CDO Market Implosion and the Pricing of CMBS and Sub-Prime ABS

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Executive Summary

The global market for collateralized debt obligations (CDOs) witnessed explosive growth over the course of the past decade, as the stock of global issuance expanded from $300 billion in 1997 to almost $2 trillion in 2006. CDO issuance importantly supported the market for commercial and sub-prime mortgage-backed securities, via the re-packaging of relatively illiquid assets into more liquid CDO securities. In a stunning turnaround in market activity, new issuance of CDOs ceased in 2007, in the wake of wholesale re-pricing of credit risk in the capital markets. In the wake of the surge in issuance of commercial real estate-backed CDOs, a marked tightening in sub-prime ABS-Treasury spreads and CMBS-Swap spreads was evidenced, suggesting some measurable effect of this market-completing vehicle on the supply/demand balance and pricing of mortgage-backed securities. More recently and in the wake of the implosion in the CDO market, spreads on mortgage-backed securities widened considerably.

This research evaluates the effects of the emergence of the CDO market on the pricing of mortgage-backed securities. In so doing, it applies high-frequency time-series to evaluate the determinants of yield spreads of sub-prime ABS to comparable-maturity Treasury bonds and tranched CMBS relative to Swap rates. Empirical tests suggest that factors associated with the termination risks of the underlying residential and commercial mortgage contracts, including interest-rate volatility, the term structure of interest rates, and proxies for mortgage credit risk, importantly affect the magnitude of mortgage security/Treasury spreads. Spreads on mortgage-backed securities also appear sensitive to returns and related return volatility among alternative asset classes, notably including equities. Finally, holding constant new issuance of mortgage-backed securities and other well-established proxies for mortgage option values, research indicates that the emergence of the CDO market was associated with a significant tightening of sub-prime ABS/Treasury yield spreads. Further, the magnitudes of the estimated CDO premia vary inversely with the credit quality of the CMBS tranche. In that regard, a 10 percent increase in CDO issuance volume from 2005 levels is estimated to result in a 10bp narrowing in BBB CMBS/Swap spreads. Research findings accordingly indicate the

importance of innovations in derivative securities markets to the pricing and related affordability of subprime mortgage debt. Results similarly show that the unexpected closure of the CDO market exerted upward pressure on MBS spreads, and in so doing contributed to a marked slowing of activity in the U.S. real estate sector.

I. Introduction

The global market for collateralized debt obligations (CDOs) witnessed explosive growth over the course of the past decade, as the stock of global issuance expanded from $300 billion in 1997 to almost $2 trillion in 2006. CDO issuance importantly supported the market for sub-prime mortgage-backed securities, via the re-packaging of relatively illiquid assets into more liquid CDO securities. In a stunning market about-face, new issuance of CDOs ceased in 2007, in the wake of wholesale re-pricing of credit risk in the capital markets. In the wake of the earlier surge in issuance of commercial real estate-backed CDOs, a marked tightening in sub-prime ABS-Treasury and CMBS-Swap spreads was evidenced, suggesting some measurable effect of this market-completing vehicle on the supply/demand balance and pricing of mortgage-backed securities. More recently and in the wake of the implosion in the CDO market, spreads on mortgage-backed securities widened considerably.

CDOs are financial structures whereby a set of assets are held in a trust formed as a Special Purpose Vehicle (SPV). A series of tranches with different exposures to the risks of the underlying assets are issued by the trust. A CDO cash-flow structure, for example, allocates the interest and principal payments of the underlying collateral pool of debt instruments to the CDO tranches. While there are many variations, a cash CDO, for example, is a senior-subordinated structure where the senior CDO debt tranches are paid first, then the mezzanine and lower-subordinated notes. Any remaining cash flow is available to equity. In the CDO structure, a set of assets (such as corporate bonds, CMBS, or residential mortgage-backed securities (RMBS)) can be packaged into claims and sold to investors.[1]

1While the rules for distributing the cash flows of the CDO bonds' underlying collateral are relatively straightforward, the valuation of the debt and equity tranches can be complicated. The reason for this complexity is that CDOs often contain a large portfolio of assets and credit exposures with diverse risk

As shown in Figure 1, issuance of sub-prime asset-backed CDOs moved up fivefold during the first half of the decade—from about $10 billion in 2000 to in excess of $50 billion in 2006. Coincidentally, spreads to Treasury on subprime residential ABS-backed CDOs narrowed substantially. Indeed, as evidenced in Figure 1, yield spreads of sub-prime residential ABS trended down from a high in excess of 500 basis points in 2000 to about two-fifths that level four years later. Similar tightening in spreads was evidenced in the CMBS market, particularly in the case of subordinated BBB tranches. Interestingly, as shown in Figure 2, that marked trending down in the sub-prime ABS to Treasury spreads occurred even as subprime ABS issuance was rapidly expanding. Indeed, increased demand for sub-prime ABS product, for purposes of derivative securitization via the CDO vehicle, may have served, all things equal, to depress sub-prime ABS-Treasury spreads. More recently, during the latter half of 2007, CDO issuance fell dramatically, to $121 billion. During that period, the underlying collateral for a variety of CDOs, subprime ABS, began to experience sharp increases in delinquencies and defaults. In the wake of collateral performance erosion, spreads began to widen markedly in both subprime ABS and CDOs and the issuance of CDOs began to decline.

The rise and fall of the CDO market provides an excellent laboratory to study spreads on credit-sensitive securities. Following previous studies on credit spreads (for example, see Collin-Defresne, Goldstein and Martin [2001], Collin-Defresne and

profiles (for example, default, loss and recovery patterns) as collateral and there are many possible capital structures from which debt and equity are issued. Unlike those mortgage obligations where prepayment-risk is the dominant focus, in CDO valuation the primary focus is typically on the credit risk. A number of practitioner-oriented papers provide excellent discussions of the CDO market (e.g., Goodman and Fabozzi [2002], Li, Roy, and Skarabot [2004], Roy and Shelton [2004] and Tavakoli [2003]).

Goldstein [2001] and Chen, Lesmond and Wei [2007]), we examine the credit spreads on CDOs and examine the relationship between the spreads on the underlying collateral and the issuance volume for CDOs. In so doing, we build on the prior literature in evaluating the determinants of yields spreads on residential- and commercial mortgage-backed securities.

Much of the research on CDOs has focused on the pricing of those derivative securities (for example, see Duffie and Garleanu [2001], Hull and White [2003], Longstaff, Mithal, and Neis [2005], Longstaff and Rajan [2006] and Noh [2004]). In addition, there has been considerable research on a related topic: correlated default between underlying assets (for example, see Duffee [1998], Duffie, Eckner, Horel, and Saita [2006], Giesecke [2004], Das, Duffie, Kapadia, and Saita [2005] and Giesecke and Goldberg [2005]). However, little research has attempted to assess the impact of CDO evolution on spreads in the underlying collateral.

Alternative hypotheses can be put forth regarding the effects of the emergence of the CDO market on the pricing of real estate asset-backed securities. On the one hand, to the extent CDOs confer efficiency benefits as market-completing investment vehicles, institutional demand for CDOs and related derived-demand for asset-backed securities may increase. According to this *market-completion hypothesis*, CDOs may have enhanced efficiency in the asset-backed securities markets, via the pooling and re-tranching of less liquid and lower-rated subprime- and commercial mortgage-backed securities into those which were more tradable. Further, a liquidity premium associated with senior CDO tranches may have reduced the cost of raising capital through tranches below the cost of acquiring the asset pool (see, for example, Greenbaum (1986), DeMarzo and Duffie (1988) and Demarzo (2003)).[2,3] Assuming other than fully elastic supply of subprime ABS in the capital markets, CDO-related related outward shifts in ABS demand would result in some contraction in asset-backed security spreads, all things equal.

On the other hand, capitalization and growth of the CDO market could serve to elicit a supply response, in the form of increased sales of sub-prime- and commercial mortgage-backed securities into the real estate asset-backed securities markets. Those sales might derive from opportunities for improved price execution and/or enhanced outlets for liquification of investor RMBS or CMBS portfolios. As suggested by Greenbaum and Thakor (1987), the advent of new securities markets allows financial institutions and others to remove financial assets from their balance sheets and reduce other costs of holding debt. All things equal, this *supply-shift hypothesis* would serve to depress subprime asset- and commercial real estate backed security prices and concomitantly result in wider ABS-Treasury spreads.

According to a simple *shell game hypothesis*, elevated demand for subprime-backed ABS might have been driven by inaccurate CDO underwriting or ratings, mis-information, mis-representations, or lack of full understanding of the risks of the CDO

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[2] DeMarzo and Duffie (1998) and DeMarzo (2003) build liquidity-based models of tranching. In those models, the security issuer may possess private information regarding security payoff that may cause illiquidity. However, the senior tranches (low risk tranches) are less sensitive to the (CDO) issuer's private information, and thus may enjoy greater liquidity than the underlying collateral.

[3] On the other hand, DeMarzo (2005) shows that for an informed intermediary, pure pooling and sales of assets from the pool is inferior to selling assets separately. This is because asset pooling eliminates the intermediary's option regarding how aggressively to market each asset and thus can reduce the payoff. This is called the "information destruction effect". However, there can be an offsetting "risk diversification effect" of pooling and tranching – in that the intermediary can create lower-risk derivative securities from the asset pool, and such securities are less sensitive to the intermediary's private information and accordingly can be more attractively priced to the investor. In the case of CDOs, gains from risk diversification were expected to exceed losses from information destruction, such that on net pooling and tranching facilitated higher gains than individual asset sales.

vehicle. Some combination of those factors could serve to explain tighter spreads to Treasury on ABS. An alternative *asymmetric information hypothesis* suggests that CDO issuers may possess private asymmetric information regarding asset returns, and can engage in price discrimination via tranching to maximize profits (Oldfield (2000) or use such pooling and tranching methodologies to diversity risk (DeMarzo (2005)).[4]

Finally, one might posit a *production efficiency hypothesis*, whereby specialization and vertical disintegration of such functions as ABS securitization, ownership and servicing, would serve to enhance production efficiency and in so doing decrease ABS production costs. This hypothesis derives from well-known work by Greenbaum (1988) and Hess and Smith (1988) which posits gains from specialization of activity in each step of the intermediation and securitization function. Here we would similarly anticipate some contraction in ABS-Treasury spreads.

