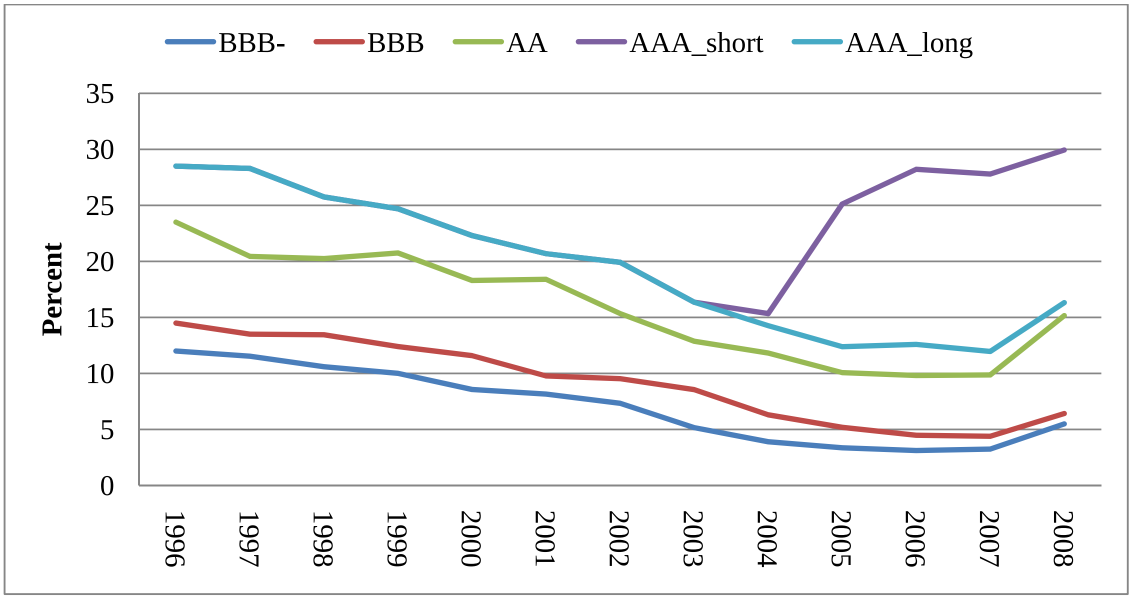
[7] The subordination level is the maximum amount of principal loss on the underlying mortgage that can occur without a given security suffering any loss. For AAA rated tranches, subordination levels fell from 35.59% to 14.08%, and for BBB tranches, they fell from 14.34% to 3.72%.

[8] The apparent rise in the subordination level for "AAA_short" is illusory. Prior to 2004, the rating agencies reported the level of subordination underlying all of the AAA securities. From 2004 on, it became standard practice to re-tranche the overall principal balance of the AAA securities into an AAA waterfall with 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, because their reported subordination included the balances of the subordinate AAA bonds. However, the principal allocation to the senior AAA bond (labeled "AAA_short") is not comparable to the AAA support in prior periods. The series labeled "AAA_long," which shows the subordination underlying the first dollar of AAA bonds, *is* consistent with the pre-2004 definition, and shows the same decline up to 2007 seen for the other ratings.

[9] See 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 531 fusion and conduit CMBS deals originated in the United States from 1996 through 2008. Conduit CMBS deals include mid-sized (median \$6M and mean \$15M original balance) commercial and multifamily loans that were originated for securitization, whereas fusion CMBS involve not only standard size conduit loans but also include large loans with balances of \$35M or more. Starting in late 2004, the overall principal balances of the AAA bonds were re-tranched into short-senior AAA bonds, mezzanine-senior AAA bonds, and long-senior AAA bonds. The long-senior AAA bonds is a junior position in the priority stack of the AAA senior bonds with respect to losses from default and is the last of the AAA bonds to receive principal distributions arising from maturity and defeasance payoffs. In contrast, the short-senior AAA bond is first to receive principal payoffs and last to experience losses from default. Series "AAA_short" shows the subordination underlying the senior AAA bond, while series "AAA_long" shows the subordination underlying all of the AAA bonds. The data were obtained from CRE Financial Council, `http://www.crefc.org/`



We find that i. (unlike the RMBS market) CMBS loans did not significantly change their characteristics during this period, ii. CMBS lenders did not change the way they priced a given loan, iii. overall, the CMBS market performed as normal during the financial crisis (at least by the standards of other recent market downturns), and iv. (unlike the ABX market) the CMBX market for indexed credit default swaps backed by CMBS behaved normally during the crisis. The only significant difference between this downturn and prior downturns was the enormous reductions in subordination levels required by the rating agencies to qualify a bond for a given credit rating. 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.

This decrease in subordination levels (with corresponding increase in the proportion of AAA-rated CMBS), unaccompanied by any change in the quality of the underlying loans, is consistent with the theoretical predictions of Opp et al. (2010). They argue that, especially for complex securities, regulatory distortions (in this case, the reduction in risk-based capital weights for AAA-rate 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.

The remainder of this paper is organized as follows. Section 2 reviews related literature; Section 3 analyzes the quality and pricing of the loans underlying CMBS before and during the crisis. Section 4 examines ex ante default expectations and realized default behavior. Section 5 examines the behavior of the CMBX market. In Section 6 we discuss the risk-based capital implications of ratings inflation for FDIC regulated financial institutions. Section 7 concludes the paper.

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 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) and Sangiorgi et al. (2009) for the first prediction and Bolton, Freixas, and Shapiro (2009) and 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, whereas the level of AAA CMBS bond issuance reached 88% in 2006.[10]

Many recent theoretical treatments of ratings shopping (see, for example, Skreta and Veldkamp (2009), Bolton et al. (2009), and Sangiorgi et al. (2009)), 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 Opp et al. (2010), Coval, Jurek, and Stafford (2009), Merton and Perold (1993)). In Opp et al. (2010), a fully rational model, large regulatory distortions are sufficient to eliminate delegated information acquisition by rating agencies and this outcome is more likely with complex securities. The importance of regulatory distortions may explain another feature of CMBS performance: the yields of AAA bonds were quite low (about 20 basis points to swaps) until the height of the crisis in July of 2007, while

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

those on BBB- bonds were consistently very high (about 200 basis points to swaps) over the same period.[11] An alternative possible explanation for the willingness of informed investors, such as financial institutions, to accept both ratings inflation and low yields on AAA CMBS tranches, may be that AAA ratings were of first order importance to the capital management strategies of these institutions, given the regulatory capital reductions afforded by the AAA label.[12]

3 Loan quality and loan pricing over time

If the drop in subordination levels was justified, there must have been other factors in the market that changed over time. We therefore here look at the quality of the underlying loans and their pricing.

3.1 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, fueled both by lower underwriting standards and by dishonesty on the part of borrowers and lenders. It is therefore important to understand whether a similar quality deterioration occurred in the commercial loan market.[13]

Table 1 shows summary statistics for the 531 conduit and fusion CMBS deals originated between 1996 and 2008 in the United States. Conduit CMBS pools include mid-sized (median \$6M and mean \$15M original balance) commercial loans that were originated for securitization, whereas fusion CMBS pools include not only standard size conduit loans but also large commercial loans with balances of \$35M or more. Overall, these CMBS pools accounted for 90,103 commercial real estate loans at origination. The data that were used to compute these summary statistics were obtained from the CRE Financial Council (`http://www.crefc.org/`), formerly Commercial Mortgage Securities Association (CMSA)). As shown in Table 1, while there are differences in the loan characteristics from year to year, there are no strong trends in either the Loan-to-Value Ratio (LTV) or Debt Service Coverage Ratio (DSCR). The LTV varies only very slightly during the sample, and

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[11] The yield data were obtained from the CRE Financial Council, Commercial Mortgage Alert, various issues, 2005–2007.

[12] See Opp et al. (2010) for a theoretical development of this argument and Coval et al. (2009) who draw the same empirical conclusion.

[13] Of course, if commercial loan quality actually *improved*, this would be one potential justification for lowering subordination levels over time.

Table 1: Loan Underwriting Trends 1996 through 2008

The table presents summary statistics for the loan-underwriting characteristics for 90,103 loans that were securitized into the universe of 531 conduit or fusion CMBS pools in the United States from 1996 through 2008. The data were obtained from the CRE Financial Council (`http://www.crefc.org/`, formerly Commercial Mortgage Securities Association (CMSA))

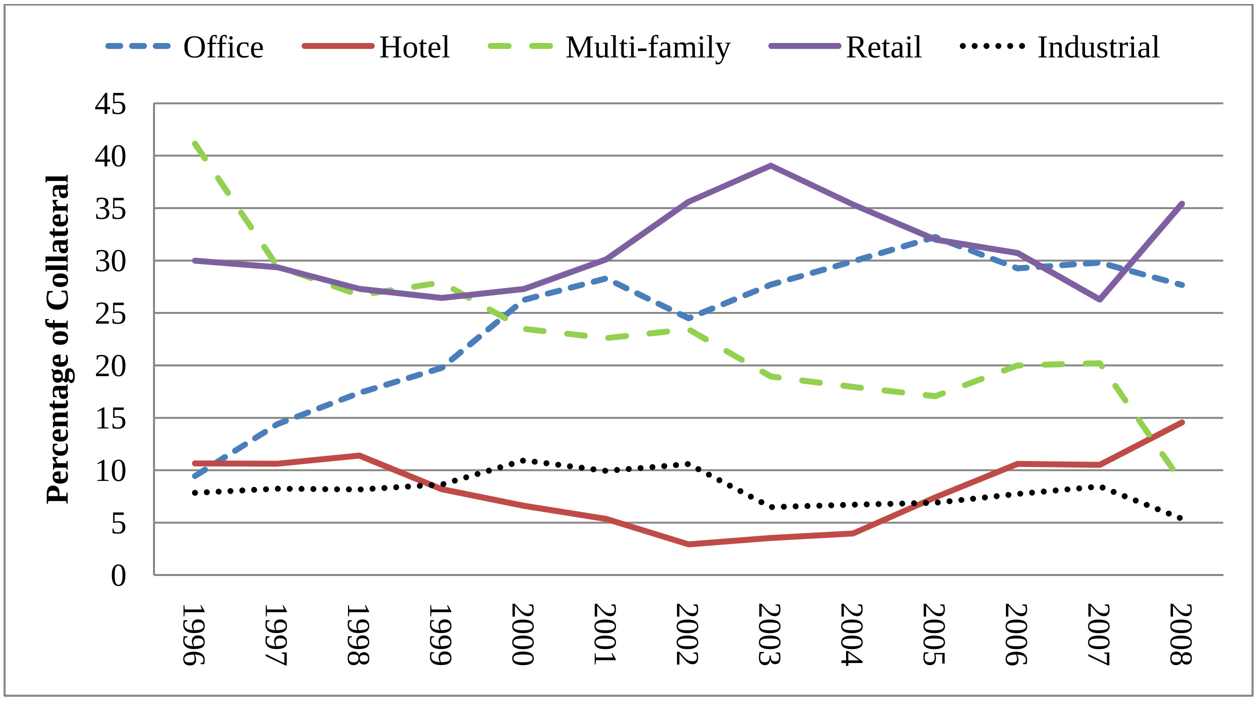
CMBS Origination Date	CMBS Pools	Loan to Value Ratio	Average Number of Loans	Debt Service Coverage Ratio	Coupon	Maturity	Pool Size ($10M)
1996	20	67.27	124.45	1.45	8.78	129.41	49.85
1997	22	69.21	181.71	1.41	8.53	129.11	78.06
1998	36	69.62	269.22	1.46	7.45	128.69	110.59
1999	38	68.94	209.11	1.43	7.54	127.06	72.53
2000	32	67.98	154.00	1.41	8.17	121.83	59.50
2001	35	68.19	143.26	1.46	7.62	113.35	60.45
2002	34	68.31	126.09	1.58	6.98	112.79	58.92
2003	45	67.07	121.76	1.77	5.69	120.47	62.51
2004	62	68.00	116.16	1.69	5.78	106.93	58.81
2005	64	68.89	170.33	1.61	5.47	110.10	90.25
2006	70	68.29	200.20	1.47	5.91	114.65	98.66
2007	65	68.90	214.25	1.40	5.99	119.67	118.40
2008	8	67.32	102.25	1.38	6.31	107.38	53.72
Overall Mean		68.36	166.77	1.52	6.68	117.33	78.50
Overall Std. Dev.		3.86	94.05	0.24	1.31	32.97	41.88

the DSCR improves slightly up to 2003, then declines slightly, but the changes are minor. There is certainly nothing in these statistics to indicate significant changes in credit quality over time that would, in turn, require corresponding changes in subordination levels.

