Did Subjectivity Play a Role in CDO Credit Ratings?

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ABSTRACT

This paper examines two subjective components in collateralized debt obligations (CDO) credit rating practices: deviations from rating criterions and deviations from model outputs. First, for 916 CDOs issued between January 1997 and March 2007, only 1.4% of AAA ratings were consistent with the AAA rating agency default probability criterion standard, but 92.7% matched the 'AA' standard. This 'A' difference largely disappeared in April 2007, when 91.2% of the newly issued CDO AAA ratings complied with the publicized standard. Nevertheless, seasoned AAA ratings (on CDOs issued prior to April 2007) continue to follow the old AA standard. Second, beyond the subjective component in the rating standard, the rating agency made substantial 'out-of-model' adjustments to the AAA tranche size, such that the actual AAA size is on average 12% more than model output. CDOs with smaller admissible AAA portions from credit rating agency models received larger adjustments. The AAA fractions from credit rating agency models are well explained by CDO characteristics and highly correlated with a similarly designed simple Monte Carlo simulation AAA fraction, but such is not the case for the actual fraction assigned AAA ratings. This AAA adjustment is positively related to future 2008 downgrades.

In discussions regarding the causes of the ongoing financial crisis, the role of collateralized debt obligations (CDO) is frequently mentioned.[1] Most CDO notes issued prior to 2007 were AAA rated.[2] However, beginning in mid-2007 banks and investment funds began to experience large losses from CDOs and other credit derivative investments. How could AAA investments lose much of their value so quickly?

Rating agencies have been scrutinized and criticized by reporters, regulators, members of congress, investors, and even the CEOs of the CDO underwriting firms, on their role in the ongoing credit crisis (e.g., CESR (2008), BIS (2008)).[3] A central question being asked is whether credit rating agencies knowingly gave inflated CDO ratings or they truthfully provided their best credit risk assessment that turned out to be inaccurate in hindsight. Stulz (2008) argues that knowing the nature of whether if a risk was mis-assessed and the nature of the mistake, is crucial for risk management practice. While there is no shortage of opinions and commentary, there has been relatively little empirical examination of the credit rating process leading to the crisis. In this paper, we separately analyze the quantitative and the qualitative aspects of the rating process by comparing credit rating agency actual practices relative to stated criteria and direct model outputs.

There are several leading explanations for what went wrong with CDO valuations. Coval, Jurek, and Stafford (2008) show that the most senior tranches of CDOs should demand a much

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[1] Brunnermeier (2009) surveys the causes of the financial crisis and highlights the important role of CDOs and accompanying amplification mechanisms. Gorton (2008) highlights the role of securitized subprime loans in the crisis but also notes that securitization per se is not the cause of the crisis. Ashcraft and Schuermann (2008) provide details of the securitization process and its potential drawbacks. Davidson, Sanders, Wolff, and Ching (2008) elaborate on the motivation for CDO securitization. Gorton and Metrick (2009) argue that banks are exposed to large amounts of securitization debt in the repo market and that panic in the repo market caused the banking crisis.

[2] We use AAA to denote both the AAA notation by Fitch and S&P as well as the Aaa notation by Moody's. We also use default and loss interchangeably to reflect both the Expected Loss (EL) based rating approach of Moody's and Probability of Default (PD) based rating approach of S&P and Fitch.

[3] John Thain, former CEO of Merrill Lynch, says, "Part of the blame must be laid at the door of the rating agencies. There has to be some fundamental change in how structured credits are rated." (*Sunday Times*, March 9, 2008). Though his firm was one of the top underwriters of CDOs, he was not in the helm until the end of 2007.

higher risk premium than observed values.[4] Furthermore, Coval, Jurek, and Stafford (2009) demonstrate the vulnerability of commonly used CDO models. Rajan, Seru, and Vig (2009) show that the securitization process itself endogenously brings up modeling difficulty. Additionally, CDO market participants may hold unrealistic assumptions regarding key model inputs such as housing market prospect and default correlations.[5] Sanders (2008) demonstrates the unexpected and sudden increased comovement and delinquency of U.S. housing markets since 2005. Model input noise can also enter through the securitization process. For example, lax standard (Keys, Mukherjee, Seru, and Vig (2008), Mian and Sufi (2008)) or fraud (Ben-David (2008)) in mortgage origination process can inflate the collateral quality of mortgage related CDOs. Finally, rating analysts could make coding errors.[6]

Our goal is to document the potentially more flexible aspects of the CDO rating practice and we abstract from deliberating the motivation, incentive system, and market structure for CDO credit ratings. It is well-known and the SEC (2008) has verified iterative interactions between CRAs and underwriters during the rating process. CDO issuers could potentially shop among two or three CRAs, the CRAs were paid by the issuer, and only fully compensated after the underwriter in some sense received the proposed rating. SEC (2008) notes that "two rating agencies frequently used 'out-of-model' adjustments in issuing ratings." The same SEC report also reveals a rating analyst's email confession that "our SF [structured finance] rating approach is inherently flexible and subjective,

[4] Longstaff and Rajan (2008) examine CDO pricing through CDX index prices and find that the CDX index is priced such that CDO losses of 35% could occur every 763 years. The authors wrote the article prior the recent crisis and are not to our knowledge claiming the rare event hypothesis to be the rapid cause of the CDO deterioration. Nevertheless, the numbers are useful to gauge that for the rare event hypothesis to completely explain the recent crisis one might need to hold that the once in every 763 year event has just occurred.

[5] The view is articulated by Deven Sharma, President of S&P states, "S&P is not alone in having been taken by surprise by the extreme decline in the housing and mortgage markets. Virtually no one — be they homeowners, financial institutions, rating agencies, regulators, or investors — anticipated what is occurring." [Testimony of Deven Sharma President of S&P before the committee on oversight and government reform US House of Representatives, Oct. 22, 2008.]

[6] The Financial Times uncovered computer modeling error for CPDO at Moody's [Jones, Tett, and Davies (*Financial Times*, March 20, 2008)] and S&P has disclosed some limited admission of computer error [Duyn and Chung (*Financial Times*, June 13, 2008)].

while much of our written criteria is detailed and prescriptive." The SEC report seems to conclude that this aspect of the business was not pervasive, as it stops short of calling for any major policy changes. In congressional testimony on October 22, 2008 the CEOs of major CRAs largely admitted to making mistakes in assumptions and not foreseeing the financial crisis, but deny any lack of integrity in the rating process. For example, Deven Sharma, President of S&P, states, "there is no evidence of any misconduct by our analysts or that the fundamental integrity of our ratings process has been compromised. Indeed, the SEC itself concluded that it found no evidence during its examination that S&P had compromised its standards to please issuers."[7] Overall, the evidence that rating agencies acted in any improper manner seem largely limited to a few published emails in an SEC examination of over 2 million emails.[8]

In this paper we use a comprehensive CDO database to examine whether a CRA deviates away from its own stated rating criterion and direct model outputs, and if it does, what are the impacts on rating accuracy regarding future rating changes. The rating criterion refers to the default probability tables publicized by CRAs for CDO rating assignment. In the first part of the paper, we document an empirical irregularity. We find that only 1.4 percent of AAA CDOs closed between January 1997 and March 2007 met the AAA default standard. The rest fell short. We find that the shortcoming was systematic and in 92.7 percent of cases the AAA CDOs only met the AA threshold for the default probability criterion. This practice changed around April 1, 2007 when 91.2 percent of CDOs suddenly began to exactly comply with the stated default criterion. This pattern is for all CDOs first-time surveillance reports. For CDOs issued prior to April 1, 2007 their reports subsequent to April 1, 2007 continued to follow the old pattern of criterion deviations, even into the

[7] Direct quotes from testimony before U.S. House of Representatives Committee on Oversight and Government Reform on Oct 22, 2008.

[8] Probably the most well known and quoted email as paraphrased in the SEC (2008) report notes, "One analyst expressed concern that her firm's model did not capture 'half' of the deal's risk, but that 'it could be structured by cows and we would rate it.'"

end of our sample in September 2008. We use a Monte Carlo simulation approach and the Vasicek model to approximate how much difference these 'criterion deviations' would lead to in terms of AAA tranche size. The relaxation in absolute AAA default criterion typically translates into a reduced rating scenario default rate by two to six percent. While this difference is not large in raw size, it is potentially very important in the rating process as CDOs are often rated at the edge and cash flow scenario analysis results are compared to rating scenario default rate results.

In the second part of the paper we examine adjustments to direct model output which we define as the difference between the proportion of a CDO actually rated AAA and the proportion assigned as AAA in the CRA model. Adjustments can be positive or negative but we find that adjustments are mostly positive and amount to an additional 12 percent on average over the January 1997 to December 1997 sample of newly issued CDOs. Adjustments are largest for CLO and CDO^2s at 16 percent and 15 percent.

We find that a linear model can deliver an adjusted R^2 of 0.83 when regressing the AAA proportion implied by the CRA model on CDO determinants, but the same simple linear model gives an adjusted R^2 of 0.29 on the actual AAA proportion, indicating that the actual amount of AAA given in practice is difficult to explain by traditional CDO determinants. However, adjustments seem to be directly related to the original model AAA proportion. For example, when sorting by the amount of AAA in the CRA model, we find that within CDO^2s the CRA model yielded 29.2 percent AAA for the smallest quintile of model implied AAA, but the adjustment added another 47.0 percent for a total of 76.2 percent issued as AAA. In the top quintile the adjustment is essentially zero and the CDO has 81.3 percent AAA. Credit enhancements such as insurance, liquidity provisions, and overcollateralization can only explain six percent of the AAA adjustment.

Ordered probit regressions indicate that the amount of adjustment at the time of CDO issuance is positively related to future downgrades through December 2, 2008.