In this paper, we undertake empirical assessment of the effects of CDO issuance on ABS pricing. Our empirical specification seeks to identify CDO issuance effects, having controlled for a myriad of pricing influences including those associated with new supply of ABS. While our specification cannot fully distinguish the relative importance of the above and other hypotheses, it does go some distance in nuancing the supply- versus demand-side effects of CDO issuance in the determination of the pricing of real estate-backed ABS.

[4] Oldfield (2000) argues that tranching may allow security issuers to further enhance returns via price discrimination. Assuming that the demand functions for various derivative products are imperfectly price elastic, Oldfield (2000) explains that the security issuer seeks private information about investor demand via the security design and sales process, and uses that information to segment the market and price discriminate among different sets of customers. In the case of CDOs, the price discrimination could be facilitated via the re-bundling of the pool and the selling the different tranches at different prices.

Note further some portion of evidenced CDO asset-backed security pricing effects likely will be passed back to borrowers in the primary mortgage markets. Indeed, as is broadly appreciated, the interest rates faced by residential and commercial borrowers in the primary market derive importantly from sales and pricing of related mortgage pools in the secondary markets. For example, the predominance of demand-side effects, per above, would suggest a perceptible role for CDO markets in the reduction of subprime mortgage rate spreads. Such results would further suggest significant related implications of the 2007 collapse of the CDO market as regards the diminished availability and increased pricing of sub-prime mortgage debt. Our results provide the first systematic evidence linking derivative CDO markets to the pricing of sub-prime and commercial mortgages.

Results of the empirical analysis suggest that factors associated with the termination risks of the underlying commercial and subprime residential mortgage contracts, including interest-rate volatility, the term structure of interest rates, and proxies for credit risk in the macro-economy, importantly affect the magnitude of mortgage security/Treasury spreads. Further, both subprime residential asset-based security (SRABS) to Treasury spreads and commercial mortgage-backed security (CMBS) to Swap spreads evidence only limited sensitivity to returns and related return volatility among alternative asset classes, notably including those of equity markets. Finally, holding constant those factors, research indicates that the emergence of the CDO market was associated with a significant contraction in sub-prime mortgage security to Treasury yield spreads. Those effects were even more pronounced over the 2000-2006 period of rapid CDO market capitalization, likely reflective of sizable increases in CDO-related demand for subprime ABS and CMBS product.

The remainder of this paper is organized as follows. Section II discusses the influence of CDOs on the pricing of subprime residential- and commercial mortgage-backed securities. Section III describes the data used in the study and presents the empirical model, and Section IV present the empirical findings and simulation results. Section V summarizes the results and makes concluding remarks.

II. The Role of CDOs in the Determination of MBS Yield Spreads

The termination risks of mortgage-backed securities differ substantially from those of U.S. Treasuries. Treasury obligations provide a U.S. government guarantee of timely repayment of principal and interest. In marked contrast, the cash flows and hence pricing of mortgage-backed securities should reflect regularities associated with borrower exercise of mortgage put and call options. Those borrower options are typically embedded in the mortgage contract. In the case of the former, mortgage borrowers put the mortgage back to the lender in the case of default. Indeed, the inadequacy of both underwriting and pricing of default risk over past years has been fundamental to the sub-prime crisis.

It should be further noted that subprime- and commercial mortgage-backed securities typically are tranched by issuers to reflect systematic increments in credit risk. Accordingly, ABS-Treasury spreads should vary directly with the subordination of the underlying mortgage debt. Historical regularities in ABS-Treasury yield spreads by tranche are documented in Figure 3; particularly evident in the figure are the substantially elevated spreads associated with subordinated BBB-rated CMBS securities.[5]

Similarly, frequent borrower call option exercise, in the form of mortgage prepayment, were indicated over the period of analysis.[6] On the commercial mortgage side, prepayments were evidenced despite the increasingly common use of such prepayment constraints as lock outs, yield maintenance, and defeasance. Indeed, the pricing of securitized mortgage product should reflect prepayment risks associated with expectations of the future path of interest rates. Also, higher levels of interest rate volatility suggest higher call option values and elevated risks of termination of the underlying mortgages. Those risks should be priced into higher mortgage spreads over Treasuries. However, this effect is mitigated somewhat in environments with steeper yield curves, as this term structure suggests that interest rate declines associated with volatility will be more muted, thereby implying diminished termination risk and risk premia for seasoned mortgage product.[7]

Spreads between mortgage and Treasury securities also may reflect supply/demand imbalances across those and related asset classes. For example, changes in investor asset allocation among mortgage and corporate debt, equity, and government

[5] In subprime residential debt markets, the ABS issued by investment banks were backed by the private mortgage insurance and other forms of credit enhancement rather than the full faith and credit of the U.S. government.

[6] Post-recession years of the current decades witnessed a secular increase in residential mortgage prepayment speeds, in the wake of technological innovation and reduced costs of mortgage re-finance, enhanced mortgage product offerings, improved borrower knowledge of and ease of loan qualification, and substantial downward adjustment in mortgage interest rates subsequent to the 2001 recession.

[7] While CMBS structures utilize various methodologies, including prepayment lock-outs, defeasance, and the like, to assure lender cash flows, incentives for mortgage termination nonetheless vary with the value of the call option. In the empirical literature, measures of both interest rate volatility and the term structure of rates have been used as important determinants of the call option's value.

bond markets could markedly affect the pricing of mortgage-backed securities. Specifically, elevated returns among alternative assets, notably including equities, may result in investor portfolio re-allocation to alternative asset classes, resulting in damped demand for and elevated premia among securitized mortgage product. However, elevated equity returns may have less influence on portfolio asset allocation to the extent the higher equity returns are accompanied by elevated return volatility.

Finally, as suggested by the above *market-completion hypothesis*, the emergence of the CDO structure has resulted in substantial derived demand among institutional investors for underlying CMBS and subprime residential ABS. As a diversified, multi-class, investment grade vehicle, CDOs may have brought new investors into the marketplace and created value as a market-completing investment. However, as in the *supply-shift hypothesis*, it is further plausible that the emergence of the CDO structure elicited a supply response, whereby mortgage lenders in the primary markets sought to originate and securitize mortgage product expressly for inclusion in CDO structures. Spreads on ABS relative to Treasuries may have tightened as well owing to the *specialization and production efficiency hypothesis* or because of mis-representations, informational asymmetries, or problems of underwriting captured in our *shell-game and asymmetric information hypotheses*. Empirically, the relative magnitudes of those influences are difficult to entangle. However, to the extent the recent surge in CDO-related demand for subprime- and commercial mortgage-backed securities has exceeded changes in the issuance of mortgage-backed securities, one would anticipate some tightening of mortgage spreads. We specify and test for those effects below.

A. Theoretical Determinants of Mortgage Bond Spreads

Changes in Slope of the Treasury Yield Curve: There exists substantial evidence on the role of the term structure in the determination of mortgage bond spreads [see, for example, Rothberg, Nothaft, and Gabriel (1989), Bradley, Gabriel and Wohar (1995), Ambrose and Sanders (2003), Titman, Tompaidis and Tsyplakov (2005)]. As is widely-appreciated, an increase in the slope of the yield curve suggests some future strengthening in economic activity. As such, a steeper yield curve imparts a higher probability of a short rate increase, while Merton (1974) has shown that the value of risky debt is a negative function of the instantaneous risk-free rate. Also, a steeper yield curve implies a higher probability of a future decline in the long-term risk-free rate, which is positively associated with prepayment risk. Accordingly, increases in the slope of the Treasury yield curve should have a positive impact on the mortgage-backed security-Treasury spread.

Changes in Volatility: Mortgage put and call option values increase with interest rate volatility. In fact, in a contingent claims framework, the debt claim has elements similar to a short position on a put option. Accordingly, mortgage bond spreads should increase with volatility. This prediction is intuitive and is well established in the literature; increased interest rate volatility implies increases in the probability of prepayment and default.

Changes in Credit Risk: Fama and French (1989) find that credit spreads widen when economic conditions are weak. We use the interest rate spread between corporate bonds rated Aaa and Baa to proxy such economy-wide credit risk. In the current application, we hypothesize that the put option embedded in the mortgage contract should vary directly with economy-wide credit risk and the market price of risk. The credit spread proxy has been previously applied to proxy mortgage default risk [see, for example, Duca and Rosenthal (1989), Bradley, Wohar and Gabriel (1995)].

Changes in Alternative Assets Returns: As evidenced in Kwan (1996) and Collin-Dufresne et al (2001), returns to alternative asset classes, notably including equity returns, may affect the demand for and yields on fixed income securities. Similar to those papers, we include excess return in the S&P 500 over the 3-month constant maturity Treasury yield as well as a measure of volatility of S&P 500 excess returns to proxy returns on alternative equity investment classes.

B. CDO Market Evolution: Determinants related to Market Capitalization and Supply/Demand Imbalances

Changes in ABS CDO Issuance/ABS Issuance: The analysis controls for the magnitude of ABS CDO monthly issuance relative to that of underlying subprime- or commercial mortgage-backed securities. Contractions in this ratio suggest ample supply of ABS available for re-securitization via the CDO vehicle. Such deviations in the trend ratio of ABS CDO to ABS issuance would be expected to exert upward pressure on spreads.

Changes in ABS CDO Issuance: Controlling for evolution in the ratio of ABS CDO to ABS issuance, positive deviations in CDO issuance (whether owing to market completion, specialization and production efficiency, asymmetric information, or other effects) should work to increase demand for underlying subprime and commercial securitized product. All things equal, increases in derived demand for underlying securitized product should result in some tightening of ABS-Treasury spreads.