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 2 shows the mix of different property types underlying the same 531 CMBS deals where, again, we obtained the data from the CRE Financial Council (`http://www.crefc.org/`). It can be seen that, after an initial drop in the proportion of office properties, the composition of the CMBS pools has not shown any major trends since about the year 2000.

Figure 2: CMBS pool composition, 1996–2008

This figure shows the property-type composition of the universe of 531 CMBS pools that were originated from 1996 to 2008. The data were obtained from the CRE Financial Council (`http://www.crefc.org/`, formerly Commercial Mortgage Securities Association (CMSA))



3.2 Loan pricing

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 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.[14]

We 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.

Regression analysis For our empirical analysis of the pre-crisis trends in loan underwriting, we assemble a sample of loan-level data for 14,041 non-seasoned fixed-rate mortgages underlying 206 public CMBS pools securitized between 1997 and the first quarter of 2005.[15] The loan data were obtained from the public access websites for two CMBS trustees: Wells Fargo Trust Services and LaSalle. The 206 CMBS pools included in the pre-crisis loan-level sample represent about 64% of the fusion and conduit CMBS deals reported Table 1 (the 1997 through 2004 pools, plus sixteen first quarter 2005 pools). 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)).

In Table 2, we report our regression analysis of the pre-crisis components of commercial

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[14] Moreover, even if everyone's expectations were wrong, the story about rating agencies becoming less conservative in their default estimates over time would be more reasonable if other market participants were also becoming less conservative.

[15] We focus on non-seasoned loans, excluding loans that exceed twelve months of seasoning, because we only observe each loan's loan-to-value ratio at the pool origination date. We also exclude floating rate loans, which appeared primarily in the 1997 and 1998 vintage loans. The seasoning exclusion eliminates about three thousand loans, and the floating rate exclusion another twenty seven hundred loans. These exclusions, plus missing data, leave 14,041 loans in our loan-level sample.

mortgage contract rate spreads to the ten-year constant maturity Treasure rates at the date of the origination 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,[16] so we report two sets of regressions. One set is for spread as a function of loan characteristics, excluding DSCR, but including property type and loan-origination year dummies for 1996–2004. Column 1 of this set does not include fixed effects; column 2 includes fixed effects and clusters the standard errors using the month of origination to control for other sources of unobserved heterogeneity. The second set of regressions excludes the LTV ratio but includes all other characteristics. Here, column 3 of this set does not include fixed effects; column 4 includes fixed effects and clusters the standard errors using the month of origination to control for other sources of unobserved heterogeneity. As shown, although all of the year dummies are different from zero, there is no obvious trend in the dummies over time other than that spreads in 2003 and 2004 were closer to the benchmark 2005 spreads than those in prior years. These results suggest that although subordination levels were changing over this period, lenders were not significantly changing the way they priced the underlying loans.

Implied volatility analysis 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 3 reports loan-by-loan implied volatility estimates. Office and industrial properties exhibit the highest implied volatilities, at 23.8% and 24.1%, respectively. For retail properties, the average implied volatility is 21.5%, and for multifamily properties it is 19.7%. These volatilities are substantially higher than the values that have previously appeared in the literature.[17]

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

[17] The few existing studies of implied volatility predate 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 through 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.

Table 2: 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 14,028 loans that were securitized in 206 CMBS pools from 1996 through 2005. The loan-level data were obtained from from the CTSlink website, `http://www.ctslink.com/`, for the Wells Fargo Trustee.

	(1) spread	(2) spread	(3) spread	(4) spread
Origination Principal (000)	-0.000552***	-0.000563***	-0.000545***	-0.000554***
	(-17.45)	(-18.31)	(-16.60)	(-17.35)
Amortization Term	-0.000534***	-0.000535***	-0.000464***	-0.000465***
	(-8.29)	(-8.55)	(-7.17)	(-7.38)
Loan-to-Value Ratio at Origination	0.329***	0.335***		
	(10.37)	(10.88)		
Debt Service Coverage Ratio on NOI			-0.100***	-0.106***
			(-13.01)	(-14.13)
Industrial Property	0.0134	0.0108	-0.00345	-0.00471
	(0.92)	(0.76)	(-0.22)	(-0.31)
Multi-Family Property	-0.192***	-0.198***	-0.186***	-0.192***
	(-17.92)	(-18.98)	(-16.42)	(-17.42)
Retail Property	0.00473	0.00426	0.00706	0.00676
	(0.45)	(0.42)	(0.64)	(0.63)
Origination year 1996	1.220***	1.325***	1.282***	1.362***
	(23.10)	(25.39)	(23.63)	(25.35)
Origination year 1997	0.795***	0.881***	0.790***	0.854***
	(27.48)	(30.28)	(27.66)	(29.58)
Origination year 1998	0.603***	0.675***	0.596***	0.650***
	(21.31)	(24.03)	(21.40)	(23.40)
Origination year 1999	1.145***	1.191***	1.090***	1.116***
	(36.22)	(38.02)	(33.94)	(34.90)
Origination year 2000	1.196***	1.267***	1.147***	1.205***
	(39.25)	(41.56)	(35.24)	(37.11)
Origination year 2001	1.271***	1.346***	1.248***	1.303***
	(44.99)	(47.76)	(44.51)	(46.34)
Origination year 2002	1.097***	1.165***	1.085***	1.137***
	(38.84)	(41.40)	(38.50)	(40.43)
Origination year 2003	0.661***	0.728***	0.654***	0.703***
	(23.25)	(25.84)	(23.14)	(24.98)
Origination year 2004	0.246***	0.318***	0.242***	0.293***
	(8.63)	(11.22)	(8.60)	(10.45)
Constant	1.228***	1.157***	1.587***	1.547***
	(32.13)	(30.66)	(43.98)	(43.30)
Observations	14041	14041	14041	14041
R^2	0.4305	0.4432	0.4344	0.4483

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Implied Volatilities by Property Type

The table presents the computed implied instantaneous volatilities for our sample of loans. The implied volatility is defined for each loan as the value of ϕ_p in Equation (8) that sets the initial value of the loan equal to par.

	No. of Obs.	Mean (%)	Std. Dev. (%)	25^{th} Percentile (%)	75^{th} Percentile (%)
Office	2,227	23.8	7.8	18.8	27.4
Multifamily	4,028	19.7	7.6	14.9	21.9
Retail	4,205	21.5	7.6	16.4	25.1
Industrial	1,234	24.1	7.8	18.8	28.2

Figure 3 shows estimated implied volatilities by property type over time. Despite some variation, the main conclusion mirrors that from the regression analysis above: there are no obvious trends in implied volatilities over time. Expressed differently, even though subordination levels were changing dramatically over this period, after controlling for loan terms, interest rates, etc., lenders' estimates of default likelihoods remained approximately the same.

4 Default behavior

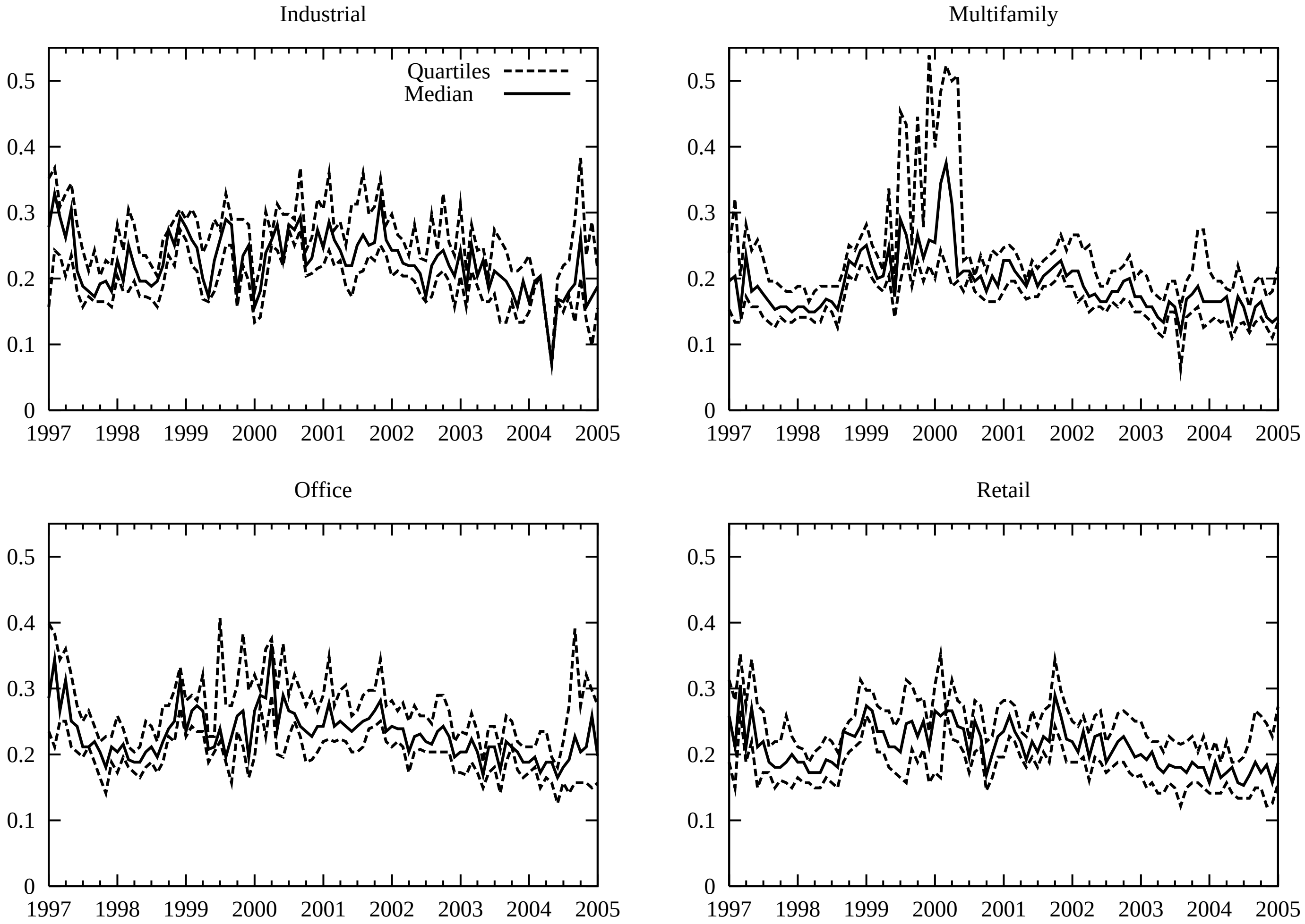
We have shown so far that, despite the changes in subordination levels required by the rating agencies, there were no other significant changes in the CMBS market over this period. Loan characteristics and pool composition remained roughly the same, and lenders did not change how they priced a given loan. The rating agencies' behavior was thus out of line with the rest of the market. However, we cannot yet conclude that subordination levels were too low at the end of the period (rather than too high at the beginning). To address this, we need to look at default behavior. In this section, we do this, looking at both ex ante default expectations and ex post performance.