Finally, we examine dollar costs of the criterion deviations and downgrades. Using the Monte Carlo simulation to approximate, we find that the CDO AAA in our sample would have been issued BBB ratings on average. The average BBB spread is 2.56 percent above the average AAA spread at issuance. If CDOs were priced at the BBB spread, it would have led to approximately a 94.13 million dollar price difference per CDO or an 86.22 billion dollar value difference for the entire set of 916 CDOs in our sample. While this value difference is large, we think it is likely an understatement of the true amount of value inflation implicit in the CDOs. This is because all of these calculations are based on using the reported rating agency assumptions for the key inputs (such as correlation and underlying asset quality) in the CDO process.

Credit ratings play an increasingly important role in financial markets.[9] Our study adds to several strands of literature. First, we investigate credit rating standards, similar to Blume, Lim, and MacKinlay (1998).[10] The analysis is relevant to the burgeoning finance literature on empirical irregularities, along the line of Christie and Schultz (1994). Additionally, our empirical focus complements recent theoretical discussions [Bolton, Freixas, and Shapiro (2008), Damiano, Li, and Suen (2008), Farhi, Larner, and Tirole (2008), Mathis, McAndrews, and Rochet (2008), Skreta and Veldkamp (2009)]. Our finding of inexplicability of actual CDO AAA rating is consistent with An, Deng, and Sanders (2008). Benmelech and Dlugosz (2009) explain CDO rating structure.[11]

[9] For example, Kisgen (2006) shows the importance of credit rating in corporate decisions.

[10] In a recent analysis of bond defaults from 1997 to 2005, Cheng and Neamtiu (2009) find that rating agencies have been improving in their accuracy, timeliness, volatility post Sarbanes-Oxley Act.

[11] There is also a broader literature on securitization. DeMarzo (2005) argues that pooling and tranching can be optimal for low default correlations among collateral assets. Stulz and Johnson (1985), Leland (2007), and Brennan, Hein, and Poon (2008) show that secured debt and structured finance, respectively, can be value-adding for equity investors, arguably via rating arbitrage. Mason and Rosner (2007) discuss the potential for agency conflicts in the crisis and Bethel, Ferrell, and Hu (2008) discuss the growing litigation surrounding CDO securities.

The rest of this paper is organized as follows. Section I provides the industry background of CDO credit rating and descriptive statistics of our data. We discuss rating criterion deviation in Section II. The issue of 'out-of-model' adjustment is addressed in Section III. We provide some economic analysis of rating agency undocumented practices and future development in Section IV. Section V concludes.

I. CDO Credit Ratings

Rating agencies have a long history assessing the credit risk of corporations, municipalities, and sovereigns. By contrast, detailed documentation on CDO rating is less common. In this section, we describe the CDO rating process, methodologies, and our data summary.

A. CDO Rating Process and Methodology

A CDO rating is different from a corporate bond rating in at least three important aspects. First, there is very little public information about the CDO issuer. Preliminary ratings are assigned before the CDO even comes alive. All CDO ratings are solicited. Credit rating agencies heavily rely on collateral and structure data provided by issuers or arrangers. Second, the capital structure of a CDO is more rigid than a corporation. Firms can easily maintain financial flexibility, rendering more stable credit ratings. Hence, CDO credit ratings could be more volatile and difficult to determine in the first place. Third, there is no distinction between issue rating and issuer rating for CDOs. Each tranche is rated separately. Ratings are more critical for CDOs than corporations, as investors may not purchase these more complex CDO notes unless they have ratings. All these factors result in a more complex rating interaction between the rating agency and the issuer/arranger.

Figure 1 illustrates the rating process and timeline. The CDO issuer, or the arranger/structurer on the issuer's behalf, submits a rating request with a CDO term sheet to one or multiple rating agencies. The business manager at the CRA will first receive the rating request. Then, the request is forwarded to a rating analytical manager for preliminary evaluation. These two groups will decide whether to rate the deal. Rating agencies argue that the 'Chinese Wall' isolating the rating analyst from rating solicitor can mitigate conflicts of interest due to the issuer pay form of business model. If the CRA agrees to rate the deal, the issuer/arranger/structurer will provide more detailed information for the formal rating process. At this stage, the collateral asset pool is usually incomplete.[12] The rating analyst will conduct credit risk analysis based on projected collateral information according to collateral requirements.

Rating analysts only directly evaluate the aggregate risk of the collateral pool. The output of CDO asset analysis is a default loss distribution for the collateral pool. Subsequently, a risk measure is derivedfor each credit rating scale associated with this pool. The structurer provides a projected risk level for each tranche of the CDO. If the risk level of the tranche is lower than the rating analyst requirement for a certain rating, then such a rating can be granted to the tranche. Once the rating team is ready to release the preliminary ratings, a pre-sale report will be published on the deal. This report will be distributed to investors. Although the arranger and manager would have sent the prospectus to potential investors, the purchasing agreement would normally be made after the pre-sale report. At the closing date, investors pay the issuer for the notes at an agreed price and coupon. The CRA will release a new issue report shortly after the closing date. Note that as long as the CRA certifies the ratings, neither the pre-sale report nor the new issue report is mandatory. Many CDOs do not have either report. After closing, the CDO manager uses the proceeds raised from investors

[12] The degree of collateral completeness is related to collateral type. For example, Synthetic CDOs, or CDOs collateralized by CDS contracts, can be completed in days.

to 'ramp up' the collateral pool. The trustee oversees the operation of the CDO and keep relevant parties informed. The CRA surveillance analyst will monitor the performance of the CDO using data from the trustee and the manager. Ratings are adjusted if necessary.

Modeling tools are limited for CDO valuation. Generic CDO models are public information. Variations mainly lie in the measurement and incorporation of model inputs such as default correlation. The CDO rating platforms of the three major rating agencies build on similar methodology. S&P and Fitch use the Gaussian Copula simulation approach as discussed in the appendix. Moody's captures default correlation through its diversity score system. The output from each of CDO models is the portfolio loss rate distribution. This distribution is used to map rating default probability criterion to scenario default rate (SDR).[13]

Default probability of single obligor such as General Motors is a straightforward concept. Rating agencies assign individual corporate credit ratings according to its default probability. We define the transformation rule from continuous default probability to discrete rating scale as rating criterion. The same idea is similarly applied to CDOs by CRAs. Rating criteria are derived from each CRA's proprietary historical default database.[14] Appendix C lists AAA rating criteria which are publicly disclosed and provided in CRA spreadsheet models. CRA CDO rating tools specifically incorporate these criteria. Fitch's VECTOR, Moody's CDO ROM, and S&P's CDO Evaluator take those criteria as inputs, which are the same across CDOs. The default criteria are derived from corporate bond data. For a CDO tranche to achieve a certain credit rating, its default probability needs to be no greater than the historical default probability of corporate bonds with the same rating. The criteria only vary across maturity. These criteria are used to translate credit ratings into 'scenarios'. If a seven-year AAA default criterion is 0.3%, then the AAA scenario is expected to

[13] Fitch, Moody's, and S&P use different terminologies. SDR of S&P is equivalent to rating default rate (RDR) by Fitch and Expected Loss Rate (ELR) of Moody's.
[14] Inevitably, rating criteria diverge significantly across CRAs. However, CDO tranche ratings rarely differ.

occur only with a probability of 0.3%. Appendix C contains the AAA criterion for maturity from one to ten year from Fitch, Moody's, and S&P. The SDR is chosen so that the probability of collateral portfolio loss rate exceeding SDR is no greater than historical corporate bond default rate of the same rating. For example, the AAA rating SDR is defined as:

$$SDR\ for\ AAA\ Tranche$$

$$\equiv \arg\inf(\alpha: \Pr(collateral\ loss > \alpha) \leq AAA\ corproate\ bond\ default\ rate)$$

In other words, the SDR is the expected default loss rate once such scenario occurs. The CRA will derive a full spectrum of SDRs for each CDO collateral portfolio. Note that AAA SDR will be larger than AA SDR and so on (because the AAA historical default rate is smaller than the AA historical default rate). This rating method is illustrated in Figure 2.

For cash deals, the CDO structurer/arranger will run cash flow simulations under different default timing scenarios, including some especially stressful scenarios ("stress test"). For a given CDO tranche, the maximum portfolio default loss rate before the tranche is eroded can be derived for each cash flow scenario. The minimum of maximum loss rates the tranche can withstand under all cash flow scenarios is called a breakeven default rate (BDR):

$$BDR\ for\ AAA\ Tranche \equiv \min_{\alpha} \max_{loss\ rate} portfolio\ loss\ rate < AAA\ Tranche\ credit\ support$$

In other words, the BDR is the maximum loss rate the tranche can withstand under all cash flow scenarios. The BDRs are compared to the SDRs. As long as a tranche's BDR is greater than the SDR for a certain rating, then the tranche can be granted such a rating, because this tranche can withstand more portfolio loss than expected in the given rating scenario.[15] The above condition is key to obtaining the desired rating. Note that cash flow analysis is not necessary for synthetic CDOs.

[15] S&P recently introduced relaxation of BDR threshold.

After the initial ratings in both the presale report and the new issue report, the CRA is also paid to monitor the performance of the CDO. Coverage tests for both the interest payment and principal are conducted periodically. Test results will be released to the manager, investors, and trustee. The surveillance report is available to the public at a fee (subject to approval). When any coverage test fails, the CDO could be restructured (e.g., paying off some of the principal of the senior tranche) or some tranches could be downgraded.

The CDO credit rating approach illustrated in Figure 2 faces several challenges in implementation. First, the default loss rate histogram from Monte Carlo simulations may not be as smooth as depicted in Figure 2 Panel A. The shape of the right tail of the histogram is especially important, given that the average maturity (6.5 years) top ratings (AAA and AA) criteria are at the 0.1% order of magnitude. The result may even be sensitive to the rounding method. Second, this histogram is a simulation outcome. Unlike analytical closed-form solutions, simulation results could differ across different simulation experiments even for the same set of parameters. The simulation error may also have systematic bias, as addressed by credit rating agencies (e.g., S&P (2002)). Rating analysts may take measures to account for the bias.[16] Lastly, the simulation could be sensitive to model parameters, especially the default correlation, as the right tail becomes extremely thin.