III. Data and Empirical Model

In this section, we describe the data used for estimating both the bond yield spreads and the empirical proxies for the spread determinants.

Yield Spreads on Asset-Backed Bonds: The subprime residential ABS yields are obtained from TrueStandings Securities. The CMBS AAA, AA, A, and BBB yields are monthly series obtained from JP Morgan. Asset-backed bond yield spreads are then defined as the difference between the yield of the bond and the associated yield of the constant maturity 10-year Treasury. We also compute and assess the robustness of results to CMBS yields to SWAPs.

Slope of the Treasury Yield Curve: The Treasury yield data—yield on the 10-year Constant Maturity Treasury (CMT) and spread between the 10-year CMT and the 3-month CMT—are obtained from the Federal Reserve Economic Data website at the Federal Reserve Bank of St. Louis. These data are published as monthly averages of their respective series. We interpret this variable as both an indicator of expectations in future short rates as well as an indicator of overall status of the economy.

Volatility: Our measure of interest rate volatility is the annualized standard deviation of the log differences in daily yields on the 10-year Treasury. We also compute the interaction of the Yield Curve and Volatility terms.

Credit Risk: The monthly time-series on corporate bonds rates Aaa and Baa are obtained from Moodys Investors Services. This variable is defined as the yield on corporate bonds rated Baa minus the yield on corporate bonds rated Aaa.

Alternative Asset Returns: The monthly S&P return series are obtained from Datastream.

CDO Market Evolution and related ABS Supply/Demand Imbalances

ABS CDO Issuance: We obtain information on CDO issuance from ABAlert.com. The ABAlert.com database contains information on the initial terms of all rated issuance of asset-backed securities, mortgage-backed issues and collateralized debt obligations.[8] The database provides the information on CDO issuance by all the major players, including Wells Fargo, ABN AMRO/ LaSalle Bank, J.P. Morgan Chase, and the like. The ABAlert.com database assigns each issue to one of five categories: Public ABS, Private ABS, MBS, Non-US ABS and CDOs. In the analysis below, we utilize information pertaining only to collateralized debt obligation issuance in the U.S.[9] To compute our CDO issuance series, we aggregate the deals by month in terms of number of deals and dollar volume of issuance. CMBS tranche issuance is computed as a three-month weighted moving average of commercial real estate CDO issuance, where an exponential decay function is used for purposes of weighting. Our sample covers the period from November 1995 - July 2006. The full data timeframe for subprime ABS is

[8] The primary objective of the ABAlert.com database is to identify the primary participants in each transaction. This database does not include information on pricing or other tranche-specific information. The database captures only the terms of each issue as of its pricing date, so it doesn't reflect subsequent events, such as paydowns and rating changes. (For further information, see: http://abalert.com/NewPages/Index.cfm?Article_ID=41086).

[9] In computing the dollar volume of CDO issuance, we exclude issuance related to bank loans (CLOs).

from 1997 January to 2006 August and for CMBS is from 1998 August to 2005 December.

ABS CDO Issuance/ABS Issuance: Sub-prime ABS-backed and CMBS-backed CDO issuance is computed per above. Subprime ABS issuance (billions of dollars) is obtained monthly from Bloomberg. Monthly CMBS trance issuance (AAA, AA, A, and BBB) is obtained from Trepp Bond.

Empirical Model

We estimate the following reduced form model.[10]

$$\Delta\left(r_{B_t} - r_{N_t}\right) = \alpha + \beta_1 \Delta Slope_t + \beta_2 \Delta Vol_{CMT\,t} + \beta_3 \Delta Slope_t \times \Delta Vol_{CMT\,t} + \beta_4 \Delta\left(r_{Aaa_t} - r_{Baa_t}\right)$$
$$+\beta_5 \Delta S\&P_t + \beta_6 \Delta S\&P_t \times \Delta Vol_{S\&P\,t} + \beta_7 \ln\left(CDO\_Iss_t\right) + \beta_8 \frac{CDO\_Iss_t}{Section\_Iss_t} + \mu_t \qquad (1)$$

where

r_B	=	yield on the indicated subprime (or commercial mortgage-backed security)
r_N	=	yield on the 10-year CMT (or Swap rate)
Slope	=	spread between 10-year CMT and 3-month CMT
Vol_{CMT}	=	10-year CMT volatility
r_{Aaa}	=	composite yield on corporate bonds rated Aaa by Moody's
r_{Baa}	=	composite yield on corporate bonds rated Baa by Moody's
S&P	=	excess return of S&P 500 (dividend included) index over the 3-mon CMT
$Vol_{S\&P}$	=	S&P 500 volatility
CDO_Iss	=	subprime CDO (or CRE CDO) issuance
Section_Iss	=	subprime residential ABS (or CMBS) issuance

t denotes time in months. Our sample covers the period from November 1995 - July 2006. The time-series for subprime ABS is from January 1997 to August 2006 August whereas that of CMBS section is from 1998 August to 2005 December.

[10] Similar specification can be found in Collin-Defresne, Goldstein and Martin (2001) to empirically estimate the determinants of credit spread changes

In the above equation, the dependent variable is measured as the basis point differential in spreads between the relevant mortgage and Treasury securities. Among CMBS, tranche spreads are computed and evaluated for CMBS rated AAA, AA, A, and BBB, respectively.[11] All models are estimated in first differences using the GMM. The Newey-West kernel approach is used for error correction. The independent variables in the estimating equations are as described above. Of central interest to this analysis is the indicator of monthly issuance of collateralized debt obligations as well as an interaction of that indicator with a categorical timing variable to indicate issuance post-2003.[12]

IV. Estimation and Simulation Results

Results from the estimation of the subprime asset-backed security/Treasury and CMBS/Swap spreads equations are summarized in Tables 1 and 2. As evidenced in Table 1, the estimated coefficients are of expected sign and (for the most part) statistically significant across the various tranche spreads. For example, our measure of interest rate volatility, the annualized standard deviation of the log differences in daily yields on the ten-year Treasury, is highly significant for subprime ABS, but not always significant for CMBS tranches. Further, the estimated coefficient on interest volatility is similarly

[11] Below estimation results also are reported for CMBS spreads to swaps.

[12] As pointed by Granger and Newbold (1974), stochastic trends (which have a unit root) can lead two time series to appear related when they actually are not. To avoid the potential estimation bias due to spurious correlations, we first subject all time series used in our analysis to Dickey-Fuller tests (1979). Results of that analysis indicate that all the time series variables used in this study are significant at the 1 percent level in our unit root tests, with the exception of the mortgage-backed security-Treasury yield spreads, y_t, which is significant at 10 percent level in our unit root test. As a robustness check to address the potential estimation bias due to the marginally significant yield spreads process , y_t, we also test our model by replacing yield spreads with the ratio of yield spreads to the 10 year Treasury yield, , y_t', such that $y_t' = X_t\beta + \mu_t$, where y_t' is significant at 1 percent level in our unit root test.

positive and highly significant in the case of the subprime ABS spread. Overall, results are consistent with expectations that higher levels of interest rate volatility, as reflective of increased investor uncertainty regarding baseline Treasury rates, are positively priced into mortgage-Treasury spreads.

The term reflecting the interaction of interest rate volatility and the slope of the Treasury yield curve enters the mortgage/Treasury spread equations with mixed results. For the subprime ABS, the interaction term is negative and significant. For CMBS, the interaction term is positive, but only significant in the second half of the sample (since 2001).

Our proxy for credit risk in the U.S. economy, the basis point spread between highly-rated AAA and BAA corporate bonds, exerts a positive effect on CMBS/Swap spreads. The corporate bond yield spread serves as a proxy for default risk on mortgage securities, consistent with previous work described in Duca and Rosenthal [1989], which indicates that yield spreads between lower-rated and higher-rated bonds may be explained in part by measures on confidence in the economy. As is consistent with our priors, the estimated magnitudes and statistical significance of the credit risk coefficients vary directly with the tranched subordination of the underlying commercial mortgage debt. Indeed, the estimated coefficient on the subordinated and highly exposed BBB tranche spread is about four times that of the senior credit-protected AAA tranche. However, our credit risk proxy does not significantly affect the determination of MBS/Treasury spreads.

As suggested above, spreads between CMBS, subprime ABS and Swap or Treasury securities also may reflect supply/demand imbalances across those and related asset classes. For example, evolution in investor asset allocations among mortgage and corporate debt, equity, and government bond markets could markedly affect the demand for and pricing of mortgage-backed securities. However, investor expectations of returns to equities and hence portfolio allocations to that asset class could be influenced as well by the volatility of equity returns. Estimation results fail to indicate a significant effect of volatility of equity returns in the pricing of CMBS or residential mortgage-backed securities.

Finally, research findings suggest that the rapid growth in CDO issuance has been significant to the pricing of commercial- and residential mortgage-backed securities. As evidenced in Tables 1 and 2, the CDO issuance coefficient is negative and significant for both subprime ABS and CMBS; further the magnitude and significance of the estimated coefficients trends up modestly with subordination level, suggesting that CDO issuance has been more important to the pricing of subordinated, higher credit risk CMBS tranches.

The analysis further seeks to sort out any change in CDO effects as might derive from the explosive growth in the CDO market post-2001. Indeed, as shown in table 1, the estimated coefficient on CDO issuance post-2001 is less significant and of magnitude similar to the CDO issuance coefficient prior-2001. Accordingly, findings for the recent period indicate substantial narrowing of CDO-related mortgage pricing premia, likely reflective of sizable increases in CDO-related demand for CMBS and subprime residential ABS product post-2001.

Finally, we use the results from Table 1 to generate a predicted value for the dependent variable from the GMM model. In addition, we simulate the effects of decreased CDO issuance on subprime ABS yields. Furthermore, we simulate changes in the interest rate volatility and default risks on subprime ABS yields. For the simulations of CDO issuance, the simulations are (a) decreasing the CDO Issuance value by 25%, (b) decreasing by 50%, and (c) setting its value as 0. Finally, we simulate combined changes in CDO issuance, volatility and default risks – a perfect storm scenario – on subprime ABS yield spreads.