4.1 Modeling ex ante default expectations

To analyze ex ante default expectations, we combine the levels of subordination with a statistical model for defaults over time to ask i. what future defaults could reasonably have

Figure 3: Implied Volatilities by Property Type

This figure plots our calibrated implied volatilities by property type. The solid line plots the median implied volatility for mortgage originated within a quarter. The bottom dashed line plots the 25th quartile and the top dashed line plots the 75th quartile of the quarterly implied volatility distributions.



been expected at the time the CMBS were issued? and ii. were these expectations consistent with the agencies' stated criteria for bonds of different ratings? 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 3.2 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,[18] it does affect the relative values of different tranches. In general, more dispersion (more correlation) lowers the value of safer tranches, and increases the value of extremely risky tranches.[19] 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:

$$\begin{aligned} dr_t &= \kappa(\theta_r - r_t)\, dt + \phi_r \sqrt{r_t}\, dW_{r,t}, && (3) \\ dp^j_{i,t} &= (\theta^j_{p,t} - q^j_p) p^j_{i,t}\, dt + \phi p^j_{i,t}\, dW_t + \phi^j_p p^j_{i,t}\, dW^i_t, && (4) \end{aligned}$$

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 3. For example, the

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[18] Ignoring spreads and/or 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 cannot cause subordination levels on all bonds to shrink at the same time.

[19] 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.

idiosyncratic volatility for office properties is set to ϕ_{p_i}=0.2274, implying a total volatility for office properties of

$$\sqrt{0.07019^2 + 0.2274^2} = 0.238,$$

the relevant value in Table 3.[20]

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 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 (3) and (4), and keep 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.[21] We compute the default frequency by quarter by computing the proportion of the original 100 mortgages in the pool that default, and then calculate cumulative default rates by summing the quarterly default rates.

Expected Default Rates Figure 4 shows the distribution of cumulative default rates 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 25th and 75th percentiles, and the dotted lines show the 5th and 95th 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. Starting around year two, defaults begin to ramp up, with the median cumulative default rate reaching 4.7% 15 quarters after origination, with an interquartile range of 6.5% to 2.3%. At the end of the 10-year horizon, the median cumulative default rate is 21%, with an interquartile range from 15% to 29%. Applying a 40% severity-of-loss rule, the 21% median cumulative default rate reported in Figure 4 implies a median 8.4% loss rate over a ten year horizon.

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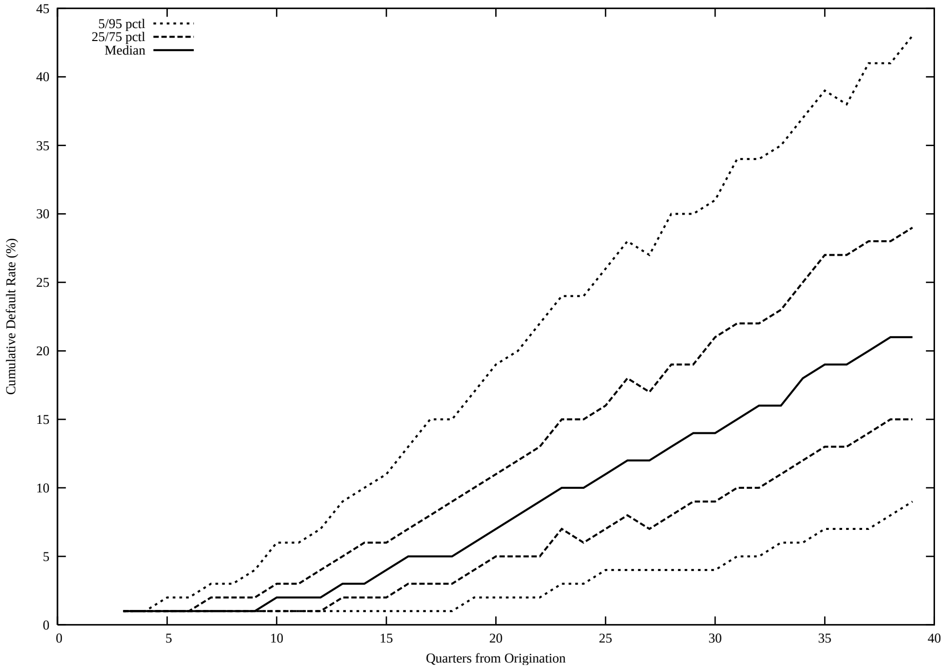
[20] Note that the common shock to the property return processes induces correlation in defaults across the mortgages in the pool.

[21] The default boundary for each loan is determined as part of the numerical solution of the pricing p.d.e., Equation (8) in the Appendix.

Figure 4: 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 25th and 75th percentiles, and the dotted lines show the 5th and 95th percentiles, respectively. We make 5,000 draws from the system of Equations (3) and (4) and keep track of the first time that each mortgage defaults along a simulated path of interest rates and property returns. For each LTV level and property type, we compute the default frequency by quarter. The weighted-average default frequency for the pool is computed using the property-type frequencies and the LTVs as weights. The cumulative default rates are computed by summing the quarterly default frequencies.



Adequacy of CMBS subordination levels Given our simulated distribution of defaults, we can now analyze the adequacy of observed subordination levels. To do so, we use the subordination levels reported in Figure 1, and assume that loan losses will stay at the historical average of 40% (see Johnson and MacNeill (2005)). Given this long-run historical loss rate and the observed subordination levels, Table 4 shows the default rates that would be required to generate losses to the various tranches, ranging from risky (class BBB-) to very safe (AAA). Focusing in particular on the BBB tranche (the story is similar for other tranches), the percent of defaults that would be required to generate losses to investors would be 13.3% for 2004 pools, 12.0% for 2005 pools, 11.5% for 2006 pools, and 11.5% for 2007 pools. Based upon the simulation results reported in Figure 4, all of these values are well below the median default rate of 21% generated by our model. Given our cumulative default estimates over a ten year horizon, defaults large enough to hit the BBB tranches for the 2004, 2005, and 2006 vintages of subordination would be expected to occur with probability 81%, 84%, 87% and 87% respectively.

To determine how large subordination levels *ought* to be, Figure 5 shows Moody's default rates on corporate bonds of different ratings between 1938 and 1995. The rating agencies were adamant that their default measures apply across market sectors.[22] Note that, ignoring dispersion in the realized default levels, even if we always saw the median default rate of 21%, given our assumed loss given default of 40%, we would need an 8.4% subordination level (21% × 40%) to avoid defaults on the BBB securities. However, dispersion in defaults magnifies this effect. Taking both expected default and dispersion into account, we would want 17.2% subordination for the BBB in 2006. This subordination level is far higher than actually observed prior to the crisis, but is close to the subordination level observed in the late 1990's.

4.2 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). However, this conclusion is drawn from one implementation of one model, and it is certainly possible to argue with many of the details of

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[22] According to S&P, "Our ratings represent a uniform measure of credit quality globally and across all types of debt instruments," (see "Principles-based Rating methodology for Global Structured Finance v Securities," Standard and Poors Ratings Direct Research, May 2007). According to Moody's, "The comparability of these opinions holds regardless of the country of the issuer, its industry, asset class or type of fixed income security," (see Moody's Investors Services, 2004, "Introduction to Moody's Structured Finance Analysis and Modelling," Presentation given by Federic Devron, May 13, 2004.

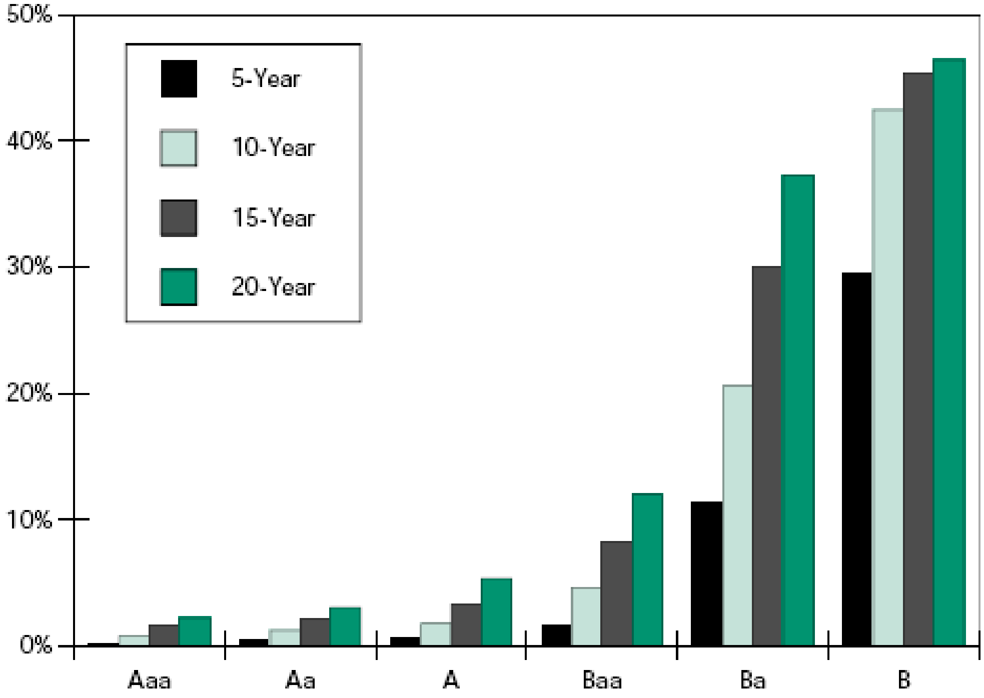
Table 4: Implied Default Rates

The table displays estimates for the percentage of loan defaults in a pool that would be required to generate losses for tranched classes with ratings from AAA to BBB-. The reported weighted-average subordination levels are those observed for the universe of CMBS pools originated in 2004 through 2007. The subordination structure for these pools were obtained from CRE Financial Council, `http://www.crefc.org/`, formerly CMAlert.

Class	Percentage Subordination %	Historical Loss Severity %	Defaults Required for Loss %
	2004 CMBS Conduit Pools - Number of Pools = 62		
AAA	15.3	40.0	38.3
AA	11.8	40.0	29.5
A	8.8	40.0	22.0
BBB	5.5	40.0	13.7
BBB-	3.9	40.0	9.8
	2005 CMBS Conduit Pools - Number of Pools = 64		
Short-Senior AAA	26.5	40.0	66.3
Long-Junior AAA	13.1	40.0	32.75
AA	10.8	40.0	27.0
A	8.1	40.0	20.3
BBB	4.8	40.0	12.0
BBB-	3.4	40.0	8.5
	2006 CMBS Conduit Pools - Number of Pools = 70		
Short-Senior AAA	28.4	40.0	71.0
Long-Junior AAA	12.4	40.0	31.0
AA	10.4	40.0	26.0
A	7.8	40.0	19.5
BBB	4.6	40.0	11.5
BBB-	3.3	40.0	8.3
	2007 CMBS Conduit Pools - Number of Pools = 65		
Short-Senior AAA	28.5	40.0	71.2
Long-Junior AAA	13.6	40.0	34.0
AA	10.5	40.0	26.1
A	8.0	40.0	19.9
BBB	4.7	40.0	11.5
BBB-	3.2	40.0	8.0

Figure 5: Moody's corporate and default rates

This figure plots Moody's default rates on corporate bonds of various ratings from 1938 to 1995.