B. Data Description

CDO databases contain asset information as well as rating performance assessment from CRAs. Our data is from one of the major CRAs with comprehensive rating input and output information. We also collect credit enhancement information such as over-collateralization (an asset-liability ratio), insurance, and liquidity facility.

[16] For example, the credit risk of low risk portfolio tends to be underestimated while the credit risk of high credit risk tends to be over estimated. CRAs may correct for such known biases to some extent.

CDO insurance could come in two forms. The first type is included in the CDO structured so that the insurance premium is paid by the CDO issuer out of asset payments. The insurance premium payment is senior to AAA tranches. The second type is bought by CDO investors from secondary market. The premium will be paid by the CDO investor directly. The latter type of insurance is similar to a credit default swap (CDS). Only the first type of insurance matters to CDO ratings as it is part of the structure (credit enhancement). We construct our CDO insurance data in the following way. First, our CDO data from the CRA rating database include an item called "Bond Insurance Provided By," which refers to the name of the insurer. To certify data accuracy, we verify with CRA rating updates. Since June 2008, all CDO insurers, most notably, Ambac and MBIA, were downgraded. Each time the CRAs downgrade an insurer, they also adjust the ratings of the CDO tranches insured by the insurer. All CDO insurers have been downgraded multiple times. We augment the original insurance information in the deal structure with the ratings affected by insurer downgrades to obtain a full set of insured CDO tranches.

We group CDOs by collateral asset type. Collateralized bond obligations (CBO) are securitized with bonds. Collateralized loan obligations (CLO) are securitized with loans. CDOs of ABS are securitized with asset-backed securities (mostly mortgage-backed securities). CDO^2 are securitized with existing CDO notes. We further separate our data into two sets: the first report available and continued reports. Those columns are labeled "first" and "continued" respectively. For the continued reports we gather data each December.[17] Table I shows that our sample is most represented by CLOs (393 out of 916) and ABS CDOs (373 out of 916). CBOs (96 out of 916) and CDO^2 (54 out of 916) consist of a smaller portion.

[17] If December data is not available, then we collect data for November, otherwise January of the next year, then October, then February of the next year, and so on.

The average collateral rating is BB+ in the overall sample. However, there is a wide dispersion among different CDO types. CLOs have the lowest collateral rating, B+, then CBOs with BB- collaterals. The structured finance CDOs have much higher rated collaterals. ABS CDOs have collateral ratings that are A-, while CDO^2s on average have BBB collateral rating. The correlation and maturity of the collateral also display similar patterns. CBOs and CLOs usually have shorter maturity with lower default correlation. ABS CDOs and CDO^2s have longer maturity and larger default correlation. Moreover, CBOs and CLOs are smaller than ABS CDOs and CDO^2s in size. CLOs have the largest number of collateral assets, while CDO^2s have the fewest number of collateral assets. Although on average 14% of our sample CDOs are synthetic, no data on synthetic CLOs is available from the CRA database.

Notwithstanding the variation in CDO compositions, the AAA portion of the CDOs is highly consistent across collateral types. The average CDO has 75% rated AAA, counting the super senior tranches as AAA. This portion ranges from 72% for CDO^2s, to 73% for CBOs and CLOs, to 80% for ABS CDOs.

A surprising finding is that the overcollateralization ratio is often below one, especially for CBOs and CLOs. This result could be due to price premium for the bonds and loans (if their coupon rates are high) and discount for ABS CDOs and CDO^2s (the secondary market price of those collaterals could be below par). Only a small fraction, 6%, of the sample CDOs is wrapped. In percentage terms, CBOs are more often insured than other CDOs. Many CDOs, 23% of the sample, have liquidity facilities such as a revolving line of credit.

Panel A of Figure 3 shows the distribution of corporate debentures from the Fixed Income Securities Database over the same 1998 to 2007 period as our original CDO ratings. The top rating of AAA counts for 11.6%, non-AAA investment grade for 63.8% (13.7% AA, 29.1% A, and 21.0%

BBB), and below investment grade 24.6%. Nevertheless, over the same time period, the rating distribution for CDOs paints a starkly different picture: 81.4% AAA, 17.1% non-AAA investment grade (8.1% AA, 5.4% A, and 3.7% BBB), 1.5% below investment grade. This highlights the prevalence of AAA CDO ratings in contrast to corporate AAA ratings.

Historical evidence shows that corporate AAA ratings are very stable. About88% of AAAs maintain their AAA status over a one year horizon (Moody's (2009)). CDOs are financial innovations with a relatively short record. At their early stage, CDO AAAs were as stable as corporate AAAs (S&P (2008)). However, the performance abruptly stopped in 2007 and 2008. We collect CDO downgrades up until December 2, 2008 and examine subsequent CDO ratings for the AAA CDO tranche. As shown in Figure 3 Panel B, only 17.3% of the CDO's original AAA ratings were re-affirmed in 2008, while 25.0% were downgraded to CC (17.8% CCC, 7.7% D). These observations of a high initial fraction of AAA and overwhelming downgrades motivate our analysis. Among other factors, these downgrades could be due to: misstated inputs, false correlation assumptions, a misguided model, a truly extreme systematic event, or too favorable of assumptions at the time of issue. We investigate this last explanation but want to be clear that these explanations are, for the most part, not mutually exclusive and may work in tandem.

II. CDO Credit Rating Criterion: Actual versus Publicized

A. The Unnoticeable Gaining in Small Numbers

Credit ratings are termed 'global scale' ratings and rating agencies have emphasized that CDO ratings were structured to have similar information quality and probability of default as corporate bond ratings.

The rating criterion is a look-up table for 'idealized default probability' with rating as one dimension (such as AAA, AA+, AA, …) and maturity as another dimension usually running from 1

year to 10 years (Fitch and Moody's) or 30 years (S&P). For example, the 10-year cumulative default rate for CDO A rating is expected to be 1.85% according to Fitch Criterion, 1.20% according to Moody's Criterion, and 2.72% according to S&P Criterion, as shown in Appendix C. These criteria are built into the rating tools such as CDOROM of Moody's, CDO Evaluator of S&P, and VECTOR of Fitch. To maintain integrity and parity with corporate bond ratings, these ratings are the same across all credit instruments. This table of idealized default probabilities has been the same going back until at least 2002 (Fitch (2006), Moody's (2003), S&P (2002)).

Our data has the actual rating default probability criterion for each of the CDOs in our database for one of the major CRAs. This vantage allows us to compare the actual criterion to the criterion published in CRA's criterion book, which is publicly implemented by CDO professionals. At first, examining the criterion was not the most obvious or promising approach for us to gain insights on CDO ratings. Most CDOs have non-integer maturity. The default probabilities for top ratings such as AAA and AA are so small that they are hardly alarming.

Figure 4 plots the simple difference between the actual AAA default and the publicized default rate criterion for AAA rating. We call this difference '*criterion deviation*' (actual criterion minus publicized criterion). The deviations are illustrated in chronicle order according to CDO deal closing time from January 1997 to December 2007. In absolute terms the number seems small, meaning that the probability of default for an AAA CDO is two tenths of one percent more than the publicized criterion.

Second, only three CDOs appear to meet the criteria prior to 2007, however, beginning in roughly April 2007 the deviations largely disappear. Panel B of Figure 4 zooms in on 2007 and show that there are relatively few deviations after April 1, 2007. In terms of timing and when the rating criteria seemed to change, it is difficult to pinpoint as we only have data from the first published

rating agency report. The deal may have been structured one or two months in advance. Differences in the length of time between when the deal was actually structured and preliminarily rated and when the surveillance report appears can vary considerably and could potentially explain why twelve CDOs issued after April 2007 continue to look similar to CDOs reports prior to April.[18]

Although only three CDOs appear to have no deviations prior to 2007, the magnitude of these deviations seems to be related to collateral asset type. However, it is important to note that the criterion deviation in Figure 4 is an approximation since it is not adjusted by differences in maturity. However, default criterion is given according to maturity in the criterion book.

We first plot lines for the publicized AAA rating criteria as a dark solid line against maturity at closing time (from the first surveillance report) in Panel A of Figure 5. The publicized criteria are smoothly distributed on a concave curve as expected. CDOs issued prior to April 2007 are shown as a light yellow triangle. Consistent with Figure 4, before April 1, 2007, most of the actual default criteria lie on another distinctive curve, slightly and seemingly related to the shape of the publicized criteria. A few CDOs seem to form a straight line, independent of the maturity. CDOs with surveillance reports after April 1, 2007 are in dark purple squares and mostly overlap with publicized criteria. The exception is about a dozen CDOs that fall on the line or curve with those issued prior to April 2007.

These deviations, may seem small and innocuous at first sight. In order to gauge the economic impact, we also plot dashed and dotted lines for the publicized criteria for AA+ rating and AA rating in Panel A. Except for a few CDOs with long maturity which meet AA+ criteria, most CDO AAA ratings only meet the AA rating criterion. To summarize this finding, we re-assign credit ratings to the CDO AAAs ratings using publicized rating criteria knowing the actual default criterion used. The results are shown in Panel B of Figure 5. For CDOs issued before April 1, 2007, 1.4% of

[18] We do not have any data available on when the CDO ratings were initiated.

AAAs comply with the publicized AAA criterion, 4.7% comply with the publicized AA+ criterion, and 92.7% comply with the publicized AA criterion. The CDOs issued after April 1, 2007 are very different: 91.2% actual AAA comply with the publicized AAA criterion, 0.7% with AA+ criterion, and 6.8% with AA criterion.

To summarize, the CRA appears to have used different criteria before and after April 1, 2007 as actual AAA default rates from the CRA model are significantly higher than those publicized as the maximum AAA default rates in the criterion book before April 1, 2007. Criterion compliance is significantly better after April 1, 2007.