The results for the simulated impacts on subprime ABS yield spreads can be found in Figures 12-15. Overall, a decrease in CDO issuance results in an increase in subprime ABS yields. The result from the perfect storm scenario is substantially stronger.

V. Conclusion

This research evaluates the effects of the emerging market for collateralized debt obligations (CDOs) on the pricing of mortgage-backed securities. In so doing, it evaluates the determinants of yield spreads of various tranches of CMBS to Swap and subprime residential ABS relative to comparable-maturity Treasury bonds. Empirical tests suggest that factors associated with the termination risks of the underlying commercial and residential mortgage contracts, including interest-rate volatility, the term structure of interest rates, proxies for mortgage credit risk, and expected returns among alternative asset classes may affect the magnitude of mortgage security/Treasury spreads. Findings also show that the emergence of the CDO market initially was associated with a significant widening of mortgage security/Treasury yield spreads. However, since 2003, in the wake of rapid growth in CDO issuance, those effects largely have reversed. Results for the recent period indicate substantial narrowing of CDO-related mortgage pricing premia, likely reflective of sizable increases in CDO-related demand for CMBS and subprime residential ABS product.

Given recent explosive growth in the CDO market, it is reasonable to anticipate ongoing strengthening in demand for asset-backed securities and concomitant tightening of mortgage-Treasury spreads. Indeed, developments in the CDO market illustrate the ever-increasing importance of global capital markets to the pricing of U.S. commercial and residential mortgage debt. Note, however, that while the strength of global demand for asset-backed securities points to pricing benefits for U.S. households and firms, the opposite could well occur. In that regard, an unanticipated cooling in the emergent CDO market could adversely affect the pricing of U.S. mortgage debt, so as to markedly slow activity in the U.S. real estate sector.

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Table 1. GMM Estimations of Subprime Yield to Treasury Spreads on Subprime CDO Issuance

	Model 1 (1997~2006)	Model 2 (2001~2006)
Constant	-0.0258	0.0174
	(-0.90)	(0.25)
ΔSlope	-0.6374	-0.7758
	(-10.57)	(-9.05)
ΔVol_{CMT}	1.6771	0.9705
	(8.34)	(1.60)
$\Delta Slope \times \Delta Vol_{CMT}$	-0.6142	-0.4416
	(-7.10)	(-2.25)
ΔDefault Risk	0.3210	0.0936
	(1.88)	(0.65)
ΔS&P	-0.0078	0.0416
	(-0.25)	(0.98)
$\Delta S\&P \times \Delta Vol_{S\&P}$	0.0442	-0.2248
	(0.45)	(-1.97)
Ln of Subprime CDO Issuance	-0.0723	-0.1435
	(-4.64)	(-4.32)
Ratio of Subprime CDO Issuance	1.7720	3.4089
to Subprime Mortgage Issuance	(3.68)	(4.98)
Number of Observations	113	67
Adjusted R^2	0.6000	0.5560

Note:

1. All models are estimated by GMM approach. Newey-West Kernel is used for error corrections. Dependent variables are the first difference of spreads between the yield on subprime mortgage debt and the 10-year Treasury CMT. Model 1 is estimated based on full sample of data from 1997.1 to 2006.8. Model 2 is estimated based on a sub sample of data from 2001.2 to 2006.8.
2. ΔSlope is change in spread between the 10-year CMT and the 3-month CMT. ΔVol_{CMT} is change in the volatility of 10-year CMT. ΔDefault Risk is measured by the change in the spread between the yields on long term Aaa and Baa corporate bonds. ΔS&P is change in excess return of S&P 500 (dividend included) index over the 3-month CMT. $\Delta Vol_{S\&P}$ is change in the volatility of excess return of S&P 500 index over the 3-month CMT. Subprime CDO issuance is measured by number of new issues (in thousands).
3. t-statistics are in parenthesis.

Table 2. GMM Estimations of CMBS Yield to SWAP Spreads on CRE CDO Issuance

	AAA	AA	A	BBB
Constant	-0.0077	-0.0160	-0.0150	-0.0098
	(-2.14)	(-3.00)	(-2.18)	(-0.68)
ΔSlope	-0.0119	-0.0278	-0.0197	0.0345
	(-0.77)	(-1.35)	(-0.61)	(0.69)
ΔVol_{CMT}	-0.0345	-0.0003	-0.0374	0.2513
	(-0.35)	(-0.00)	(-0.22)	(1.16)
$\Delta Slope \times \Delta Vol_{CMT}$	0.0014	-0.0089	0.0154	-0.0447
	(0.04)	(-0.18)	(0.23)	(-0.50)
ΔDefault Risk	-0.0144	0.0178	0.0755	-0.0929
	(-0.34)	(0.32)	(0.93)	(-0.84)
ΔS&P	-0.0016	-0.0030	-0.0006	0.0061
	(-0.21)	(-0.34)	(-0.05)	(0.30)
$\Delta S\&P \times \Delta Vol_{S\&P}$	0.0266	0.0436	0.0411	0.0052
	(1.03)	(1.59)	(1.10)	(0.09)
Ln of CRE CDO Issuance	-0.0006	-0.0018	-0.0023	-0.0034
	(-0.90)	(-2.51)	(-2.24)	(-2.79)
Ratio of CRE CDO Issuance to CMBS Issuance	0.0013	0.0011	0.0004	0.0004
	(0.29)	(1.32)	(1.40)	(0.99)
Number of Observations	89	89	89	89
Adjusted R^2	-0.127	-0.092	-0.063	0.008

Note:

1. All models are estimated by GMM approach. Newey-West Kernel is used for error corrections. Dependent variables are the first difference of CMBS to SWAP spreads by various credit ratings. Sampling period spans from 1998.8 to 2005.12.
2. ΔSlope is change in spread between the 10-year CMT and the 3-month CMT. ΔVolatility is change in the volatility of 10-year CMT. ΔDefault Risk is measured by the change in the spread between the yields on long term Aaa and Baa corporate bonds. ΔS&P500 is change in excess return of S&P 500 (dividend included) index over the 3-month CMT. $\Delta Vol_{S\&P}$ is change in the volatility of excess return of S&P 500 index over the 3-month CMT. CRE CDO issuance is measured by 3-month weighted average of CRE CDO issuance dollar amount (in millions), where exponential decay function is used as weights, i.e. $\sum_{t=0}^{2} CDO_{-t} \times e^{-t}$.
3. t-statistics are in parenthesis.

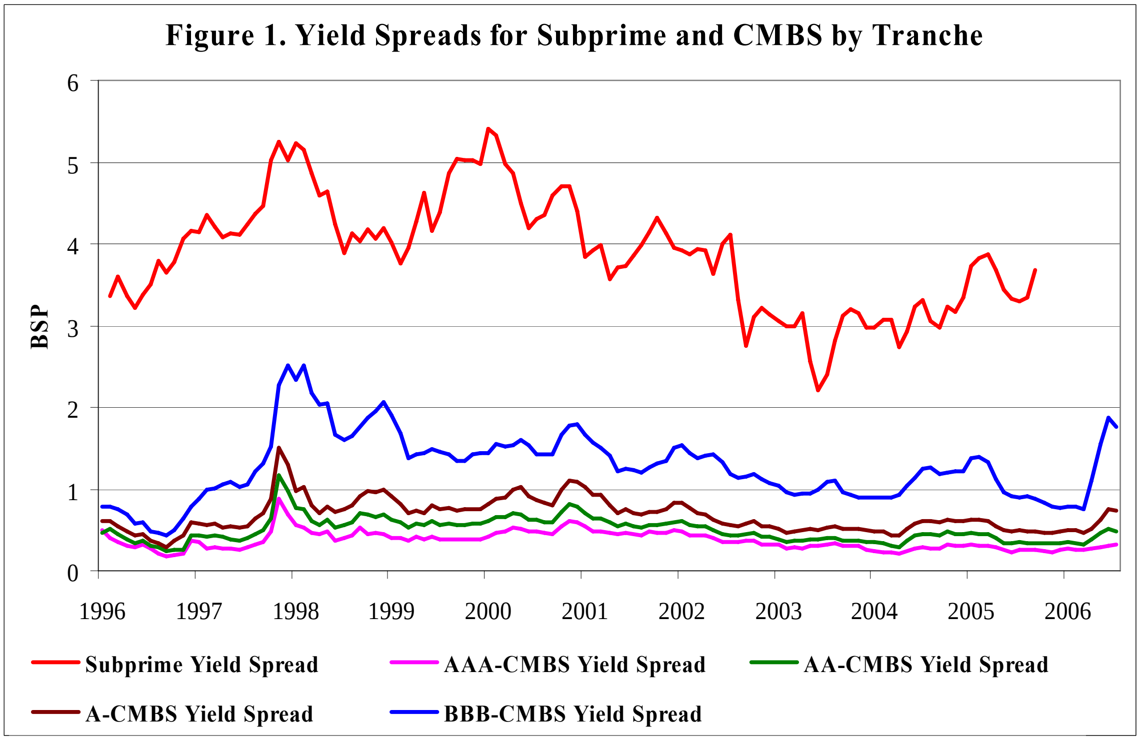


Figure 1. Yield Spreads for Subprime and CMBS by Tranche
BSP
6
5
4
3
2
1
0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Subprime Yield Spread
AAA-CMBS Yield Spread
AA-CMBS Yield Spread
A-CMBS Yield Spread
BBB-CMBS Yield Spread