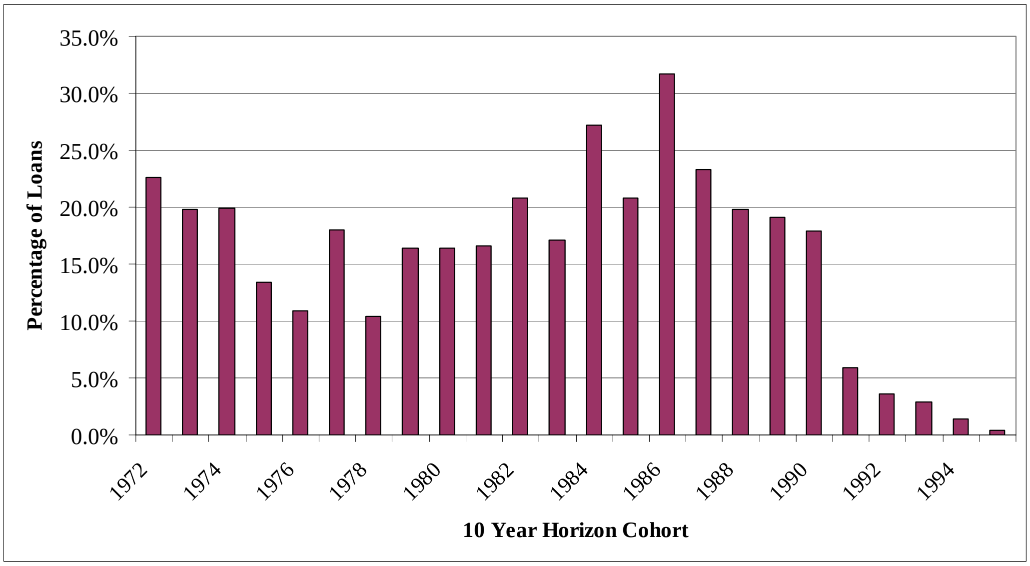


our implementation. In particular, the model's estimated median 10-year cumulative default rate of 21% is substantially higher than default rates observed in the few years immediately prior to the recent crisis. Given this, how can we rule out the alternative explanation that i. the model is just unduly pessimistic, ii. observed subordination levels were completely reasonable given the market's expectations at the time, and iii. realized default rates were substantially higher than those expectations?

To address this question, rather than redoing our analysis with many different models and many different sets of assumptions, we instead compare its results with historical CMBS default experience. Figure 6, based on Esaki (2002) [see also Esaki (2003)], shows realized 10-year default rates on loans issued from 1972–1996. As mentioned above, default rates in the 1990s were substantially below the 21% median level predicted by our model. However, it is clear from the figure that these default rates were markedly lower than at any other time in the prior 20–25 years, perhaps reflecting the large number of previously restructured loans in the market then, in the aftermath of the savings and loan crisis. Defaults between 1972 and 1990 were uniformly much higher, never falling below 10%, at times exceeding 30%, and with an average of around 20%, very close to the model's predictions.

Figure 6: Historical Realized Default Levels

This figure plots the lifetime default rates (loan counts) by origination cohort for 116,595 commercial real estate loans held by a sample of major insurance companies. These default rates were reported in "Commercial Mortgage Defaults: 1972-2000," by H. Esaki, *Journal of Real Estate Finance*, Winter, 2002.



All of our conclusions above about ex ante default likelihoods and subordination levels thus apply equally well to observed default levels from 1972–1990 as they do to our model-implied default rates, and we are forced to conclude that subordination levels of CMBS issued in the years immediately prior to the crisis were too low. As a benchmark for comparison, according to Moody's, the 10-year cumulative default rate on BBB-rated corporate bonds is approximately five percent [Moodys (1996)]. The simulation results shown in Figure 4 indicate that this rate of cumulative defaults is exceeded 95 times out of 100.

4.3 Ex post default behavior

While we have shown that subordination levels were too low ex ante, is it possible that even much larger subordination levels would not have protected investment-grade CMBS against the default levels seen during the recent crisis?

Figure 7 shows the cumulative default and loss rate as of March 3, 2010, for 444 CMBS pools by year of pool origination.[23] The data for this graph were obtained from Bloomberg.

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[23] Default is defined as the aggregate percent of pool balances that is 60 days delinquent, 90 days delinquent, Real Estate Owned (REO), or in foreclosure. The loss rate is the total percentage of the pool balances that have been lost due to default principal recoveries that are less than the outstanding loan principal.

As shown, in this figure the default rates for 1999 vintage CMBS are currently over 15% and the loss rates are 1.3% and the default rates for the 2000 vintages are nearly 13% and the loss rates are 1.4%. Of course, due to loan extensions and current workouts, the ultimate realized default and loss rates on these pools is not known. For the recent vintages, such as the 2007 and 2008 CMBS pools, the default are already 5.2% and 6.9% even though the pools are seasoned by only three and two year respectively. Although not shown in the Figure, overall delinquencies in U.S. CMBS rose by 29 basis points in the last month and overall delinquencies are about 6.9%. Approximately 30% of the newly delinquent loans in March 2010 were from 2005 transactions and most of these loans are past their 2010 maturity dates and are, therefore, categorized as non-performing matured loans. Recently accelerating trends in CMBS delinquency rates, particulary for loans that are "maturity defaults" caused by the inability to refinance the balloon payments at the end of the amortization period suggest that the elevated current levels of default performance for the 2007 and 2008 vintage are likely to easily reach the historical averages reported by Esaki (2002) as these loans continue to season. Thus, the long run default and delinquency rates of the current era appear comparable to the documented experience of prior loan vintages over nearly the past three decades.

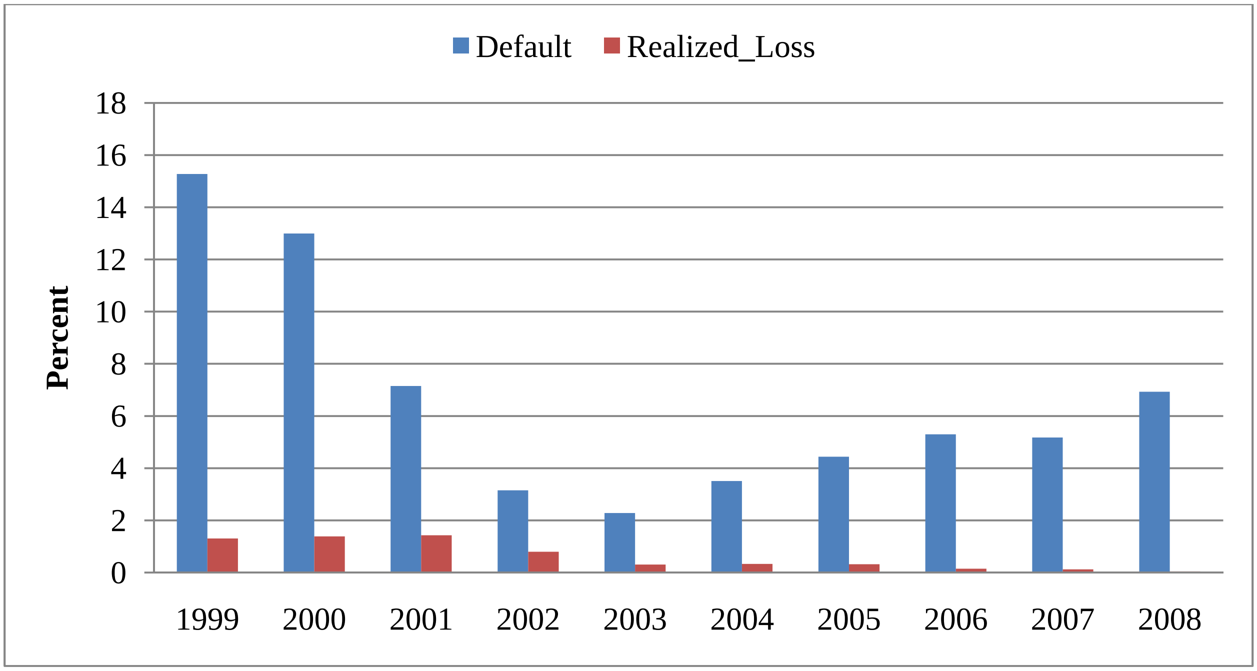
5 Performance of CMBX market

In many markets during the crisis, related credit default swaps (CDS) markets also collapsed, and CDS have subsequently been blamed for causing the crisis in the first place. For example, in the residential mortgage-backed security (RMBS) market, Stanton and Wallace (2009) show that, during the crisis, prices for ABX.HE indexed CDS, backed by pools of RMBS, the implied default rates over 100% on the underlying loans, and were uncorrelated with the credit performance of the underlying loans. The performance of the ABX CDS may have contributed significantly to liquidity problems in the underlying market, as many institutions used ABX prices to mark their portfolios to market, and were forced to recognize large mark-to-market losses as a result.

Stulz (2009) analyzes the CDS market more broadly, and concludes that it did not cause the financial crisis. However, a reasonable defense against underestimating subordination levels in the CMBS market might be to point to a simultaneously malfunctioning CDS market, and claim that many people were confused at this time. It is therefore important to understand whether CDS backed by CMBS performed abnormally during the crisis (like the ABX indexes), or whether CDS backed by CMBS were, in fact, mostly immune to the

Figure 7: CMBS default performance

This figure plots the average default and loss performance for 444 CMBS pools as of March 3, 2010, by year of pool origination. Default is defined as the aggregate percent of pool balances that is sixty days delinquent, ninety days delinquent, Real Estate Owned (REO), or in foreclosure for each pool vintage. The loss rate is the total percentage of the pool balances that have been lost due to default principal recoveries that are less than the outstanding loan principal. The data for this graph were obtained from Bloomberg.



turmoil observed in other markets.

The CMBX market is a market for credit default swap contracts that have been written on the default performance over time of a fixed-basket of specific tranches (CUSIPs) selected from 25 CMBS pools. CMBX were issued semi-annually from January of 2006 through January of 2008. For each vintage, seven CMBX contracts were issued, and each of these contracts was written on the performance of a basket of 25 CMBS tranches with the same credit rating. Prices in the CMBX market are quoted as \$100 minus the price of protection on \$100 of CMBS principal. Thus, a quoted price of \$93.59 for the AAA 06-1 CMBX contract on March 30, 2008 would cost \$6.41 up-front per \$100 of notional. The advantage of the CMBX prices for the purposes of our analysis is that these prices are widely viewed as indicative of the expected default risk of specific tranches, their subordination structures, and their credit ratings. By linking loan-performance data to the CMBX price dynamics, we can determine whether: i. CMBX market prices are moving with default; ii. specific tranches, their subordination structure and credit rating, differ in their sensitivities to the default risk of the underlying mortgage collateral, iii. other factors, unrelated to default, appear to be driving the CMBX prices.

In a recent paper, Van Hemert (2009) finds that a structural option-valuation model calibrated to REIT stock and option data explains more than 86% of daily price variation in the 2007-2 AAA and AJ CMBX indices. Van Hemert (2009) also documents some predictability in short-run CMBX daily price changes, which he concludes are consistent with price pressure from banks seeking to hedge their CMBS and commercial mortgage exposure. These results for the CMBX market are quite different from those of Stanton and Wallace (2009) for the ABX CDS market. To further analyze the broader implications of the Van Hemert (2009) result that CMBX prices are moving with the dynamics of real estate fundamentals, we undertake a regression analysis of the factors that appear correlated with observed CMBX price dynamics for indices with different subordination protection and credit ratings.

In Figure 8, we present the end-of-day price dynamics for the 2006-1, 2006-2, 2007-1, 2007-2, and 2008-1 Markit CMBX contracts on baskets of AAA short-senior (also called super-seniors), AJ (AAA long-seniors), AA, A, BBB, and BBB- tranches from March 31, 2008 through March 29, 2010.[24] As shown, the CMBX indices experienced significant price decreases (increases in the cost of insuring \$100 of notional) in the third quarter of 2008. By March 2009, the BBB(BBB-) CMBX required an up front payment of about \$91(\$92.2) per \$100 of notional. After the second quarter of 2009, however, all CMBX indices, except the BBB and BBB- indices, had made significant price gains (due to decreases in the cost

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[24] Since the CMBX market is an over-the-counter market, the quoted prices are a trimmed average of prices from the trading desks of Markit's member market makers in the CMBX.

of insuring \$100 notional). Surprisingly, the relatively higher subordination levels of 2008 pools, did not appear to improve the relative price performance of the 2008-1 CMBX. The likely reason for this outcome is that 20 of the 25 pools used in the 2008-1 were actually originated in 2007 and seven of these pools were also included in the 2007-2 index.