So far we have only examined the default rating criterion in the first surveillance report after issue whereas we also have subsequent year end surveillance reports. To further understand the nature of the criterion deviation, we further plot the AAA rating criteria for all CDOs that are still in existence from April 1, 2007 to September 30, 2008. We separate these post April 2007 reports into those where the first surveillance report for the CDO was issued prior to (yellow triangle) or after (purple square) April 1, 2007. The finding as depicted in Panel C of Figure 5 demonstrates that the CDOs issued before April 1, 2007 under the lax criterion continue to use the same criterion after April 1, 2007, although most CDOs with initial surveillance reports after April 1, 2007 stringently follow the publicized criterion. If the criterion deviation were a simple model error one would think that it would shift for all CDOs beginning around April 2007. It is hard to understand how a model can generate two different default thresholds without some subjectivity in the process.

We focus on the AAA rating as AAA rated issuance counts for 81.4% of the rated tranches. If actual AAA default rates mostly follow publicized AA criterion for CDOs issued before April 1, 2007, other ratings may be impacted accordingly. From a theoretical standpoint, all 19 rating scales (from AAA to CCC-) need to be placed in order on the default loss distribution. The deviation

pattern may be different for different ratings. We find from Figure 6 that BBB+ rating seems to be a 'crossing point': the actual BBB+ criterion matches well with publicized BBB+ criterion even for CDOs issued before April 1, 2007, except for the 'one size fit all' criterion independent of maturity and a few others. Although Figure 6 only displays four ratings, A-, BBB+, BBB, and CCC, our investigation of overall ratings shows that indeed there is a uniform pattern: ratings higher than BBB+ are more lax in reality, ratings below BBB+ are more restrictive in reality. This result is further shown in Figure 7 with all ratings for a typical 7-year CDO. In slicing the CDO default loss distribution, the publicized criteria are more dispersedly distributed than actual criteria in use. Since only 1.5% of CDOs had below an investment grade rating (BB+ and below), this practice likely works to the benefit of the underwriters.

B. Consequences of the Criterion Deviation

It remains unknown the direct incentives and benefits of this criterion deviation. We are unable to find any documentation of this deviation on any of the credit rating websites. Although in recent testimony before congress the Moody's CEO did indicate a tightening of standards for MBS securities in April 2007 and this time was associated with bad news regarding mortgage securities.[19] The exact motivation may be hard to pin down and beyond the scope of this study. Below we attempt to measure potential consequences in a straightforward way.

A more lax default criterion naturally allows a higher default probability for a given rating, in the language of CRA CDO rating approach, a lower SDR. We cannot directly investigate this conjecture as we do not know the exact model used by the CRA. However, we can use alternative models, such as the Vasicek model which has a closed form solution, or the Monte Carlo Simulation

[19] In discussing MBS securities, Raymond McDaniel states, "A first, limited set of rating actions were taken in November 2006, with broader actions beginning in April 2007," [Direct quotes from testimony before U.S. House of Representatives Committee on Oversight and Government Reform on Oct 22, 2008].

approach which is similar to the CRA model, to approximate the impact due to a criterion deviation. The advantage of the Vasicek model is its tractability and efficiency, at the cost of not fully capturing CDO structure. The advantage of Monte Carlo Simulation is its similarity to the CRA approach, though it only uses information on the average characteristics (such as asset quality and correlation) rather than detailed structure information.

The effects of criterion deviation on SDR are described in Table II for all CDOs issued prior to April 1, 2007. In Panel A, we report the average decrease of the SDR for the entire sample of CDOs issued with a criterion deviation is 5.74% with the Vasicek model and 3.18% with the Monte Carlo simulation.

In unreported results, we find that the range of the effect is from -1.0% to 6.2% according to Monte Carlo Simulation and 0.1% to 13.2% according to Vasicek model. To further see what types of CDOs the criterion deviation may most affect, we further stratify the sample by collateral credit rating in Panel B, collateral maturity in Panel C, and default correlation in Panel D. One may find the effects rather small as the average SDR is about 37%. However, a 3% reduction in SDR can be critical in practice when the only condition for granting the rating or not is to have a SDR smaller than breakeven default rate (BDR). If the CDO underwriter structures the CDO so that the condition is barely satisfied (e.g., BDR-SDR<2%), then the change in the SDR would lead to easier rating targeting, especially for the AAA rating.

C. Other Changes around April 1, 2007

If the CRA were to make a strategic change over CDO credit ratings around April 1, 2007, its decision might go beyond adjusting rating criterion. A key parameter to CDO rating and the only free parameter for the CRA is default correlation. In Figure 8, we show default correlation across

issuance date for each type of CDOs. CLOs, which are the most active CDOs after April 1, 2007, seem to experience an increase in default correlation. CLOs issued after April 1, 2007 may be different from CLOs issued before April 1, 2007. To evaluate this possibility, we match each new CLO with a seasoned CLO issued before April 1, 2007 on data reporting time (after April 1, 2007), collateral pool size, maturity, and rating. As shown in Figure 9 Panel A, default correlation of the new CLOs is higher than the matched seasoned CLO. Moreover, Panel B of Figure 9 shows that the average default correlation is higher after April 1, 2007 for each CDO type than before April 1, 2007 with the same reporting time after April 1, 2007, though the difference is only small for ABS CDOs. It would be difficult to fully control for unobserved variables leading to a shift in correlations. Thus, we only document this shift in CLO correlations but leave it to future work to more fully understand the reason for this increase in CLO correlations after April 2007.

In sum, we have shown that most CDO AAAs only comply with the AA criterion before April 1, 2007. Even after April 2007, CDOs issued before this point continue to use the old criterion. The magnitude of the deviation might be important for a CDO that was structured with a break-even default rate within striking distance of the scenario default rate, the so-called "rating at the edge" practice (Brunnermeier (2009)).

III. Adjustment for Tranche Rating

For a generic credit portfolio, the amount admissible for AAA rating is 1−SDR if subordination is the only credit support.[20] However, the legal structure of the CDO, such as bankruptcy remoteness, cash flow waterfall for both the interest and principal payments, and senior tranche holders control rights over liquidation, makes the CDO AAA tranche safer than AAA tranche in plain vanilla securitization structure.

[20] This is particularly the case for synthetic CDOs as there is no cash flow analysis.

The order to obtain the desired rating, the underwriter/arranger/structurer can boost the credit quality of certain tranches with other credit enhancers. First, the underwriter may be able to purchase collaterals at discount prices, so that the total asset value of the CDO will exceed the total liabilities. This overcollateralization will likely raise the creditworthiness of all CDO tranches.[21] Second, the structure of the CDO may include insurance from an outside insurer ('wrap') for certain (senior) tranches, essentially making them risk-free by transferring the credit risk to the insurer. Furthermore, the underwriter may also bring in a revolving line of credit, a put option, or swap agreement to attenuate liquidity concerns. These liquidity facilities will improve the CDO's resilience against market stress.

The benefits of the above credit enhancers are relatively easy to measure. The credit rating agencies also consider qualitative measures such as manager experience and skills, surveillance quality, and counterparty risk. The critical condition for a tranche to receive the desired rating is to have a scenario default rate (SDR) smaller than the breakeven default rate (BDR). SDR is determined by the collateral asset portfolio. For a given portfolio, SDR is fixed. However, BDR can be flexibly managed by the underwriter, by both quantitative and qualitative credit enhancers. The actual AAA fraction is very likely to be different (mostly higher than) from 1−SDR. We define 1−SDR as the CRA model fraction. The difference between model fraction and actual rated tranche size is called 'adjustment'. In this section, we document the magnitude of the adjustment, stylized features of the adjustment, and see if the adjustment at the time of issue can bear any relation to subsequent CDO downgrades.

A. CRA model and AAA Adjustment

[21] Another related type of credit enhancement is excess spread: higher coupon from assets than liabilities, but we do not have the coupon data for the assets.

Panel A of Figure 10 examines the AAA assigned by the credit rating agency model from AAA SDR on the x-axis as compared to that of a simple Monte Carlo simulation which just uses the average asset quality characteristics as reported by the rating agency. Because our simulation uses a constant recovery rate of 40 percent, the maximum loss rate for the entire CDO is sixty percent and the minimum amount of AAA from our simple simulation is 40 percent. Interestingly, the AAA assigned by the simple simulation seems to correlate quite well with the CRA model. The figure shows that on average most CDOs fall to the right of the 45 degree line meaning that the credit rating agency model gives out a larger fraction of AAA than our simple simulation. We want to be clear that the simple simulation is being used as a comparative benchmark and not to make statements about the appropriate amount of AAA.

Panel A of Table III shows that over the whole period for the 916 CDOs on the first report after issue, the Monte Carlo simulation yields 60 percent AAA and the credit rating agency gives 63 percent. Using the same inputs, the Vasicek model gives only 45 percent AAA. The differences between the Vasicek and the simulation and the CRA model are largest for CBOs and CLOs. As shown in Panel B of Table III, the Vasicek model has a simple correlation of only 0.43 with the rating agency model as compared to 0.83 between the CRA model and our Monte Carlo simulation, indicating that our Monte Carlo exercise is a reasonable approximation for the CRA agency model.

As shown in Panel A, the actual AAA on average after issuance, is 73 percent. This leads to an adjustment of 10 percent as the CRA model calls for 63 percent AAA on average. If we treat unrated super senior tranche as AAA rated, the adjustment accounts for an extra 12 percent AAA. The adjustment is smallest for ABS CDOs (8 percent) and CBOs (10 percent), and largest for CDO^2s (15 percent) and CLOs (16 percent).

Panel B of Figure 10 plots the actual AAA given and the AAA from the model. One can see that the adjustment varies widely across CDOs. Most of the CDOs are above the line, indicating that most but not all of the adjustments are positive. Panel B of Table III shows a low correlation of 0.26 between the CRA model and actual AAA.