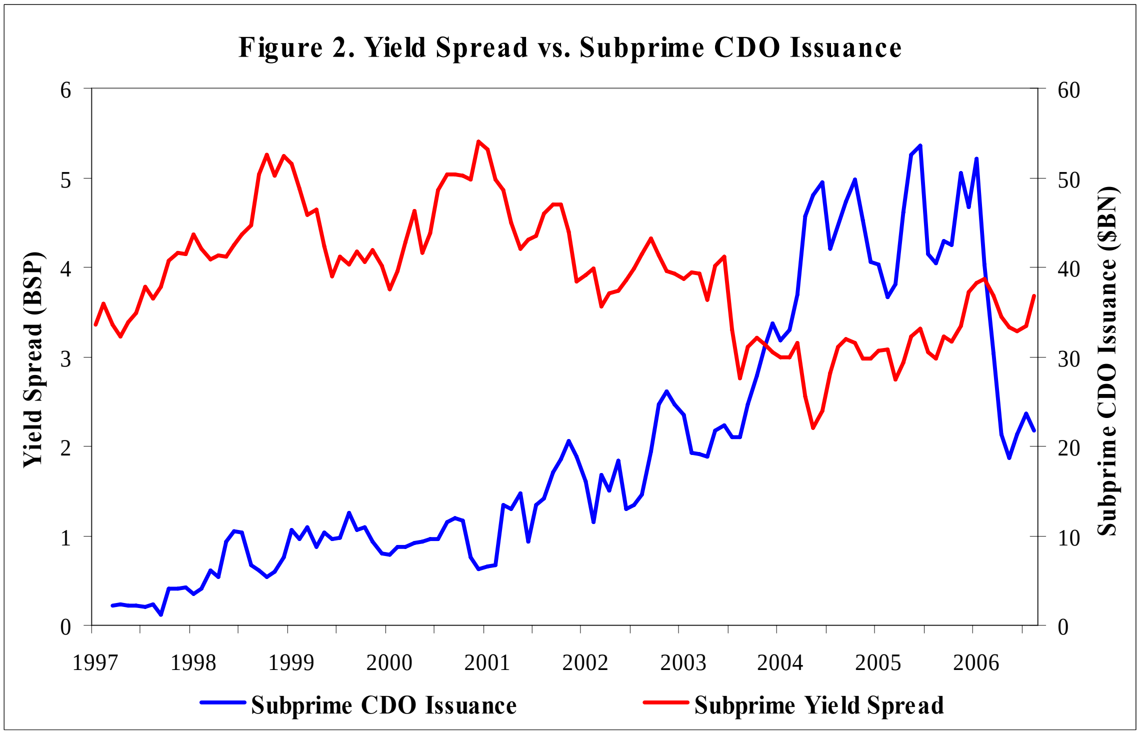


Figure 2. Yield Spread vs. Subprime CDO Issuance
Yield Spread (BSP)
Subprime CDO Issuance ($BN)
0
1
2
3
4
5
6
0
10
20
30
40
50
60
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Subprime CDO Issuance
Subprime Yield Spread

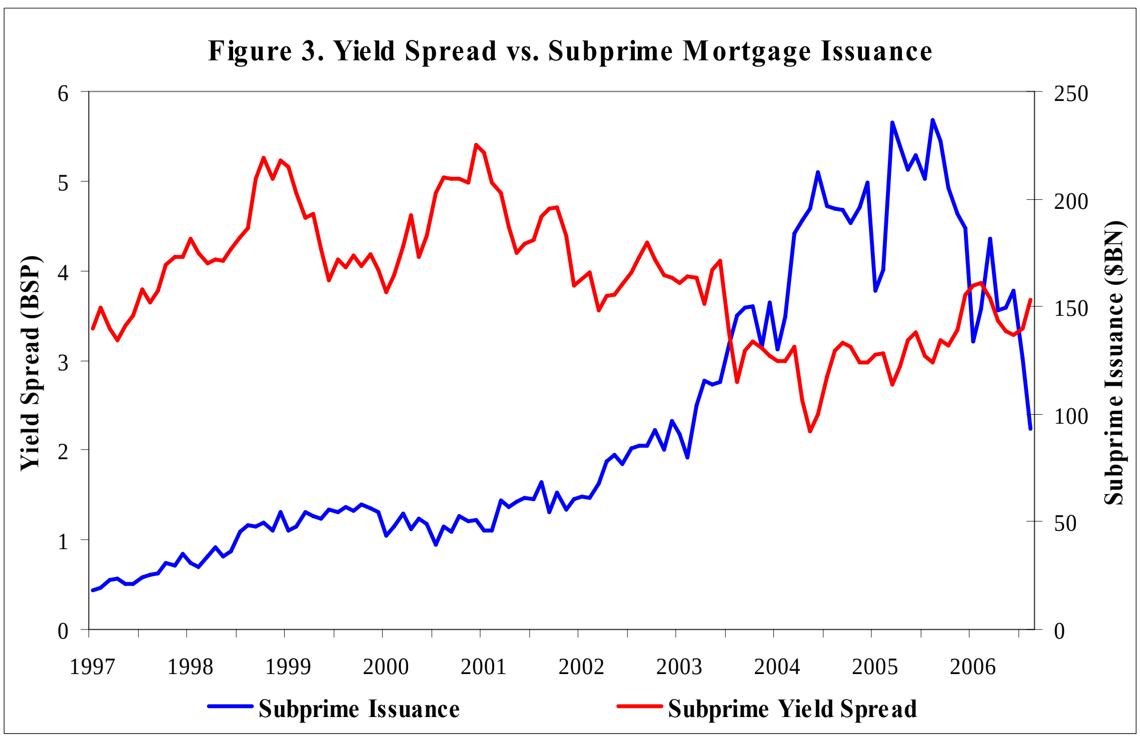


Figure 3. Yield Spread vs. Subprime Mortgage Issuance
Yield Spread (BSP)
Subprime Issuance ($BN)
0
1
2
3
4
5
6
0
50
100
150
200
250
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Subprime Issuance
Subprime Yield Spread

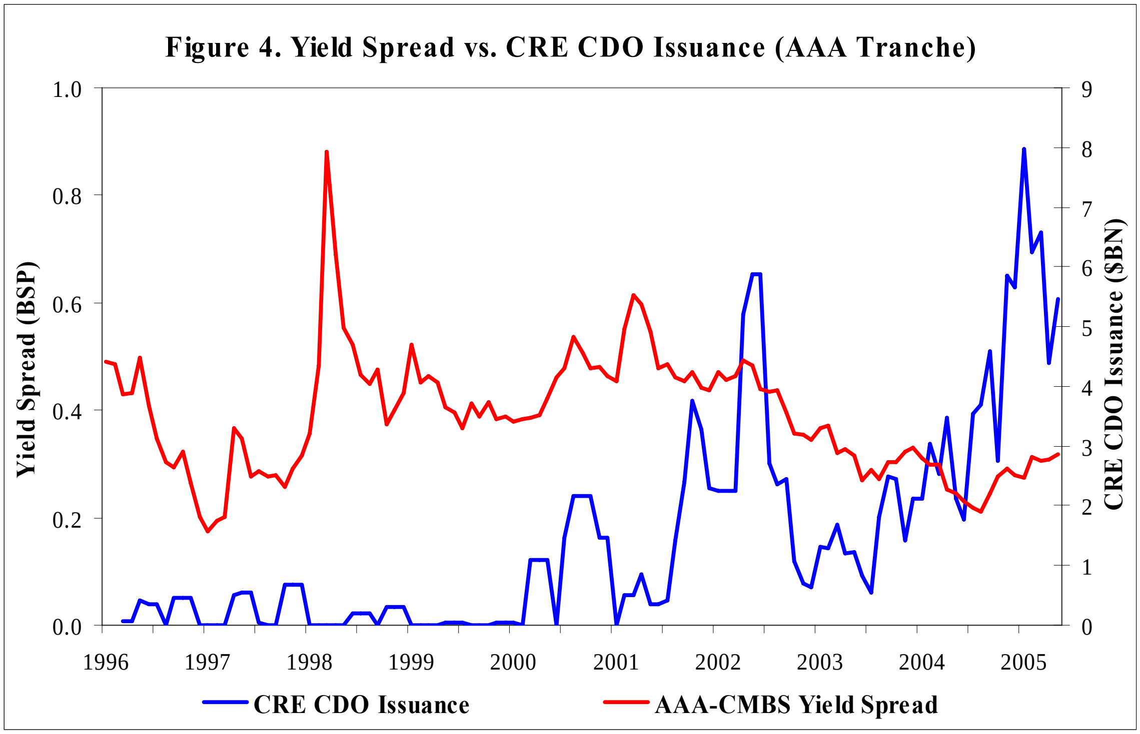


Figure 4. Yield Spread vs. CRE CDO Issuance (AAA Tranche)
Yield Spread (BSP)
CRE CDO Issuance ($BN)
1.0
0.8
0.6
0.4
0.2
0.0
9
8
7
6
5
4
3
2
1
0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
CRE CDO Issuance
AAA-CMBS Yield Spread