The CMBX price dynamics reported in Figure 8 suggest that market participants believe that the BBB and BBB- CMBS are expected to experience significant default related losses. We use regression to analyze whether these observed price dynamics are primarily determined by default experience, consistent with Van Hemert (2009), or are driven by supply and demand forces for hedging that are unrelated to the default experience of the underlying commercial mortgages. The average subordination levels of the 118 conduit and fusion CMBS pools that comprise the six CMBX indices are consistent with those reported in Figure 1 and with the summary statistics presented in Table 1 for all conduit and fusion CMBS. For each index, we obtain loan-level mortgage performance data from Bloomberg. We then construct a monthly aggregate measure of the percent of total principal within a CMBX index basket that is 30 day delinquent, 60 day delinquent, 90 day delinquent, Real Estate Owned (REO), and foreclosed. We match each of the 25 CMBS tranches within each index to the underlying mortgages for those pools and then track the aggregate default performance for all the mortgage principal.

Following Stanton and Wallace (2009) and Van Hemert (2009) we consider the effects of market fundamentals such as the movements in REIT returns (measured by the daily FNAR index on Bloomberg), repo rate dynamics (measured as the U.S. Treasury repo over-night rate, Government General Collateral Repo Rate, downloaded from Bloomberg), and the OIS spread (measured as OIS minus Libor obtained from Bloomberg). We obtain S&P daily returns, the S&P volatility index, VIX, the 10-year constant maturity Treasury rate, and the slope of the yield curve, measured as the differences between the 10 year CMT Treasury rate and the 3 month T-Bill rate) from Datastream. To capture the potential effects of supply and demand imbalances in the market for insuring mortgage risk, we follow prior authors (see Lamont and Stein (2004), Fishman, Hong, and Kubik (2007), and Jones and Lamont (2002)) and use a value-weighted short-interest ratio (the market value of shares sold short, divided by the average daily trading volume) for banks, investment banks, the government sponsored enterprises (GSEs — Fannie Mae and Freddie Mac), and the public home builders.[25] We obtain monthly data for the short-interest ratio from Shortsqueeze.com

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[25] The short-interest ratio is a measure of how long it would take short sellers, in days, to cover their entire positions if the price of a stock began to rise. A higher short-interest ratio is usually viewed by market participants as a bearish signal about a specific stock, and higher ratios have been found to be associated with other measures of demand pressure for shorting, such as high premia paid to borrow the stock.[26]

from January 2006 to March 2010, and then use splines to estimate a daily series.[27]

In Table 5 through Table 9, we report five regression specifications for each CMBX index. The first column presents the results of an OLS regression of the percent change in the indices on changes in aggregate default performance of the underlying mortgage pools and REIT and S&P return dynamics. In columns 2 and 3 of each table, we report an OLS specification and a fixed effects specification where we cluster the standard errors by CMBX vintage. In columns 4 and 5, we replace the individual credit variables with a summed variable equal to the sum of the 60 day delinquency, 90 day delinquency, REO and foreclosure rate changes, and we replace the individual short-interest ratio variables with a single variable equal to their sum. We again run an OLS regression with these new measures and a fixed effects regression where we cluster the standard errors by the CMBX vintage. We use percentage changes in the daily CMBX price series for the time period presented in Figure 8; March 31, 2008 through March 29, 2010.

Table 5 reports the results for the AAA short-senior CMBX. As shown, the key economic determinants of AAA price changes are changes in REIT and S&P returns, consistent with Van Hemert (2009). The sixty day delinquency rates exhibits a modest effect on price changes, a small coefficient and statistically significant at the .10 level, and the aggregate effect of the short interest ratio is not statistically significant.

The results for the more junior AAA tranches, the AJ CMBX indices, are presented in Table 6. As previously discussed the long-senior tranches experienced important reductions in the rating agencies' subordination requirements between 2005 and 2007 – the vintages included in the 2006 through 2008 CMBX. As shown in Table 6, the price dynamics of the AJ CMBX are statistically significantly related to measures associated with repo rate dynamics, short open interest on builders and the GSEs, both heavily involved in either the production of, or the financing on, multifamily housing, and on the short open interest ratios of the investment banks. In addition, the sixty day delinquency rate has a statistically significant affect on these price dynamics at the .05 level. The summed credit effects and summed short-interest ratios remain statistically significant in the fixed effects specification.

Results similar to those of the AJ CMBX index are again found in the regression results of the AA and A CMBX index price dynamics and these are reported in Table 7 and

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[27] The public companies that we track are: Ambac Financial Group Inc.; Bank of America Corp.; Bank of New York Company; Barclays PLC; Capital One Financial Corp.; Centex Corp.; Citigroup Inc.; Countrywide Financial Corp.; Credit Suisse Group; Deutsche Bank Aktiengesellschaft; Fannie Mae; Flagstar Bancorp Inc.; Freddie Mac; Goldman Sachs Group Inc.; HSBC Holdings PLC; JPMorgan Chase & Co.; Kaufman and Broad; KeyCorp; Lennar Corp.; Merrill Lynch & Co. Inc.; Morgan Stanley; Pulte Homes Inc.; Sovereign Bancorp Inc.; SunTrust Banks Inc.; The PNC Financial Services Group Inc.; The Ryland Group Inc.; Toll Brothers Inc.; U.S. Bancorp; UBS AG; Wachovia Corp.; Webster Financial Corp.; and Wells Fargo & Company.

Table 8, respectively. Again both the AA and the A tranches experienced significant reductions in collateral support over the period and the CMBX price trends for these indices are statistically significantly related to changes in both the sixty day delinquency rates of the underlying collateral and with the aggregate effects of the credit performance variables. The short open interest channel is statistically significant at the .05 level in the aggregate for the AA Index written on AA tranches and is not statistically significant for the A CMBX written on A tranches.

Finally as shown in Table 9 and Table 10, a similar pattern appears in the regression results for the BBB and BBB- CMBX. The sixty day delinquency rates have a statistically significant effect on the index price changes and the summed credit effects go through in the fixed effects regression. The aggregate changes in the short-interest ratio have a small economic effect on CMBX price changes and they are statistically significant at only the .10 level.

The effects of other dislocations in the fixed income mortgage markets appear to have varying levels of statistical and economic significance in these regressions. The repo rate and the OIS LIBOR spreads have statistically significant effects on the price dynamics of the more junior AJ, AA, A, BBB, and BBB- CMBX indices consistent with recent research on the importance of these short-term funding sources for the securitized bond markets (See Gorton and Metrick (2009). One anomalous result that we find in all our regression is that the 30 day delinquency rate appears to be positively correlated with the price changes of all the junior CMBX indices. Recent moderate positive price changes in the CMBX market have been associated with quite large positive changes in the 30 day delinquencies rates, suggesting that the market does not see short-term delinquencies as a harbinger of serious problems in the future. This optimistic view may, however, be premature because the March 2010 overall rates of CMBS special servicing rose to 10%.[28] Currently, an important proportion of special serviced loans in CMBS pools includes loans that are 30 day delinquent, implying that the borrower has indicated that default is likely despite the grace periods that are allowed in the pooling and servicing agreements. In addition, loans on watchlist (indicating DSCR of less than 110% or asset values of less than 80% of the origination value) now account for 19.12% of the outstanding principal in the CMBS pools.

Our regression results are consistent and add to those of Van Hemert (2009) and suggest that in contrast to the ABX.HE CDS market, the CMBX index price dynamics were largely driven by the default dynamics of the underlying mortgage collateral and other price trends

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[28] Special servicers exist in the CMBS pools to manage workouts and defaults. Typically, under the pooling and servicing agreements, the Master Servicer would refer a given mortgage to the CMBS special servicer only once the loan is 90 days delinquent, the borrower has declared bankruptcy, or the borrower has indicated that default is imminent.

in real estate fundamentals, such as REIT return dynamics. In addition, our regressions demonstrate that the credit channels to CMBX price dynamics are important for the bonds that experienced the largest reductions in subordination levels from 2005 through 2007. Finally, again in contrast to findings in the ABX CDS market, we find only mixed results for an important CMBX pricing effect driven by supply and demand imbalances in the markets for hedging CMBS risk. Overall, our regression results confirm that the CMBX index did not perform unusually during the financial crisis.

Figure 8: CMBX prices,2008–2010

This figure plots the end-of-day prices for Markit CMBX for five vintages of CMBX issuance including the 2006-1, 2006-2, 2007-1, 2007-2, and 2008-1 from March 31, 2008 through March 29, 2010.

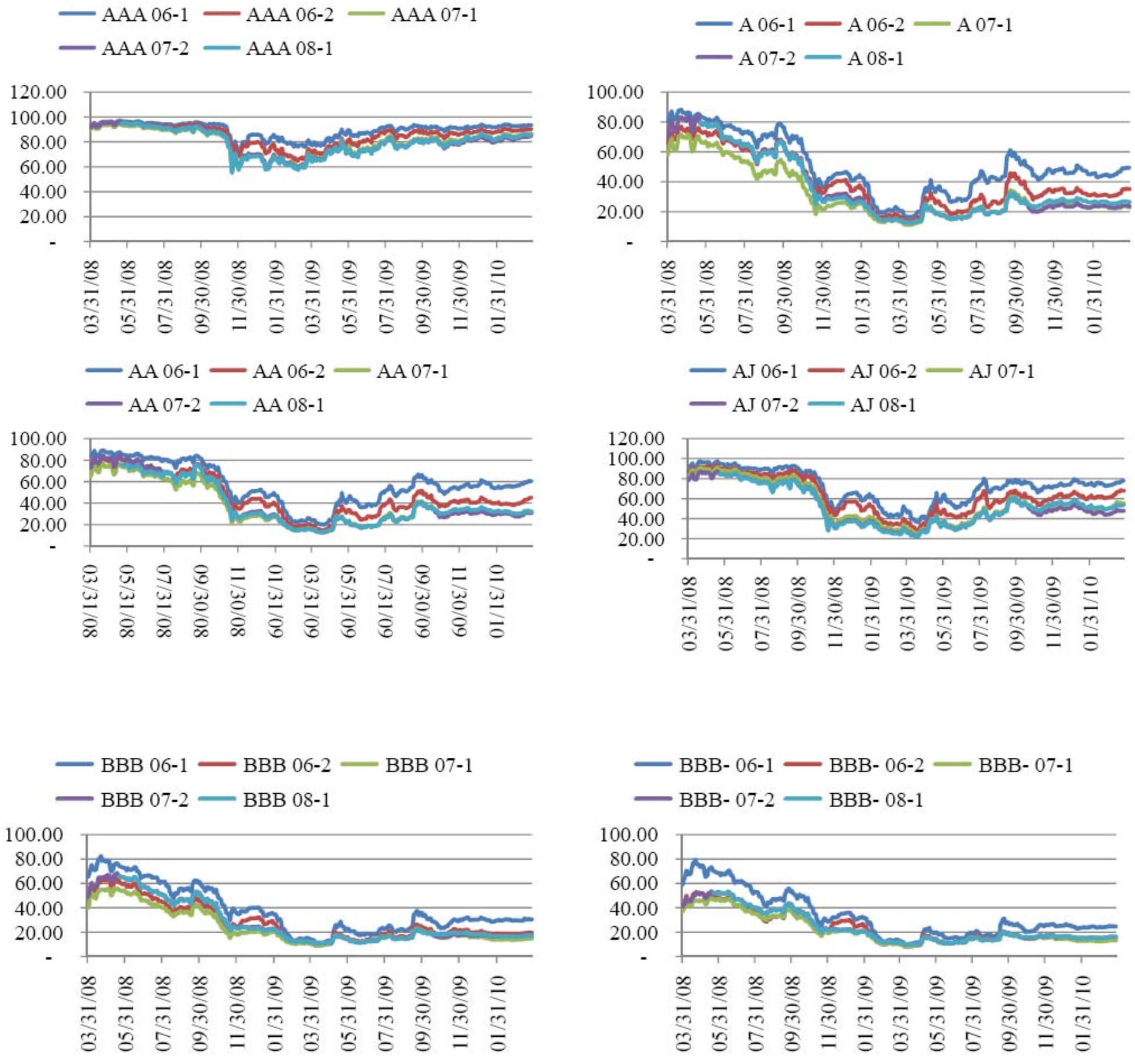

Table 5: CMBX AAA Long-Senior Regression results

The table presents the regression results for daily percentage changes in the quoted prices of the 2006, 2007, and 2008 vintage AAA short-senior CMBX indices, using Markit CMBX end-of-day price quotes from March 31, 2008 through March 29, 2010.