B. Features of the Adjustment

We seek to first understand the systematic nature of the fraction rated AAA under the Vasicek, Monte Carlo Simulation, and the credit rating agency model and then to compare the fit relative to what is actually rated AAA. Since modeling is inherently non-linear, we do not expect a linear model to capture all the variance, but it does give a gauge for the systematic nature of the process. The average correlation and rating of the underlying collateral are key inputs into any model. Hence, the regression is simply a mechanical unwinding of the underlying model.[22] Table IV shows an adjusted R^2 of 0.96 for the Vasicek model, 0.94 for our simple Monte Carlo simulation, and 0.83 for the CRA agency model. Interestingly, this R^2 drops to only 0.29 when looking at the amount rated AAA on the first report after the issue. This adjusted R^2 drops further to only 0.18 for the continuing ratings though continuing ratings under the CRA model is 0.87. This highlights the importance of the AAA adjustment and suggests that its variation is not systemically explained by traditional CDO determinants.

To gather how the AAA adjustment may vary across CDOs, we first sort each type of CDO at issuance into five groups based on the amount of AAA specified by the CRA model. Figure 11 shows a monotonic pattern that the AAA adjustment is largest in CDOs that receive the lowest

[22] This is reflected in the unrealistically large t-stats. This is to be expected since the left hand side of the regression is a functional form of many of the right hand side variables.

fraction of AAA as implied by the CRA model. For all types of CDOs, the adjustment is more than an additional 20 percent AAA in the lowest quintile. For the lowest quintile of CDO^2s, it amounts to an additional 47 percent AAA. CDO^2s without the adjustment in the lowest quintile would have only received 29 percent AAA without the additional 47 percent AAA enabling a total AAA rating for 76 percent of the CDO. In most of the groups there is an almost monotonic decrease in the amount of AAA issued as the CRA model AAA becomes larger. Average adjustments are slightly negative for the top quintile of CBOs and in the top two quintiles of ABS CDOs.

To understand the driver of this adjustment, we regress the AAA adjustment on variables that are reported to be related to it. Overcollateralization, insurance, and liquidity are major reasons for an adjustment. Surprisingly, all three variables can only explain six percent of the adjustment, as shown in Table V. Overcollateralization and liquidity also enter with the opposite sign, suggesting that overcollateralizing the CDO and liquidity provisions would lead to less, not more, AAA. In the second specification we include the CRA AAA and here the variable enters with a strong negative coefficient and the adjusted R^2 of the model jumps to 0.40. Adding the amount of AAA predicted from the Vasicek and Monte Carlo model does little to explain the adjustment. Dummies for the type of CDO (with CBOs as the base case) show that ABS and CDO^2s receive more adjustments. Synthetic CDOs receive relatively less adjustments. The right hand side of the table replicates the analysis using the adjustment that treats the unrated super senior tranche as part of the total AAA. Overall, the results are similar and again show that less AAA from the CRA model is associated with a very positive adjustment.

We must note that our analysis cannot rule out an unknown omitted variable that is highly correlated with the amount AAA from the CRA model. Although all CDO insurers and most liquidity providers have been downgraded and affected CDOs have been identified, our data on

credit enhancement such as insurance and liquidity may not cover all CRA considerations. For example, manager quality is often emphasized by CRAs, it is possible that manager skill can significantly substitute for asset quality. Nevertheless, if this unobserved CDO factor plays such a crucial role in the rating process, then it is difficult to understand why so much effort is taken in the modeling stage and what the exact role for the CRA model is.

C. The Adjustment and Future Downgrades

If the adjustment was for good economic reason and the CDOs were structured optimally, then the adjustment should make all AAAs equal in credit quality. Therefore, the adjustment could be a positive signal. However, if the adjustment was simply a way to get more AAA, then the AAA adjustment can be a negative signal. In this sub-section we analyze the predictive power of this adjustment.

We first sort each of our four CDO types into three groups based on the AAA adjustment at time of rating. As shown in Table VI, in each of the four groups there is a higher proportion of downgrades in CDOs which initially were in the top quartile of adjustments, though the difference is only significant for ABS CDOs. In CLOs, there has only been one minor downgrade so far. For this reason, we exclude CLOs from our regression analysis.

Panel A of Table VIII uses an ordered probit to predict downgrades as of December 2, 2008. The AAA adjustment is a significant predictor of the magnitude of 2008 downgrades in spite of controlling for the type of CDO, whether the CDO was synthetic. AAA tranches with positive adjustment are more likely to be downgraded. The odds ratios range from 8.9 to 69.3. The inclusion of overcollateralization, insurance, and liquidity does not change the positive relation between the adjustment and the magnitude of 2008 downgrades.

In Panel B we use logit rather than ordered logit and hence ignore the magnitude of the downgrade but treat large and small downgrades the same. Although the t-stat weakens slightly, AAA adjustments are strongly related to future occurrences of downgrade. On the right side of Panel B we use OLS regressions for robustness and find similar results. Overall, the result is rather robust that CDOs issued with large AAA adjustments have larger subsequent downgrades.

IV. Discussion on Implications

In our empirical analysis, we identified two little known practices in the CDO credit rating process: criterion deviation and 'out-of-model' adjustment. In this section we explore the potential costs to CDO investors resulting from imperfect understanding of CRA rating information content. Additionally, we provide our views on CLOs, which seemed particularly robust in the downgrading wave in 2008.

A. Valuation Effect from Criterion Deviations and Adjustments

We first focus on criterion deviation. Without imposing an extra assumption, the only valuation effect due to CRA practice is on the rating criterion deviation (mostly moving AA to AAA) or the adjustment. Doing so requires a model as we do not know the exact model for the CRA to derive the SDR, so we apply the Monte Carlo Simulation and Vasicek model to find the resulting SDR difference. We re-rate the CDO using Monte Carlo Simulation or the Vasicek model for the given structure of the CDO. If the publicized criterion only allows 60% AAA but 75% is given, the resulting credit rating could be BBB for the entire tranche, rather than having part of the tranche valued as AAA and part as AA. We rate and re-value the entire AAA tranche.

We first find the rating for each of the AAA tranches of the CDOs in our sample, and then we calculate the value difference between what the model assigns and what the value of the AAA

tranche is. As shown in Table VIII, according to the Monte Carlo Simulation, the average rating across collateral type is BBB as shown in Panel A, resulting in $94.13 billion value inflation over our sample of 916 CDOs, 20% of the AAA tranche or 15% of the total CDO value. The value inflation is slightly bigger for ABS CDOs than other CDOs. The overall effects are not significantly different before and after April 2007. The results from the Vasicek model are different from the Monte Carlo Simulation. Specifically, the Vasicek model assigns significantly higher ratings (AA+/AA) to ABS CDOs and CDO^2s than Monte Carlo Simulation (BBB/BBB+). However, Hanson, Pesaran, and Schuermann (2008) show that the Vasicek model underestimates portfolio credit risk hence it gives higher ratings for high correlation portfolios.[23] The simulation approach is used by all major CRAs as well as professionals.

B. CLO Rating Prospect

In our sample of 916 CDOs, 393 are CLOs, but only one CLO AAA was downgraded to AA in 2005. Even in the entire CRA database of 5499 CDOs or other similar rated credit products (many of which we do not have asset data to be included in our analysis), such as credit-linked notes, only three were CLOs that were downgraded. Moreover, no CLOs are even on the CRA's watch list for potential downgrade (rating watch negative, RWN). There are several ways to understand this CLO rating robustness. First, unlike ABS CDOs and CDO^2s which experienced widespread downgrade in 2008 after the burst of the credit crisis, CLOs are not directly related to the subprime mortgage market therefore may be fundamentally different. Second, loan data is less readily available, especially for synthetic CLOs. Hence, CRAs may have limited information to update the ratings.

[23] Our comparative analysis of the application of Vasicek model to CDO valuation also reveals bad behavior for the high correlation (about 0.30) cases.

Lastly, it is possible that a CRA's capacity constraint requires it to prioritize, delaying the downgrading of CLOs.[24]

Nevertheless, CLOs in our sample have the largest 'out-of-model' adjustment, as shown in Table IV, on average 16% for the AAA tranche. In addition, for those issued prior to April 2007, they are also subject to a criterion deviation. Hence, we believe that CRAs are merely delaying the eventual downgrading of CLOs.

V. Conclusion

Using CDO data available from a major credit rating agency (CRA), we show that the rating criterion was systematically deviated from before April 1, 2007. Thereafter, it switched for most of the newly issued CDOs but not the existing CDOs. We also document substantial "out-of-model" adjustments that amount to an additional 0.12 percent AAA threshold. CDOs with lower proportions of AAA implied by the CRA model received higher adjustments. While the CRA model seems to correlate fairly well with a simple simulation approach and with CDO rating determinants, the final AAA proportion is not easily explained by these determinants or by data on CDO insurance. The adjustments at time of issue are positive predictors of 2008 defaults, indicating that they were not helpful in practice.

Our results have important implications for regulators and investors. There has been some recent movement to blame modeling and make the rating process more qualitative and less quantitative. Our results indicate that the qualitative aspects of the CDO rating were harmful and it is unclear why those aspects would be more helpful in the future. It would seem sensible to make key inputs and outputs to the rating process available to the public to increase transparency. While

[24] As of our writing in March, 2009, the media has reported downgrading consideration for CLOs by CRAs, e.g., "Downgrading of CLOs Looms" by Michael Aneiro and Mark Brown in *Wall Street Journal* on March 5, 2009. Moody's started downgrading non-AAA ratings of CLOs on March 16, 2009.

we help answer part of the question, it is important to note that our study is not meant to be interpreted as a comprehensive analysis of what caused CDOs to fail so quickly. In addition to the factors in this paper, we find it quite likely that other effects are at work and may actually have interesting connections with the subjective components in the rating process. We hope to see future empirical work to more fully investigate causes of the CDO boom and bust.