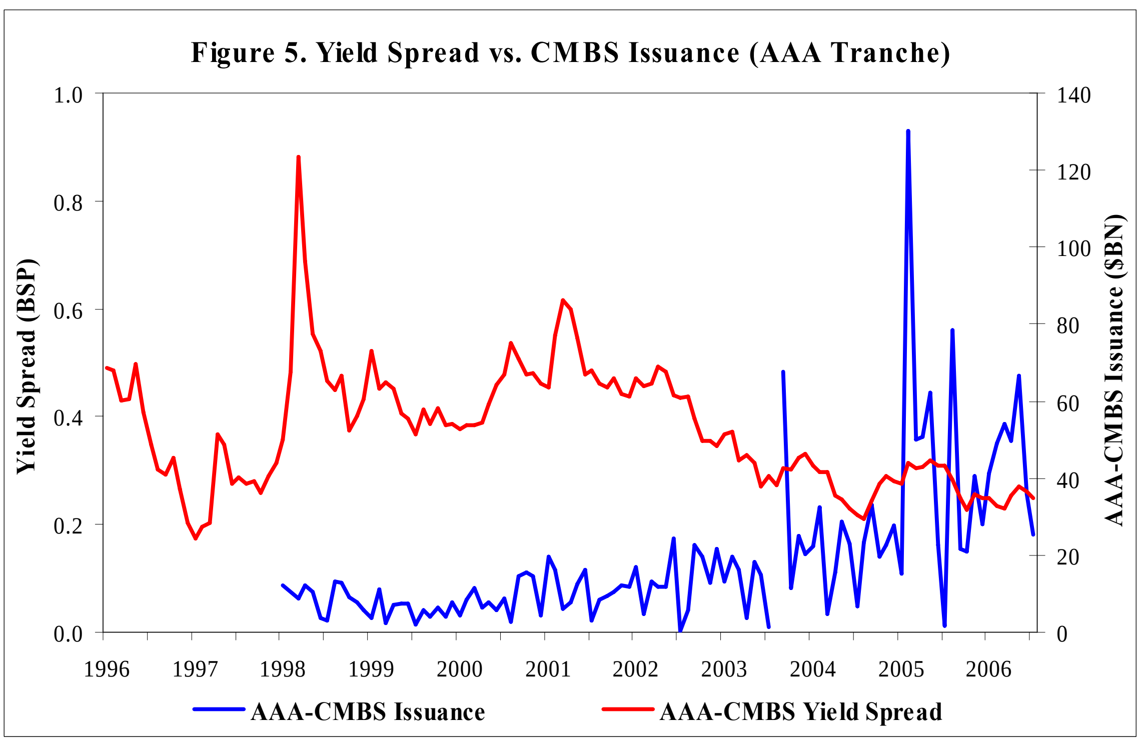


Figure 5. Yield Spread vs. CMBS Issuance (AAA Tranche)
Yield Spread (BSP)
AAA-CMBS Issuance ($BN)
1.0
0.8
0.6
0.4
0.2
0.0
140
120
100
80
60
40
20
0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
AAA-CMBS Issuance
AAA-CMBS Yield Spread

Figure 6. Yield Spread vs. CRE CDO Issuance (AA Tranche)

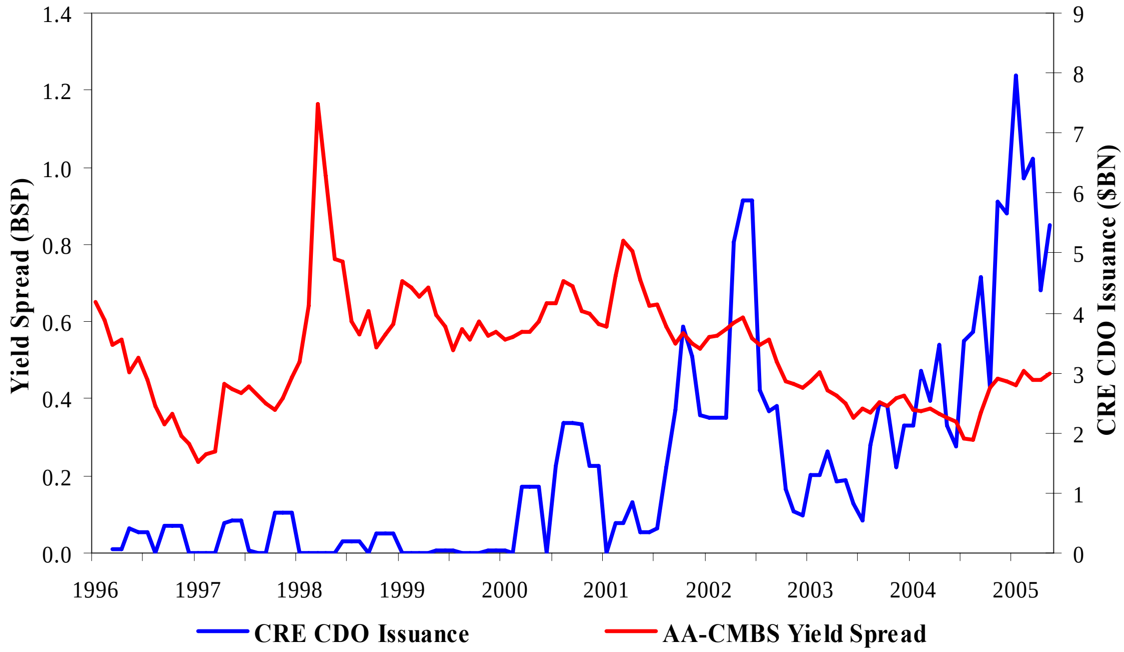
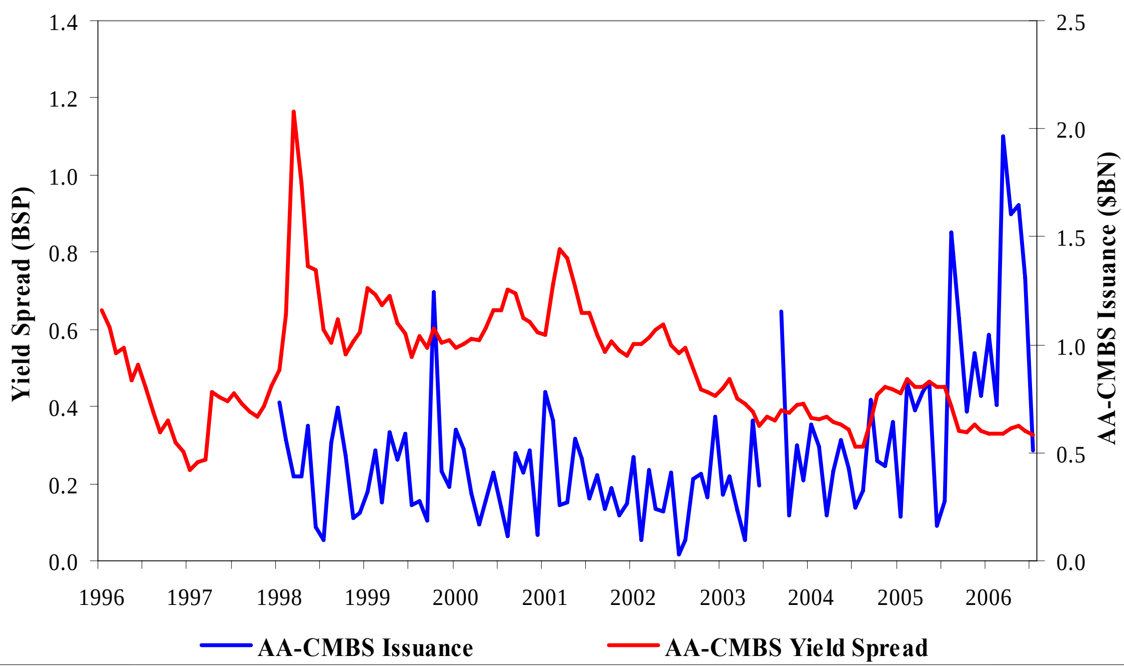


Figure 7. Yield Spread vs. CMBS Issuance (AA Tranche)



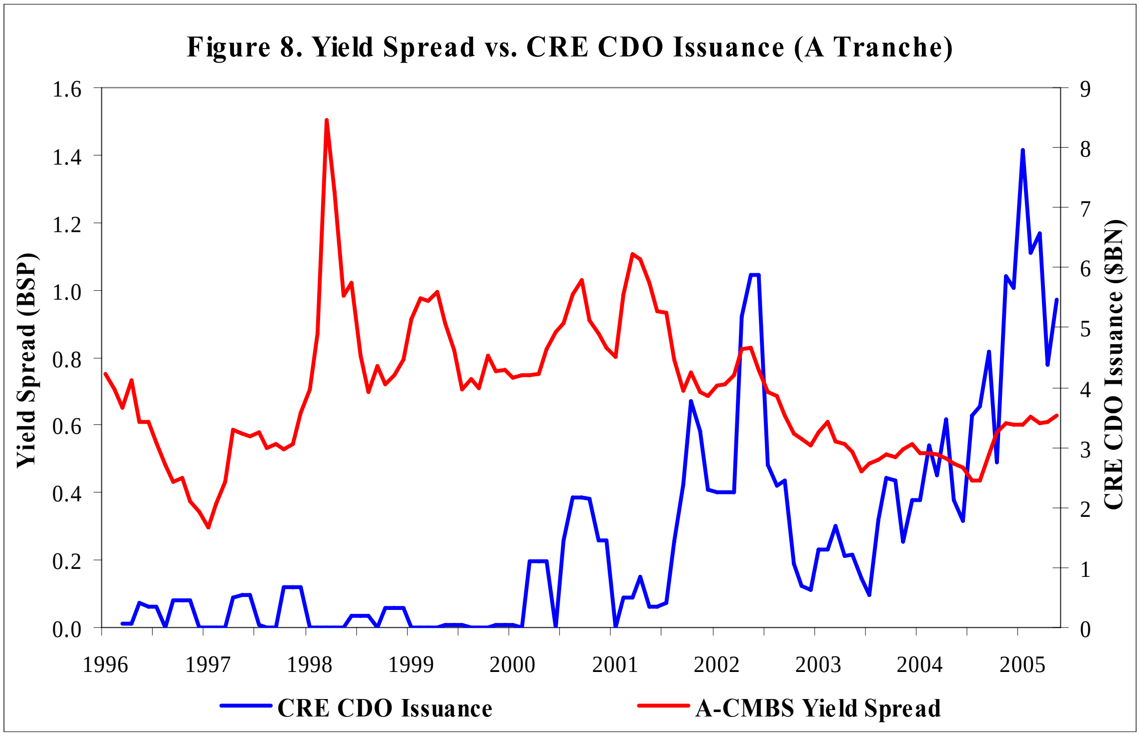


Figure 8. Yield Spread vs. CRE CDO Issuance (A Tranche)
Yield Spread (BSP)
CRE CDO Issuance ($BN)
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
CRE CDO Issuance
A-CMBS Yield Spread