	(1) % Δ AAA	(2) % Δ AAA	(3) % Δ AAA	(4) % Δ AAA	(5) % Δ AAA
Lag 1 Δ CMBX Quoted Price Changes	0.283*** (14.16)	0.289*** (14.05)	0.289*** (14.03)	0.290*** (14.16)	0.290*** (14.14)
Δ 30 Day Delinquency	0.000896 (0.91)	0.000576 (0.53)	0.000564 (0.52)	0.00120 (1.20)	0.00118 (1.18)
Δ 60 Day Delinquency	-0.00276 (-1.62)	-0.00315* (-1.75)	-0.00323* (-1.78)		
Δ 90 Day Delinquency	-0.00312 (-1.63)	-0.00282 (-1.36)	-0.00294 (-1.39)		
Δ REO Rate	-0.00362 (-0.41)	-0.00343 (-0.37)	-0.00382 (-0.41)		
Δ Foreclosure Rate	0.0000458 (0.01)	0.000255 (0.05)	0.000590 (0.11)		
Δ Principal Loss Rate	-0.000372 (-0.02)	-0.000116 (-0.00)	0.00157 (0.06)	0.00402 (0.16)	0.00556 (0.22)
Δ S&P	-0.0710*** (-4.30)	-0.114*** (-3.81)	-0.114*** (-3.80)	-0.118*** (-3.99)	-0.118*** (-3.98)
Δ REIT Returns	0.00350** (2.54)	0.00482*** (3.17)	0.00482*** (3.17)	0.00357** (2.54)	0.00357** (2.54)
Δ Bank Ratio		0.0734 (1.28)	0.0732 (1.28)		
Δ Builder Ratio		0.00341 (0.06)	0.00382 (0.07)		
Δ GSE Ratio		-0.000295 (-0.69)	-0.000298 (-0.70)		
Δ IV Bank Ratio		-0.00429** (-2.27)	-0.00430** (-2.27)		
Δ LIBOR minus OIS		-0.0101 (-1.34)	-0.0101 (-1.34)	-0.0124* (-1.67)	-0.0124* (-1.67)
Δ Repo Rate		-0.000588 (-1.03)	-0.000588 (-1.03)	-0.000578 (-1.01)	-0.000578 (-1.01)
Δ 10-year Treasury		-0.00915 (-1.43)	-0.00914 (-1.42)	-0.0101 (-1.59)	-0.0101 (-1.58)
Δ Slope (10-year CMT minus 3-month Rate)		0.0153 (1.17)	0.0153 (1.16)	0.0161 (1.22)	0.0161 (1.22)
Δ VIX Rate		-0.0190** (-2.12)	-0.0190** (-2.12)	-0.0210** (-2.35)	-0.0210** (-2.35)
Δ Sum of credit variables				-0.00274* (-1.80)	-0.00282* (-1.82)
Δ Sum of short interest ratios				-0.000430 (-1.04)	-0.000432 (-1.04)
Constant	0.000405 (0.79)	0.000182 (0.33)	0.000188 (0.34)	0.000212 (0.41)	0.000222 (0.42)
Observations	2318	2190	2190	2190	2190
R^2	0.0929	0.1063	0.1063	0.1033	0.1033

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: CMBX AJ Regression results

The table presents the regression results for daily percentage changes in the quoted prices of the 2006, 2007, and 2008 vintage AJ long-senior CMBX indices, using Markit CMBX end-of-day price quotes from March 31, 2008 through March 29, 2010.

	(1) % Δ AJ	(2) % Δ AJ	(3) % Δ AJ	(4) % Δ AJ	(5) % Δ AJ
Lag 1 Δ CMBX Quoted Price Changes	0.266***	0.269***	0.269***	0.276***	0.276***
	(13.40)	(13.16)	(13.14)	(13.51)	(13.49)
Δ 30 Day Delinquency	0.00369**	0.00280	0.00277	0.00510***	0.00505***
	(2.08)	(1.45)	(1.43)	(2.88)	(2.84)
Δ 60 Day Delinquency	-0.00627**	-0.00619*	-0.00636**		
	(-2.04)	(-1.94)	(-1.97)		
Δ 90 Day Delinquency	-0.00597*	-0.00358	-0.00389		
	(-1.72)	(-0.97)	(-1.04)		
Δ REO Rate	-0.00219	-0.00692	-0.00758		
	(-0.14)	(-0.42)	(-0.46)		
Δ Foreclosure Rate	-0.00327	-0.00456	-0.00448		
	(-0.36)	(-0.49)	(-0.46)		
Δ Principal Loss Rate	-0.000431	-0.00794	-0.00319	0.0140	0.0201
	(-0.01)	(-0.17)	(-0.07)	(0.31)	(0.44)
Δ S&P	-0.0853***	-0.00669	-0.00671	-0.0257	-0.0255
	(-2.87)	(-0.13)	(-0.13)	(-0.49)	(-0.48)
Δ REIT Returns	0.00542**	0.00724***	0.00724***	0.00573**	0.00573**
	(2.19)	(2.69)	(2.69)	(2.30)	(2.29)
Δ Bank Ratio		-0.159	-0.159		
		(-1.56)	(-1.57)		
Δ Builder Ratio		-0.351***	-0.351***		
		(-3.51)	(-3.50)		
Δ GSE Ratio		-0.00164**	-0.00165**		
		(-2.17)	(-2.17)		
Δ IV Bank Ratio		-0.00593*	-0.00594*		
		(-1.77)	(-1.77)		
Δ LIBOR minus OIS		-0.0171	-0.0171	-0.0165	-0.0165
		(-1.28)	(-1.28)	(-1.25)	(-1.25)
Δ Repo Rate		-0.00222**	-0.00222**	-0.00219**	-0.00219**
		(-2.19)	(-2.19)	(-2.16)	(-2.16)
Δ 10-year Treasury		-0.0257**	-0.0257**	-0.0234**	-0.0234**
		(-2.26)	(-2.26)	(-2.06)	(-2.06)
Δ Slope (10-year CMT minus 3-month Rate)		0.0236	0.0235	0.0208	0.0208
		(1.01)	(1.01)	(0.89)	(0.89)
Δ VIX Rate		0.0148	0.0148	0.0103	0.0104
		(0.93)	(0.93)	(0.65)	(0.65)
Δ Sum of credit variables				-0.00525*	-0.00553**
				(-1.94)	(-2.01)
Δ Sum of short interest ratios				-0.00182**	-0.00183**
				(-2.47)	(-2.48)
Constant	0.000874	-0.000101	-0.0000674	0.000340	0.000371
	(0.94)	(-0.10)	(-0.07)	(0.37)	(0.40)
Observations	2318	2190	2190	2190	2190
R^2	0.0881	0.1065	0.1065	0.1000	0.1001

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: CMBX AA Regression results

The table presents the regression results for daily percentage changes in the quoted prices of the 2006, 2007, and 2008 vintage AA CMBX indices, using Markit CMBX end-of-day price quotes from March 31, 2008 through March 29, 2010.

	(1) % Δ AA	(2) % Δ AA	(3) % Δ AA	(4) % Δ AA	(5) % Δ AA
Lag 1 Δ CMBX Quoted Price Changes	0.375***	0.371***	0.371***	0.388***	0.388***
	(19.72)	(18.96)	(18.93)	(19.93)	(19.89)
Δ 30 Day Delinquency	0.00472**	0.00329*	0.00325	0.00620***	0.00614***
	(2.52)	(1.65)	(1.63)	(3.37)	(3.33)
Δ 60 Day Delinquency	-0.00691**	-0.00658**	-0.00683**		
	(-2.13)	(-2.00)	(-2.06)		
Δ 90 Day Delinquency	-0.00435	-0.00187	-0.00223		
	(-1.19)	(-0.49)	(-0.58)		
Δ REO Rate	-0.00905	-0.0176	-0.0190		
	(-0.53)	(-1.04)	(-1.11)		
Δ Foreclosure Rate	-0.00131	-0.00325	-0.00263		
	(-0.14)	(-0.34)	(-0.26)		
Δ Principal Loss Rate	0.0108	-0.000335	0.00526	0.0311	0.0386
	(0.24)	(-0.01)	(0.11)	(0.68)	(0.82)
Δ S&P	-0.135***	-0.0577	-0.0578	-0.0828	-0.0827
	(-4.29)	(-1.06)	(-1.06)	(-1.51)	(-1.51)
Δ REIT Returns	0.00528**	0.00726***	0.00726***	0.00543**	0.00543**
	(2.02)	(2.61)	(2.61)	(2.10)	(2.10)
% Δ Bank Ratio		-0.396***	-0.396***		
		(-3.78)	(-3.78)		
% Δ Builder Ratio		-0.596***	-0.595***		
		(-5.73)	(-5.72)		
% Δ GSE Ratio		-0.00160**	-0.00161**		
		(-2.05)	(-2.06)		
% Δ IV Bank Ratio		-0.00637*	-0.00638*		
		(-1.84)	(-1.85)		
Δ LIBOR minus OIS		-0.0250*	-0.0251*	-0.0211	-0.0211
		(-1.82)	(-1.82)	(-1.54)	(-1.54)
% Δ Repo Rate		-0.00231**	-0.00231**	-0.00228**	-0.00228**
		(-2.21)	(-2.21)	(-2.17)	(-2.17)
% Δ 10-year Treasury		-0.0521***	-0.0520***	-0.0467***	-0.0467***
		(-4.44)	(-4.44)	(-3.98)	(-3.98)
Δ Slope (10-year CMT minus 3-month Rate)		0.0780***	0.0779***	0.0731***	0.0730***
		(3.24)	(3.23)	(3.02)	(3.01)
Δ VIX Rate		0.00505	0.00500	0.000106	0.000120
		(0.31)	(0.30)	(0.01)	(0.01)
Δ Sum of credit variables				-0.00533*	-0.00568**
				(-1.90)	(-1.99)
Δ Sum of short interest ratios				-0.00188**	-0.00189**
				(-2.47)	(-2.47)
Constant	0.000888	-0.000380	-0.000347	0.000367	0.000406
	(0.91)	(-0.38)	(-0.35)	(0.38)	(0.42)
Observations	2318	2190	2190	2190	2190
R^2	0.1679	0.2004	0.2004	0.1864	0.1865

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: CMBX A Regression results

The table presents the regression results for daily percentage changes in the quoted prices of the 2006, 2007, and 2008 vintage A CMBX indices, using Markit CMBX end-of-day price quotes from March 31, 2008 through March 29, 2010.