Appendix: Portfolio Credit Risk Analysis

The appendix provides a brief introduction about the Vasicek portfolio credit risk model and the Gaussian Copula Monte Carlo Simulation approach. More detailed explanations can be found in Duffie and Garleanu (2001) or Duffie and Singleton (2003).

A. Vasicek Model (Granular Portfolio Approach)

The contingent claim model of Merton (1974) provides an elegant way to calculate single obligor default probability. Define default as firm asset value V drops below a threshold X, then default probability at time T is

$$p_T = \Pr(V_T \leq X | V_0 > X)$$

Assume asset value follows a geometric Brownian motion

$$dV_t = \mu V_t dt + \sigma V_t dW$$

Then the probability of default can be solved analytically

$$p_T = N\left(-\frac{\ln\left(\frac{V_0}{X}\right) + \left(\mu - \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}} \right)$$

where N(•) is the cumulative normal probability function.

Vasicek (1987) applies the Merton model to credit portfolio. In doing so, the portfolio is assumed to be granular in the sense that each individual asset has homogeneous effects on the portfolio risk profile. Subsequently the Law of Large Numbers (LLN) can be applied to derive a closed form solution for portfolio default probability. Specifically, if each individual default probability is derived from the Merton model:

$$p_i = N(-c_i) \equiv p$$

and each individual stochastic variable can be decomposed as follows:

$$W_i = \rho X + \sqrt{1-\rho^2} Z_i$$

where Z_i and Z_j are independent for any $i \neq j$. Then, for a portfolio with N assets, the cumulative probability of portfolio loss rate not exceeding α is

$$F_N(\alpha) = \sum_{k=0}^{[\alpha N]} P_k$$

where P_k is the probability of k defaults. For a granular portfolio, Vasicek shows that the portfolio default probability is

$$F_\infty(\alpha) = N\left(\sqrt{\frac{1-\rho}{\rho}}\, N^{-1}(\alpha) - \sqrt{\frac{1}{\rho}}\, N^{-1}(p)\right)$$

The above formula can be flexibly applied to CDO valuation. For example, when we fix α, we can find the default probability $F_\infty(\alpha)$. We can also back α given $F_\infty(\alpha)$.

B. Monte Carlo Simulation (Gaussian Copula Approach)

The key to CDO valuation is default correlation. A high correlation collateral asset portfolio will have more clustered defaults. In such a case, the benefit of portfolio diversification is limited. Senior tranches and junior tranches will have similar cash flow streams. An intuitive way to calculate default correlation is to first model the default process. Let X_i be the fundamental determinant of default for obligor *i*, so that the default probability of obligor *i* is:

$$p_i = F(X_i)$$

If we can model the dynamics of X_i and default function $F(\bullet)$, then we can estimate the default correlation between any two obligors *i* and *j*:

$$\rho_{ij} = \frac{Cov(p_i, p_j) - Var(p_i) - Var(p_j)}{\sqrt{Var(p_i)Var(p_j)}} = \frac{p_{ij} - p_i - p_j}{\sqrt{p_i(1-p_i)p_j(1-p_j)}}$$

This structural approach is economically sensible. The Vasicek model discussed in the previous section is a special case when the fundamental variables can be decomposed into a common factor and a residual term.

However, defaults are rare and irreversible events. Historical data is sparse. Modeling default time is challenging as it is a point process. Consequently, deriving default correlation from fundamental default drivers can be inaccurate. Compared to the above structural approach, a

reduced approach is to directly impose correlation structure on default probability, then back out individual default time using a copula function:

$$C_\rho(p_i, p_j) = F_\rho\left(F^{-1}(p_i), F^{-1}(p_j)\right)$$

The above approach can be used to simulate joint default probability first then determine individual default time. We use this approach for our Monte Carlo Simulation practice.

For a CDO portfolio of N assets, let τ_i be the default time and T_i the maturity for obligor i and $p(\tau_i < T_i) = p_i$ be the default probability. Instead of building the default correlation matrix from individual asset fundamentals, we assume the default correlation follows:

$$\mathrm{P} = \begin{bmatrix} 1 & \cdots & \rho \\ \vdots & \ddots & \vdots \\ \rho & \cdots & 1 \end{bmatrix}$$

So the diagonal elements are all 1 and ρ for other element, i.e., all pair-wise correlations are ρ. We draw N independent random numbers from a standard normal distribution. We transform these N independent random numbers into N correlated random numbers using the Cholesky decomposition of P. Those N correlated random numbers are transformed into realized default time using cumulative standard normal (Gaussian Copula) density function, subsequently converted into a default time using the expected default probability. After the default time is determined, the cash flow of the entire portfolio as well as for different tranches can be calculated straightforwardly. This simulation is repeated many times (100,000 runs take about 210 seconds).

C. CDO Default Probability Rating Criterion for AAA

	Maturity in Years									
All In percent	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Fitch Criterion	0.00	0.00	0.01	0.02	0.03	0.05	0.08	0.11	0.15	0.19
Moody's Criterion	0.0001	0.0002	0.0007	0.0018	0.0029	0.0040	0.0052	0.0066	0.0082	0.0100
S&P Criterion	0.000	0.009	0.030	0.065	0.118	0.190	0.285	0.405	0.552	0.728

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Figure 1. CDO Credit Rating Timeline and Sample Construction. This graph demonstrates the CDO credit rating process and our data construction. The CDO note issuer, or the arranger/underwriter on behalf of the issuer, initiates the rating process. After receiving the rating request and the CDO term sheet, the credit rating agency (CRA) decides whether to rate the deal or not. If the CRA agrees to rate the deal, the issuer then supplies more detailed deal information and collateral guidelines. Credit rating analysts conduct analysis and communicate the rating outcome with the CDO arranger who may withdraw the rating request at any time with a cancellation fee. Once the CRA and CDO arranger agree on the preliminary ratings, the CRA releases a presale report which can be distributed to potential CDO investors and other relevant parties. Subsequently, the CRA releases a new issue report with official ratings shortly after the CDO closing date, on which investors purchase the CDO notes. (Neither the pre-sale report nor the new issue report is mandatory.) After the deal is closed, the CDO manager uses the proceeds from investors to purchase collateral assets and complete the portfolio during the "ramp up" period. After the completion of the ramp-up, the trustee will be informed of the collateral changes and distribute the trustee reports periodically. The CRA will use the current information to monitor the CDO performance and take necessary rating actions. Our data comes from the CRA's surveillance reports, including the first report for the CDO (starting January 2002), every December report (or neighboring month if unavailable), and the latest report as of September 2008. The data covers CDO collateral asset characteristics as well as the CRA's credit risk assessment. Other deal information and rating history data comes from the CRA CDO rating database and SDC Platinum.

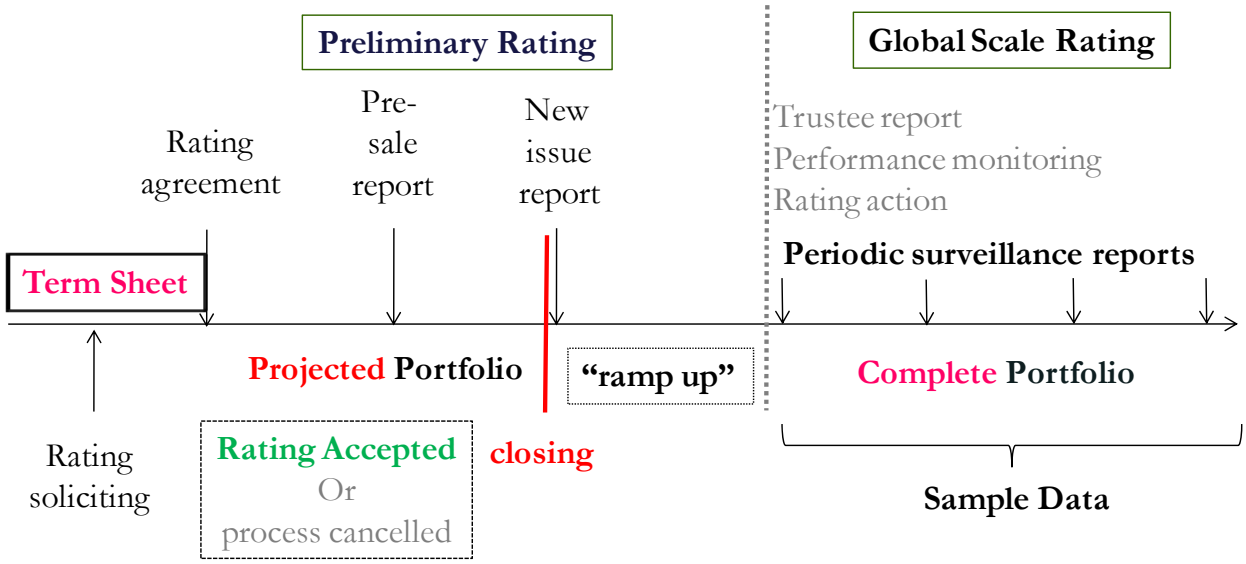


Figure 2. CDO Credit Rating Approach. This figure illustrates the CDO rating approach commonly used by major CRAs. Using CDO collateral asset information, the CRA first simulates portfolio loss rates and draws the histogram. This histogram is then used in the second step to map the "idealized default rate" into a scenario default rate according to CRA rating criterion. The first 1% of the histogram probability is zoomed in to show the high quality ratings such as AAA and AA. The idealized default probability for AAA scenario, say, *y*% according to CRA criterion (from the historical AAA corporate bond default rate), is mapped to a scenario default rate *x*% using the expected portfolio loss histogram, so that the shaded area equals y%. If a CDO tranche can withstand at least *x*% portfolio loss in the cash flow scenarios then an AAA rating can be granted.