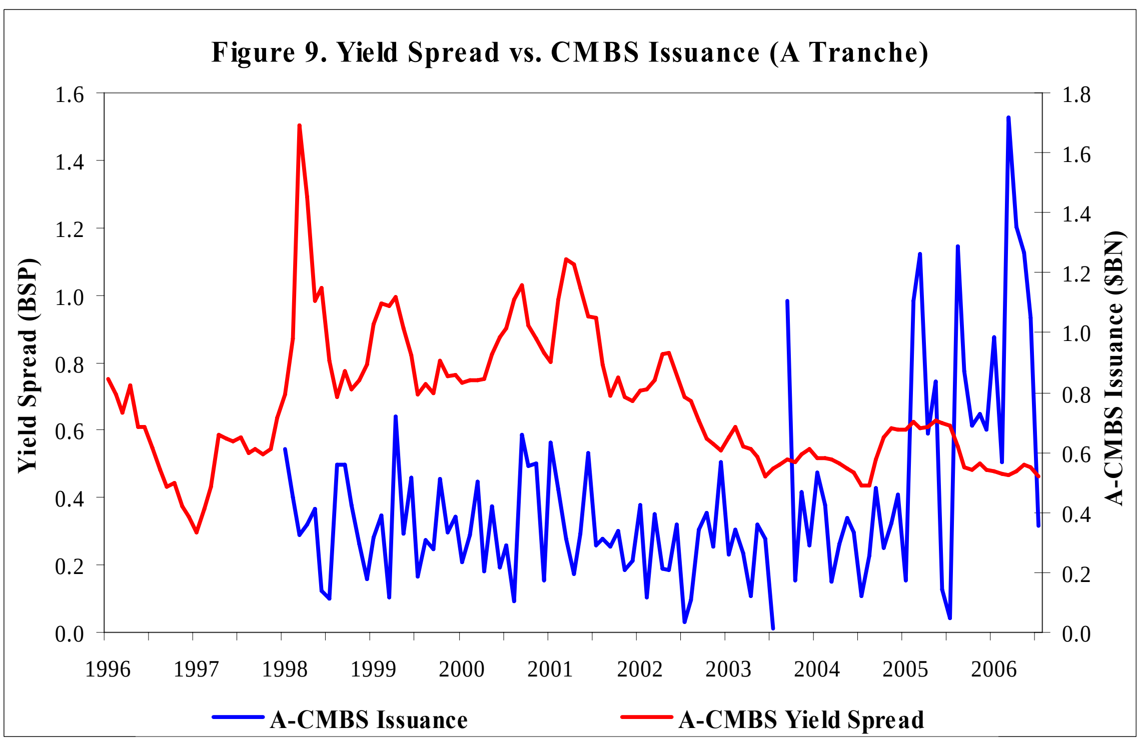


Figure 9. Yield Spread vs. CMBS Issuance (A Tranche)
Yield Spread (BSP)
A-CMBS Issuance ($BN)
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
A-CMBS Issuance
A-CMBS Yield Spread

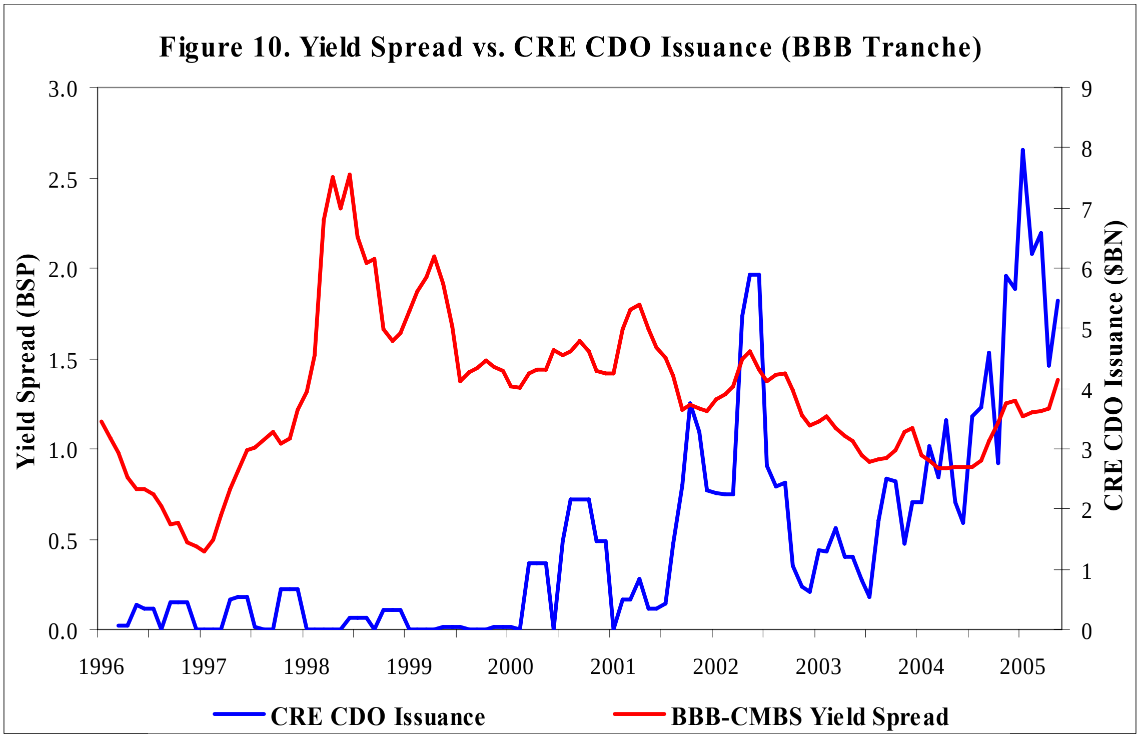


Figure 10. Yield Spread vs. CRE CDO Issuance (BBB Tranche)
Yield Spread (BSP)
CRE CDO Issuance ($BN)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
9
8
7
6
5
4
3
2
1
0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
CRE CDO Issuance
BBB-CMBS Yield Spread

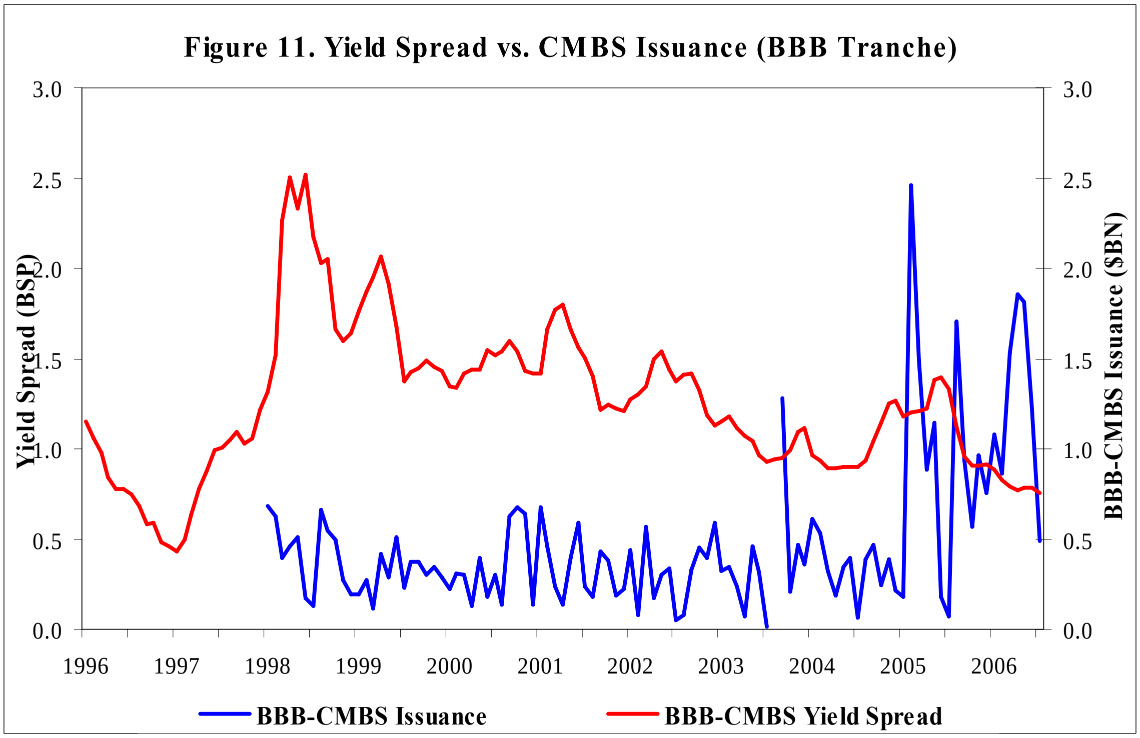


Figure 11. Yield Spread vs. CMBS Issuance (BBB Tranche)
Yield Spread (BSP)
BBB-CMBS Issuance ($BN)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
BBB-CMBS Issuance
BBB-CMBS Yield Spread

Figure 12. Actual, Predicted, and Simulated Subprime Yield Spreads (2001-2008)

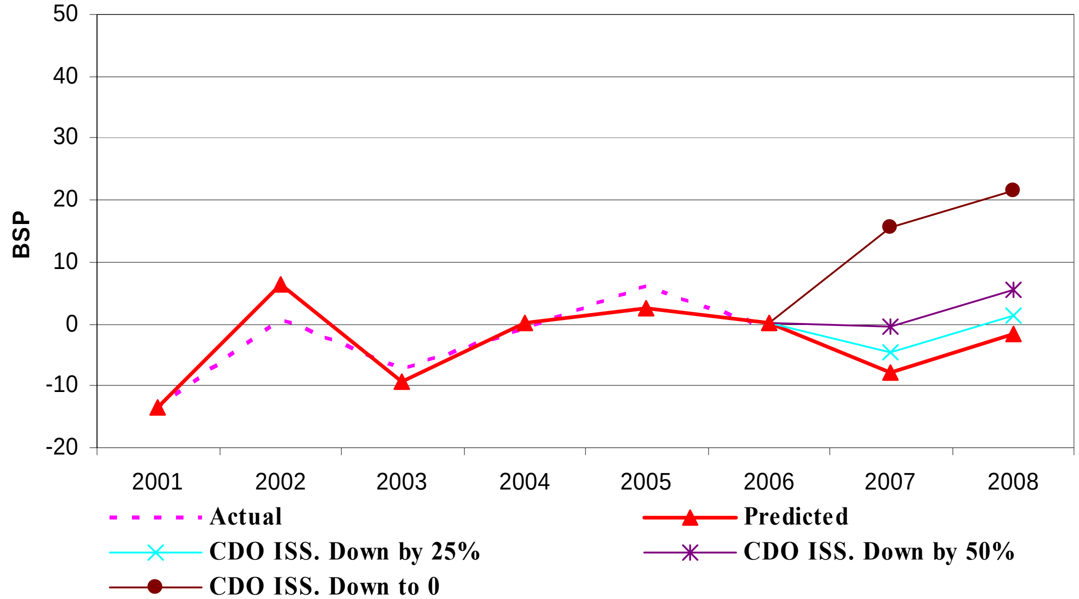


Figure 13. Actual, Predicted, and Simulated Subprime Yield Spreads (2001-2008)