	(1)	(2)	(3)	(4)	(5)
	% Δ A	% Δ A	% Δ A	% Δ A	% Δ A
Lag 1 Δ CMBX Quoted Price Changes	0.374***	0.366***	0.366***	0.383***	0.382***
	(19.60)	(18.52)	(18.47)	(19.42)	(19.37)
Δ 30 Day Delinquency	0.00447**	0.00314	0.00308	0.00589***	0.00579***
	(2.33)	(1.52)	(1.49)	(3.10)	(3.04)
Δ 60 Day Delinquency	-0.00758**	-0.00714**	-0.00754**		
	(-2.28)	(-2.10)	(-2.19)		
Δ 90 Day Delinquency	-0.00446	-0.00216	-0.00283		
	(-1.19)	(-0.55)	(-0.71)		
Δ REO Rate	-0.0119	-0.0204	-0.0222		
	(-0.68)	(-1.17)	(-1.26)		
Δ Foreclosure Rate	-0.00238	-0.00447	-0.00412		
	(-0.24)	(-0.45)	(-0.40)		
Δ Principal Loss Rate	0.0203	0.00905	0.0192	0.0383	0.0500
	(0.44)	(0.18)	(0.38)	(0.81)	(1.02)
Δ S&P	-0.129***	-0.0755	-0.0756	-0.102*	-0.101*
	(-4.02)	(-1.34)	(-1.34)	(-1.80)	(-1.79)
Δ REIT Returns	0.00617**	0.00832***	0.00832***	0.00608**	0.00608**
	(2.31)	(2.90)	(2.89)	(2.28)	(2.28)
Δ Bank Ratio		-0.424***	-0.425***		
		(-3.92)	(-3.92)		
Δ Builder Ratio		-0.599***	-0.597***		
		(-5.57)	(-5.56)		
Δ GSE Ratio		-0.000628	-0.000640		
		(-0.78)	(-0.79)		
Δ IV Bank Ratio		-0.00685*	-0.00687*		
		(-1.92)	(-1.92)		
Δ LIBOR minus OIS		-0.0303**	-0.0304**	-0.0261*	-0.0262*
		(-2.13)	(-2.14)	(-1.84)	(-1.85)
Δ Repo Rate		-0.00264**	-0.00264**	-0.00261**	-0.00262**
		(-2.45)	(-2.45)	(-2.41)	(-2.41)
Δ 10-year Treasury		-0.0579***	-0.0579***	-0.0524***	-0.0524***
		(-4.78)	(-4.77)	(-4.32)	(-4.32)
Δ Slope (10-year CMT minus 3-month Rate)		0.0884***	0.0882***	0.0833***	0.0831***
		(3.55)	(3.54)	(3.32)	(3.32)
Δ VIX Rate		-0.00594	-0.00601	-0.0112	-0.0111
		(-0.35)	(-0.35)	(-0.65)	(-0.65)
Δ Sum of credit variables				-0.00597**	-0.00655**
				(-2.06)	(-2.22)
Δ Sum of short interest ratios				-0.00101	-0.00103
				(-1.29)	(-1.30)
Constant	0.00125	-0.000107	-0.0000307	0.000663	0.000732
	(1.24)	(-0.10)	(-0.03)	(0.66)	(0.73)
Observations	2318	2190	2190	2190	2190
R^2	0.1652	0.1934	0.1935	0.1792	0.1794

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: CMBX BBB Regression results

The table presents the regression results for daily percentage changes in the quoted prices of the 2006, 2007, and 2008 vintage BBB CMBX indices, using Markit CMBX end-of-day price quotes from March 31, 2008 through March 29, 2010.

	(1) % Δ BBB	(2) % Δ BBB	(3) % Δ BBB	(4) % Δ BBB	(5) % Δ BBB
Lag 1 Δ CMBX Quoted Price Changes	0.368***	0.359***	0.358***	0.374***	0.373***
	(19.18)	(18.11)	(18.05)	(18.94)	(18.88)
Δ 30 Day Delinquency	0.00344*	0.00230	0.00223	0.00473***	0.00464**
	(1.89)	(1.17)	(1.13)	(2.62)	(2.56)
Δ 60 Day Delinquency	-0.00667**	-0.00635*	-0.00673**		
	(-2.11)	(-1.96)	(-2.06)		
Δ 90 Day Delinquency	-0.00329	-0.000787	-0.00141		
	(-0.93)	(-0.21)	(-0.37)		
Δ REO Rate	-0.0138	-0.0224	-0.0242		
	(-0.84)	(-1.35)	(-1.44)		
Δ Foreclosure Rate	-0.00423	-0.00654	-0.00619		
	(-0.45)	(-0.70)	(-0.62)		
Δ Principal Loss Rate	0.0283	0.0159	0.0250	0.0387	0.0496
	(0.65)	(0.34)	(0.52)	(0.85)	(1.06)
Δ S&P	-0.101***	-0.0321	-0.0322	-0.0565	-0.0563
	(-3.32)	(-0.60)	(-0.60)	(-1.05)	(-1.04)
Δ REIT Returns	0.00413	0.00608**	0.00608**	0.00418	0.00418
	(1.62)	(2.22)	(2.22)	(1.65)	(1.64)
Δ Bank Ratio		-0.385***	-0.386***		
		(-3.73)	(-3.74)		
Δ Builder Ratio		-0.548***	-0.547***		
		(-5.36)	(-5.35)		
Δ GSE Ratio		-0.000900	-0.000911		
		(-1.17)	(-1.18)		
Δ IV Bank Ratio		-0.00609*	-0.00611*		
		(-1.79)	(-1.79)		
Δ LIBOR minus OIS		-0.0346**	-0.0347**	-0.0307**	-0.0307**
		(-2.56)	(-2.56)	(-2.27)	(-2.28)
Δ Repo Rate		-0.00196*	-0.00196*	-0.00192*	-0.00192*
		(-1.91)	(-1.91)	(-1.86)	(-1.86)
Δ 10-year Treasury		-0.0666***	-0.0666***	-0.0613***	-0.0613***
		(-5.78)	(-5.77)	(-5.31)	(-5.30)
Δ Slope (10-year CMT minus 3-month Rate)		0.104***	0.104***	0.0993***	0.0991***
		(4.39)	(4.38)	(4.17)	(4.16)
Δ VIX Rate		-0.00233	-0.00240	-0.00707	-0.00706
		(-0.14)	(-0.15)	(-0.44)	(-0.43)
Δ Sum of credit variables				-0.00534*	-0.00590**
				(-1.94)	(-2.10)
Δ Sum of short interest ratios				-0.00123	-0.00125*
				(-1.64)	(-1.66)
Constant	0.00129	0.0000530	0.000129	0.000749	0.000818
	(1.35)	(0.05)	(0.13)	(0.79)	(0.86)
Observations	2318	2190	2190	2190	2190
R^2	0.1541	0.1826	0.1826	0.1692	0.1694

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: CMBX BBB- Regression results

The table presents the regression results for daily percentage changes in the quoted prices of the 2006, 2007, and 2008 vintage BBB- CMBX indices, using Markit CMBX end-of-day price quotes from March 31, 2008 through March 29, 2010.

	(1) % Δ BBB-	(2) % Δ BBB-	(3) % Δ BBB-	(4) % Δ BBB-	(5) % Δ BBB-
Lag 1 Δ CMBX Quoted Price Changes	0.360***	0.352***	0.352***	0.371***	0.371***
	(18.69)	(17.61)	(17.57)	(18.63)	(18.59)
Δ 30 Day Delinquency	0.00427**	0.00289	0.00283	0.00544***	0.00536***
	(2.38)	(1.50)	(1.46)	(3.06)	(3.00)
Δ 60 Day Delinquency	-0.00573*	-0.00575*	-0.00608*		
	(-1.84)	(-1.80)	(-1.89)		
Δ 90 Day Delinquency	-0.00261	-0.000330	-0.000914		
	(-0.75)	(-0.09)	(-0.24)		
Δ REO Rate	-0.0153	-0.0244	-0.0258		
	(-0.95)	(-1.49)	(-1.56)		
Δ Foreclosure Rate	-0.00539	-0.00741	-0.00734		
	(-0.59)	(-0.80)	(-0.75)		
Δ Principal Loss Rate	0.0280	0.0163	0.0246	0.0382	0.0483
	(0.65)	(0.35)	(0.52)	(0.86)	(1.05)
Δ S&P	-0.103***	-0.00234	-0.00238	-0.0283	-0.0281
	(-3.42)	(-0.04)	(-0.05)	(-0.53)	(-0.53)
Δ REIT Returns	0.00273	0.00500*	0.00500*	0.00279	0.00279
	(1.09)	(1.86)	(1.85)	(1.11)	(1.11)
Δ Bank Ratio		-0.405***	-0.406***		
		(-3.99)	(-3.99)		
Δ Builder Ratio		-0.584***	-0.583***		
		(-5.79)	(-5.78)		
Δ GSE Ratio		-0.000957	-0.000966		
		(-1.26)	(-1.28)		
Δ IV Bank Ratio		-0.00708**	-0.00710**		
		(-2.12)	(-2.12)		
Δ LIBOR minus OIS		-0.0325**	-0.0326**	-0.0284**	-0.0284**
		(-2.44)	(-2.44)	(-2.14)	(-2.14)
Δ Repo Rate		-0.00236**	-0.00236**	-0.00231**	-0.00231**
		(-2.33)	(-2.33)	(-2.27)	(-2.27)
Δ 10-year Treasury		-0.0633***	-0.0633***	-0.0578***	-0.0578***
		(-5.58)	(-5.57)	(-5.08)	(-5.08)
Δ Slope (10-year CMT minus 3-month Rate)		0.101***	0.101***	0.0962***	0.0960***
		(4.33)	(4.32)	(4.09)	(4.09)
Δ VIX Rate		0.00888	0.00883	0.00372	0.00373
		(0.56)	(0.55)	(0.23)	(0.23)
Δ Sum of credit variables				-0.00503*	-0.00555**
				(-1.85)	(-2.00)
Δ Sum of short interest ratios				-0.00134*	-0.00135*
				(-1.82)	(-1.83)
Constant	0.00114	-0.000188	-0.000115	0.000485	0.000548
	(1.22)	(-0.20)	(-0.12)	(0.52)	(0.58)
Observations	2318	2190	2190	2190	2190
R^2	0.1488	0.1813	0.1815	0.1656	0.1658

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6 CMBS Ratings and Regulatory Arbitrage

We have shown that the observed inflation in CMBS ratings cannot be explained by any change in the credit quality of the underlying loans. It is, however, consistent with the theoretical predictions of Opp et al. (2010). They argue that, for complex securities, regulatory distortions can reduce or eliminate the incentive for rating agencies to acquire information, in turn leading to rating inflation. In this case, the relevant regulatory distortion is the very generous risk-based capital weights applied to AAA and other highly rated CMBS, as compared with the weights that apply to the underlying whole loans.

Table 11 reports the risk-based capital weights for CMBS long-term investments held by FDIC-regulated financial institutions after a regulatory rule change on January 2, 2002. Prior to this rule change, all investment grade CMBS, and most commercial real estate loans, received a risk weight of 100%, implying that a \$100 investment in CMBS required the institution to hold \$.08 of capital (\$100 × 100% × 8%).[29] However, after 2002, whole commercial loans and BBB-rated CMBS retained a 100% risk weight, whereas as shown in Table 11, all AAA and AA-rated CMBS fell to a 20% risk-weight, requiring only 1.6 cents of capital per dollar of investment. 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. BB-rated CMBS carried a risk-weight of 200% or 16 cents of capital for every dollar of investment, and B or unrated CMBS bonds required the financial institution to hold capital equal to 100% of the face amount of the bond. Not too surprisingly, the share of total CMBS origination rated AAA and AA grew by an average rate of 2.2% per year between 1998 and 2004.[30]

Calculating the economic implications of these capital weights for the risk management practices of regulated financial institutions is challenging for a number of reasons. First, ratings inflation implies that AAA-rated bonds would have higher credit risk over time, and the reduced capital requirements would allow firms to lever up more. Thus, we should expect to see greater default risk over time for firms holding large positions in AAA-rated CMBS, which could be measured by valuing put options on the firms' equity. However, CMBS represented only .4% of the total assets of FDIC financial institutions,[31] so accurately

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[29] Additionally, 50% of that capital would be expected to be Tier 1 capital. Tier 1 capital includes common stock, undivided profits, paid-in-surplus; non-cumulative perpetual preferred stock; minority interests in consolidated subsidiaries; minus, all intangible assets (with limited exceptions); identified losses; and deferred tax assets in excess of certain limits.

[30] These calculations were obtained from ABSnet data on the ratings of the outstanding stock, measured by face amount, of CMBS bonds.

[31] This ratio is computed at the end of Q2 2009, the earliest date for which the Reports of Condition and Income (Call Reports) provide information on the stock of CMBS investments on bank balance sheets along with the face amount of total assets.

measuring the increment to default risk using, say, the standard Black/Scholes computations would be difficult.