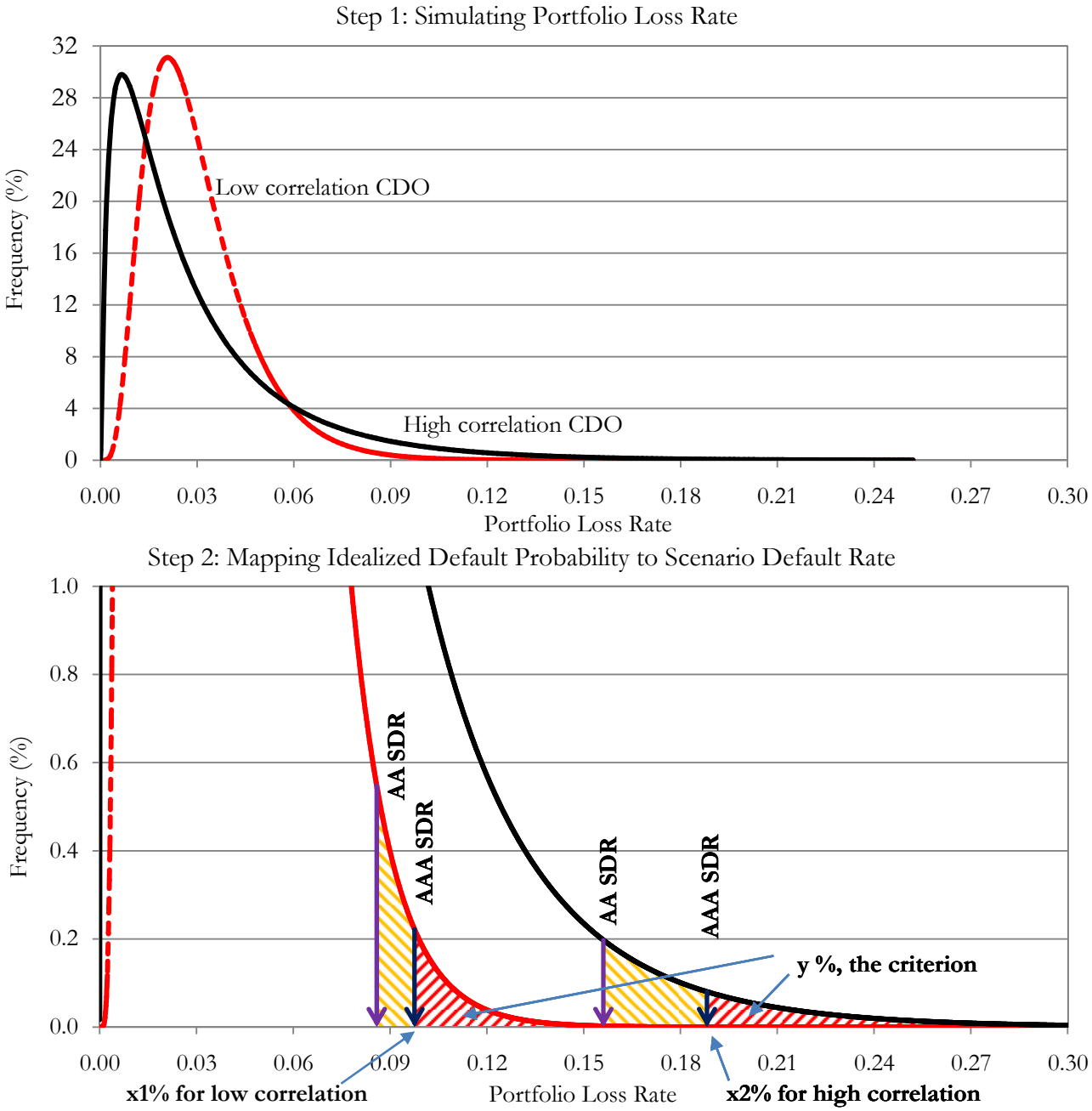


Figure 3. Credit Rating Distribution from 1997 to 2008. The top figure graphs the rating distribution for CDOs and corporate debentures over the period of 1998-2007. The vertical axis is the issuance amount portion for the corresponding credit rating out of all rated debt issuance. The corporate debenture data is from the Fixed-Income Securities Database (FISD) master sample. The bottom graph describes the rating distribution for all active CDOs ratings in 2008 with initial AAA rating (issued between 1998 and 2007), by CDO collateral asset type. The sample only includes CDO ratings updated in 2008 (upgraded, downgraded, or affirmed) from the CRA rating database.

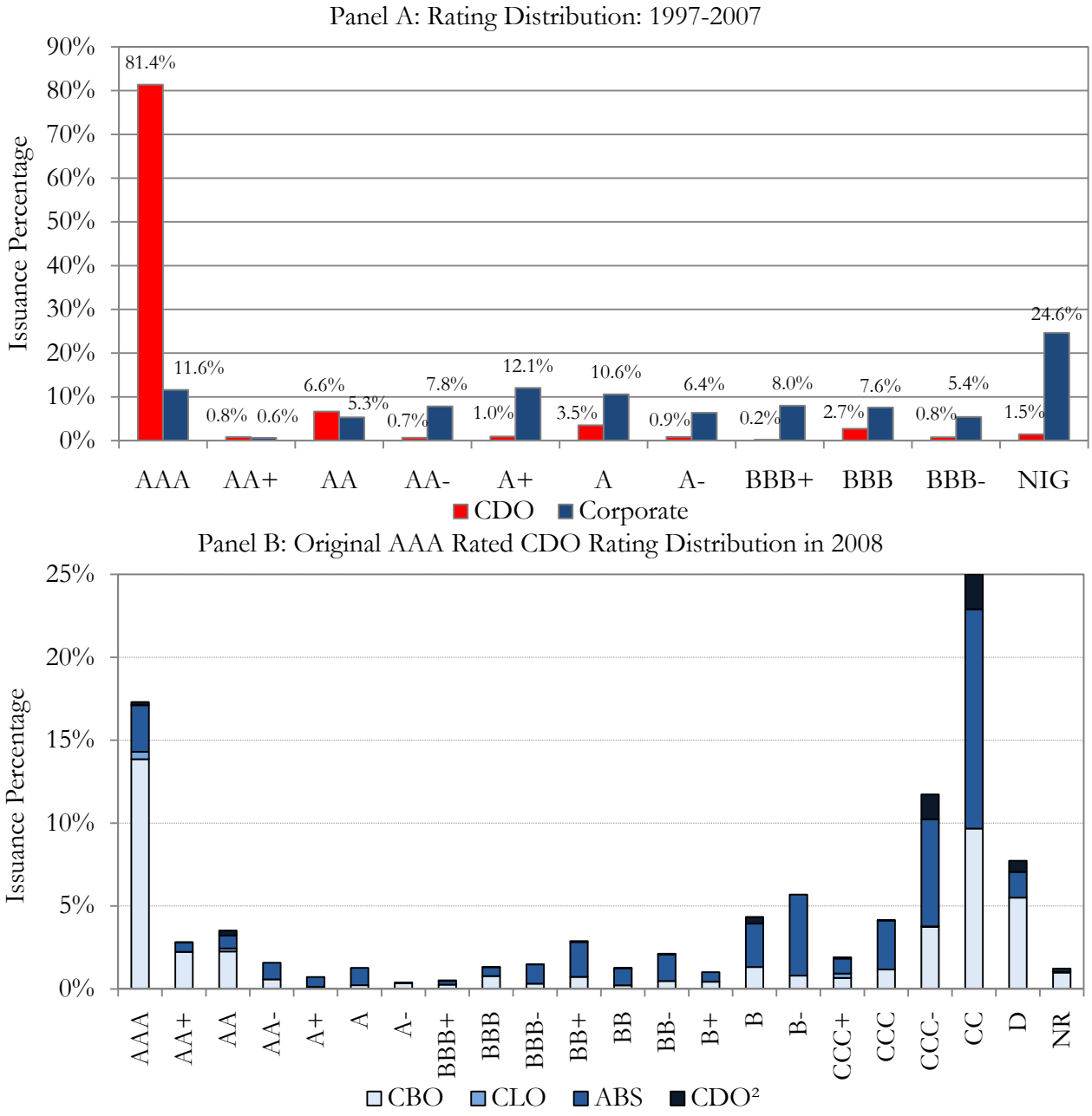


Figure 4. CDO AAA Credit Rating Criterion Deviation in First Surveillance Report, for CDOs issued in 1997-2007. This figure graphs the time series of the deviation from the publicized criterion (the "idealized default probability") for CDO AAA credit rating. The deviation is defined as the difference between the actual criterion in the CRA surveillance report and the publicized criterion with the same maturity. The numbers on the y-axis are not shown to keep the anonymity of the data source.