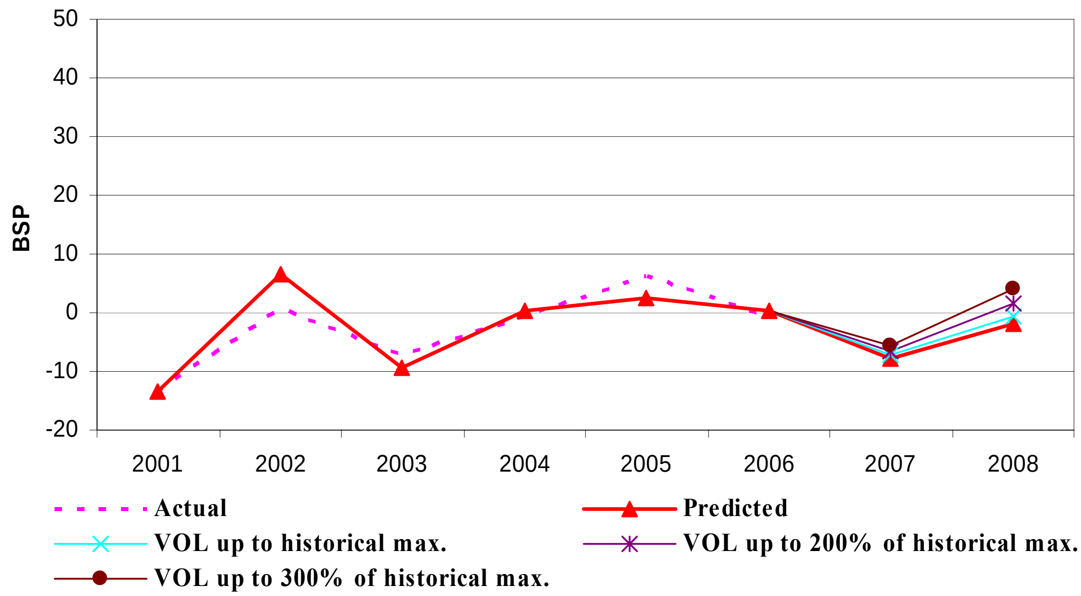


Figure 14. Actual, Predicted, and Simulated Subprime Yield Spreads (2001-2008)

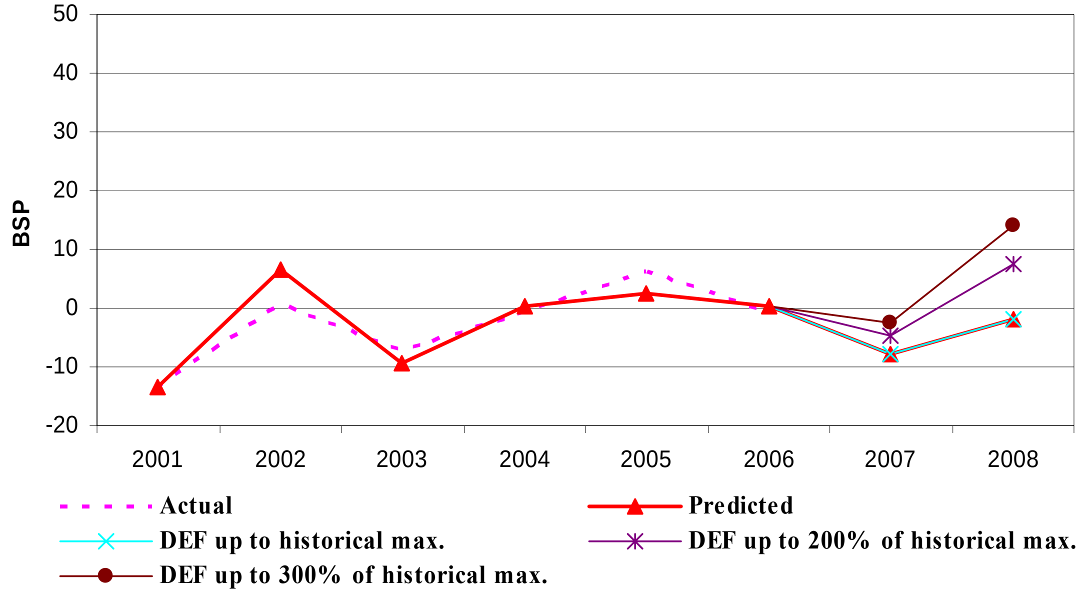
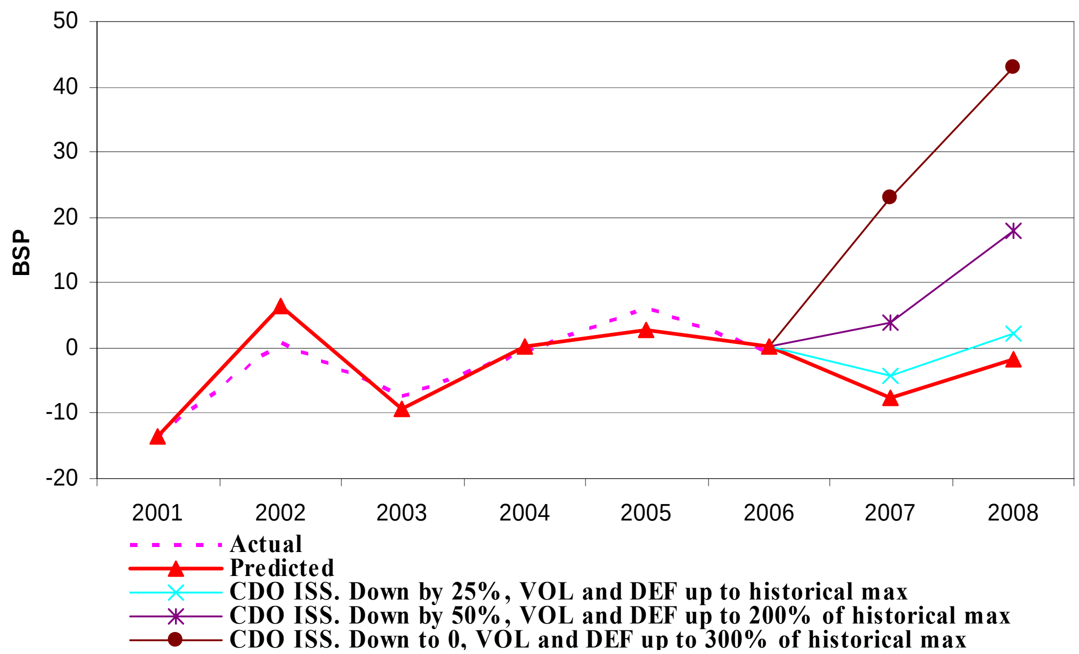


Figure 15. Actual, Predicted, and Simulated Subprime Yield Spreads (2001-2008)



APPENDIX: Table A1. Data Description

Data/Variable Name	Definition	Source	Available Period	Forecasted Period	Forecast Method
Subprime* (or CMBS Tranche) *Yield Spread	**Subprime:** Spread between the subprime yield and the 10-year constant maturity Treasury rate; **CMBS:** Spread between the CMBS AAA, AA, A, and BBB tranche yield and the LIBOR Swap	Subprime: TrueStandings Securities CMBS: JPMorgan, Markit Partners	**Subprime:** 01/1997–08/2006 **CMBS:** 08/1996–11/2007		
CMT10Y	10-year constant maturity Treasury Note rate (CMT);	Fed. Reserve Bank at St. Louis	08/1996–10/2007	11/2007–12/2008	AR(2)
SLOPE	Spread between 10-year CMT rate and the 3-month CMT		08/1996–09/2007	10/2007–12/2008	AR(1)
$\boldsymbol{VOL_{CMT}}$	10-year CMT volatility		08/1996–09/2007	10/2007–12/2008	AR(2)
$\boldsymbol{SLOPE \times VOL_{CMT}}$	Interaction between ***VOL*** with ***SLOPE***.				
DEF	Spread between the yields on long-term Aaa and Baa corporate bonds	Moody's Investors Service	08/1996–09/2007	10/2007–12/2008	AR(1)
S&P	Excess return of S&P 500 (dividend included) index over the 3-mon CMT	Datastream	08/1996–10/2007	11/2007–12/2008	AR(2)
$\boldsymbol{S\&P \times VOL_{S\&P}}$	The interaction between ***S&P500*** and its volatility				
CDO Issuance	**Subprime:** Aggregated Subprime CDO issuance; **CMBS:** 3-month weighted moving average of CRE CDO issuance, where exponential decay function is used as weighting function.	ABAlert.com	**Subprime:** 01/1997–08/2006 **CMBS:** 08/1996–12/2005	**Subprime:** 09/2006–12/2008 **CMBS:** 01/2006–12/2008	Hold the last observation value
Section Issuance	Subprime residential ABS or CMBS tranche (AAA, AA, A, or BBB) issuance (in billion dollars)	**Subprime:** Bloomberg **CMBS:** Trepp	**Subprime:** 01/1997–08/2006 **CMBS:** 08/1998–02/2007	**Subprime:** 09/2006–12/2008 **CMBS:** 03/2007–12/2008	Hold the last observation value
RATIO	Ratio of ***CDO Issuance*** to ***Section Issuance***				