Second, Froot and Stein (1998a,b), Froot (2001), and Merton and Perold (1993) argue that applying the classical approach to capital budgeting, assuming Modigliani and Miller (1958) and/or frictionless hedging, to determine the incremental cost of capital for any given incremental investment decision, is likely to understate the true economic costs of illiquid bank investments. These investments impose risks on banks, which might be diversifiable by shareholders, but because they cannot be readily hedged by banks, they require holding more equity capital. Bank-level risk-management concerns would therefore enter into the pricing of these assets, as would the risk characteristics of unrelated assets held on the banks' balance sheets. For these reasons, bank practitioners have relied on the concept of the risk-adjusted return on capital (RAROC) to assess the "capital-at-risk" premium on investments, whereas Froot (2001) and Froot and Stein (1998a,b) recommend a decision rule that quantifies the trade-off between managing the incremental risks of investments via ex ante capital structure policy and managing these risks via capital budgeting and hedging policies. Neither framework is easily adapted to an accurate measurement of the incremental cost of capital arising from increases in CMBS investments, since all hedging positions, along with capital budgeting and capital structure policies, must be accounted for in order to produce accurate estimates.

Table 11: Risk-Based Capital Weights Post FDIC and OCC Rule Changes

The table presents the risk-based capital weights required after the FDIC rule changes for CMBS held in long-term investments of FDIC insured financial institutions. Prior to the rule change all CMBS rated AAA, AA, A, or BBB received an 100% risk-based capital weight. The capital requirement is computed by multiplying the face amount of the position by the appropriate risk weight times the 8% capital requirement.

Bond Category	Rating	Risk-Weight	Capital Required per $1 of Investment
a) Investment Grade:			
	AAA or AA	20%	$ 0.016
	A	50%	$ 0.04
	BBB	100%	$ 0.08
b) One Category Below:			
	BB	200%	$ 0.16
c) Below B and all unrated	B or NR	Not Eligible	$ 1.00

[1] Source: Rosenblatt (2001)

[2] IO's and PO's are not eligible for less than 100% risk weighting.

Despite data-related constraints on accurately measuring the securitized asset holdings of financial institutions,[32] we undertake a rough numerical estimate of the capital savings to FDIC insured financial institutions from the 2002 regulatory changes in the risk-based capital weights for investment grade CMBS. In the second column of Table 12, we report the total outstanding stock of CMBS using data from ABSnet and Bloomberg. From the same data, we then compute the year-over-year outstanding stock of AAA and AA-rated bonds, since these are the bonds that would be eligible for the 20% risk weight reductions post 2001. We report the shares of the total outstanding stock of CMBS that were rated AAA or AA in the third column of Table 12, and we report the outstanding face amount of AAA and AA-rated CMBS in the fourth column. It can be seen that the AAA and AA-rated shares of CMBS grew rapidly between 1998 and 2004.

Data limitations require further assumptions to compute our estimates of the risk-based capital requirements for the CMBS investments of FDIC-insured financial institutions. Starting in the second quarter of 2009, the Reports of Condition and Income (Call Reports) from the FDIC Statistics on Depository Institutions (SDI) provide the total holdings of CMBS each quarter.[33] We assume that the observed share (8.5%) of the total CMBS holdings of FDIC-insured financial institutions to the total stock of CMBS between Q2 through Q4 of 2009 was constant from 1998 through 2007. Using this share, we compute an estimate of the face value of the CMBS holdings of FDIC institutions for the years 1998 through 2007, by multiplying the 8.5% share times the values reported in column two of Table 12. We further assume that the CMBS investments made by commercial banks from 1998 to 2007 were rated either AAA or AA. Our estimate of the CMBS investments by FDIC-insured financial institutions is reported in the fifth column of Table 12.[34] In column six, we report the risk-based capital requirements for these estimated levels of CMBS investments using the pre-2002 risk-based capital weights for 1998 through 2002 and the revised weights from 2002 through 2007. In column seven, we report the capital requirements if the underlying whole loans had been retained on the firm's balance sheet, or alternatively if the risk-based capital weights on investment grade CMBS had not been changed in 2002. Column eight reports the difference between these capital requirements through 2007 (thus avoiding the subsequent ratings downgrades for outstanding AA and AAA bonds in 2008 and to the present). The values in column eight are zero from 1998 through 2001, because the risk weights would have been 100% whether the investments were AAA, AA, A, or BBB-rated CMBS or whole loans.

As shown in column eight of Table 12, our (admittedly rough) estimate of the capital savings from holding AA and AAA-rated CMBS is approximately $3.5 billion by the year

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[32] See He, Khang, and Krishnamurthy (2010) for an in-depth discussion of these measurement problems.

[33] See http://www2.fdic.gov/sdi/index.asp.

[34] These calculations were informed by discussions with bankers and data from Structured Investment Vehicles that were reconsolidated onto bank balance sheets.

2007. This savings compares to $363 billion of tier 1 capital held at the end of December 2007 by the ten FDIC insured financial institutions with the largest holdings of CMBS in 2009 when the FDIC began recording these holdings.[35]

Table 12: Risk-Based Capital Savings from Holding AAA CMBS

The table presents estimates for the risk-based capital requirements for long-term portfolio investments in CMBS at FDIC insured financial institutions. We assume in the table that the CMBS holdings of these institutions accounted for recently reported levels of about 8.5% of the stock of all CMBS in the United State (CMBS portfolio holdings of FDIC insured financial institutions were not reported prior to Q2 2009). We assume that these institutions invested in AAA and AA-rated CMBS securities, given the predominance of those ratings in the overall stock of CMBS and the regulatory benefits of the two ratings. We then compute the required risked-based capital requirements under the post FDIC risk-based capital rate rule change for AAA and AA-rated CMBS investments compared to risk-based capital requirements for the same face amount of underlying commercial mortgages, or investment grade CMBS prior to the change.

	Total Stock CMBS ($ Billions)[1]	AAA and AA % of Total CMBS[2]	Total AAA and AA ($ Billions)	Projected Bank CMBS Holdings ($ Billions)[3]	Risk Based Capital ($ Billions)[4]	Risk Based Capital pre-2002 ($ Billions)[5]	Savings ($ Billions)
1998	124.0	76%	94.44	10.55	0.84	0.84	0.00
1999	158.8	78%	123.56	13.51	1.08	1.08	0.00
2000	191.2	81%	155.36	16.27	1.30	1.30	0.00
2001	223.4	83%	184.80	19.00	1.52	1.52	0.00
2002	248.4	84%	207.88	21.13	0.34	1.69	1.35
2003	291.0	86%	250.70	24.76	0.40	1.98	1.58
2004	336.9	89%	298.61	28.66	0.46	2.29	1.83
2005	420.1	89%	374.18	35.74	0.57	2.86	2.29
2006	523.0	89%	467.82	44.49	0.71	3.56	2.85
2007	650.5	89%	580.05	55.34	0.89	4.43	3.54

[1] Source: Flow of Funds Accounts of the United States, Z.1

[2] Source: Authors' calculations using Bloomberg, CMAlert, and ABSNet data.

[3] Source: Authors' calculations using FDIC Statistics on Depository Institutions (SDI) of 8.5% market share.

[4] Source: Authors' calculations using post-January 1, 2002 capital weights (See: Rosenblatt (2001)).

[5] Source: Authors' calculations using pre-January 1, 2002 capital weights (See: Rosenblatt (2001)).

7 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

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[35] These holding accounted for 91.7% of CMBS assets held by FDIC insured institutions in 2009. Our comparison assumes that institutions with the largest holdings of CMBS as of 2009 are also the largest CMBS holders in 2007. The total tier 1 capital for all FDIC-insured financial institutions that held any CMBS was $420 billion.

unambiguously due to the presence of many other confounding factors. We show that almost 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. During the crisis, while commercial loans bore their share of defaults, realized defaults were in line with levels observed over almost the whole of the 40-year period before the crisis, excluding the most recent few years. Finally, unlike the ABX market, the CMBX market for CDS backed by CMBS also behaved normally during the crisis.

Putting all of this together, we see that both before and during the crisis, the only significant shift in the market was the reduction in allowable subordination levels by the rating agencies. By contrast, neither lenders nor traders in the CMBX market changed their behavior. It is possible that these over-optimistic subordination levels were caused by too much reliance on very recent default data, but whatever the cause, the overall effect was to expose investors in "safe" CMBS bonds to losses (caused by defaults completely in line with both model-implied expectations and historical experience) that would have been completely avoided had subordination levels remained at their 2000 levels.

A Calculating implied volatilities

Calculating implied volatilities for commercial mortgages is similar to using option prices to infer implied volatility for an equity option, and requires a mortgage pricing model. We use the two-factor model first proposed by 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 In Titman and Torous (1989), interest rates are governed by the Cox, Ingersoll, and Ross (1985) model,

$$dr_t = \kappa(\theta_r - r_t)\, dt + \phi_r \sqrt{r_t}\, dW_{r,t}, \tag{5}$$

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 the following 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 for the period 1968–2006:

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

Property prices Property prices follow the geometric Brownian motion process,

$$dp_t = (\theta_{p,t} - q_p) p_t\, dt + \phi_p p_t\, dW_{p,t}, \tag{6}$$

where $\theta_{p,t}$ is the expected return on the property, q_p is the net income (on an unlevered basis), and ϕ_p is the volatility of the property return. We assume $\theta_{p,t} = r_t + \mu$, where r_t is the risk-free interest rate and μ is the risk-premium (assumed constant) on the property type in question, discussed below.

For pricing, we use the "risk-neutral" process,

$$dp_t = (r_t - q_p) p_t\, dt + \phi_p p_t\, dW_{p,t}, \tag{7}$$

in which $\theta_{p,t}$ is replaced with r_t.

The key parameters for the property price process in equation (6) are $\theta_{p,t}$, the expected return on the property (equal to r_t, the risk-free interest rate, plus μ, the risk-premium) and q_p, the net income. As discussed above, we solve for the implied volatilities using the risk neutral property price process, but we also need the risk premium, μ, in order to estimate default probabilities. Both q_p and μ are estimated from market data. q_p is estimated from the realized income returns, obtained from NCREIF, between the first quarter of 1978 and the first quarter of 2005, [36] leasing to estimates of:

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

We estimate the risk premium, μ, using the average excess return for NCREIF properties over 90 day T-Bills, quarterly from 1978 to 2005, leading to the estimates: The estimates values of μ for each property type are:[37]

$$\mu = \begin{cases} 3.11\% & \text{for office properties;} \\ 5.79\% & \text{for multifamily properties;} \\ 4.22\% & \text{for retail properties;} \\ 4.26\% & \text{for industrial properties;} \\ 3.85\% & \text{for other properties.} \end{cases}$$

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:

$$\begin{aligned} \frac{1}{2}\phi_r^2 r M_{rr} + \frac{1}{2}\phi_p^2 p^2 M_{pp} + \rho\phi_r\phi_p p\sqrt{r} M_{rp} + (\kappa(\theta_r - r) - \eta r)\, M_r & \\ + ((r - q_p)p_t)\, M_p + M_t - rM + C &= 0, \end{aligned} \tag{8}$$

where $E\left[dW_r dW_p\right] = \rho\, dt$, subject to boundary conditions described in detail in Titman and Torous (1989). For our initial baseline estimates, we assume that $\rho = 0$, and later consider

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[36] The returns are measured as (*Net Operating Income*) $\div$ (*Beginning market value* + .5 $\times$ *capital improvements* $-$ .5 $\times$ *partial sales* $-$ .333 $\times$ *Net Operating Income*). The adjustments are made to: 1) account for the assumption that net operating income (NOI) is received at the end of each month during the quarter; 2) the assumption that capital improvements occur at mid-quarter; 3) the assumption that partial sales occur at mid-quarter; 4) the assumption that the NOI is received monthly so that the cash flow received from the NOI in effect reduces the average investment in the property by .333 of NOI. These measures are the average property-type specific income returns for the properties held in the investment portfolios of pension funds.

[37] We use the excess return estimate for the national property series as our estimate for an "other" category of properties which includes hotels, healthcare, self-storage, among others that exist in CMBS pools. The NCREIF return series do not include these other categories.

the implications of relaxing this assumption through a series of robustness checks. We solve the model numerically, using a finite difference method to value the security and also to determine the critical default boundary.[38] Given this valuation model, 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 at par.

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[38] For details of the finite difference method used, see Gourlay and McKee (1977) and Downing, Stanton, and Wallace (2005).

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