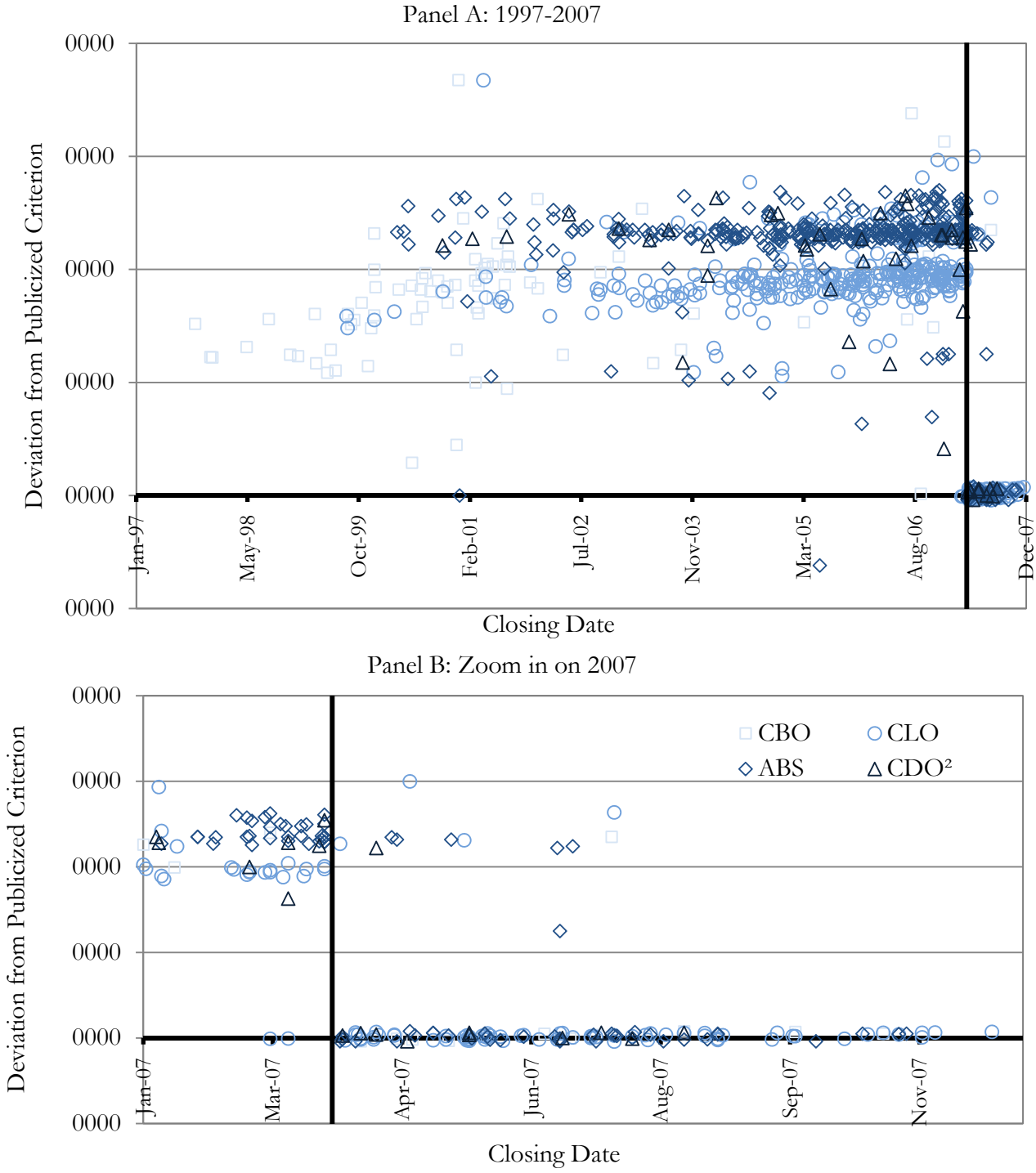
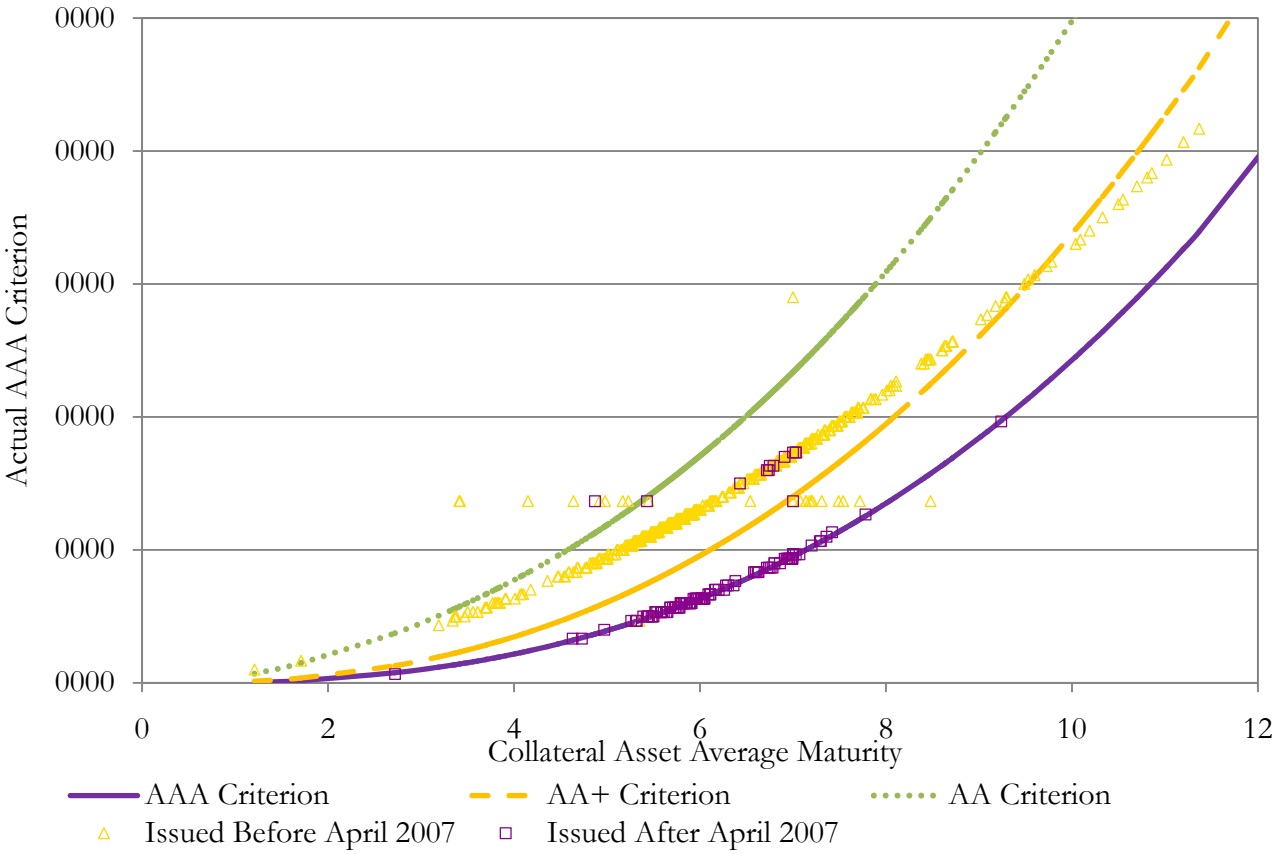
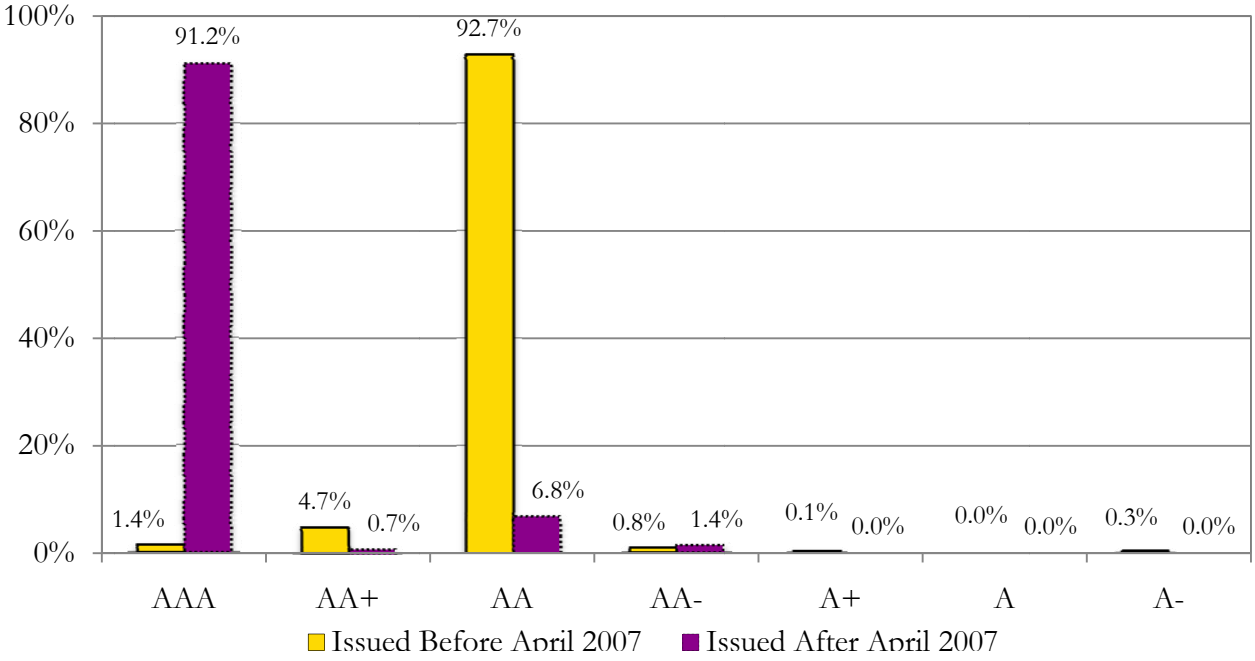


Figure 5. Publicized and Actual CDO AAA Credit Rating Criterion in First Surveillance Report, for CDOs Issued in 1997-2007. Panel A graphs the actual AAA criterion against CDO collateral asset average maturity, using data from the first CRA surveillance report after the completion of the ramp-up period, along with CRA publicized criteria for AAA, AA+, and AA in rating software and handbooks. Panel B presents the rating quality distribution for AAA rated CDO tranches using CRA publicized criterion. For each CDO, the actual AAA idealized default probability is compared to the publicized criterion of the same maturity to determine the corresponding credit rating. The distribution of these collated ratings is plotted by rating scale. Panel C graphs the actual AAA criterion against CDO average asset maturity, using data from the CRA surveillance reports issued between April, 2007 and September, 2008. The publicized criteria for AAA, AA+, and AA are also plotted. For Panel A and Panel C, the numbers on the y-axis are not shown to keep the anonymity of the data source.

Panel A: Publicized and Actual CDO AAA Credit Rating Criterion in First Surveillance Report, for CDOs Issued in 1997-2007



Panel B: Credit Quality Distribution According to Publicized AAA Criterion for CDO Tranches with Initial AAA Rating, Issued in 1997-2007



Panel C: Publicized and Actual CDO AAA Credit Rating Criterion, April 2007 to September 2008

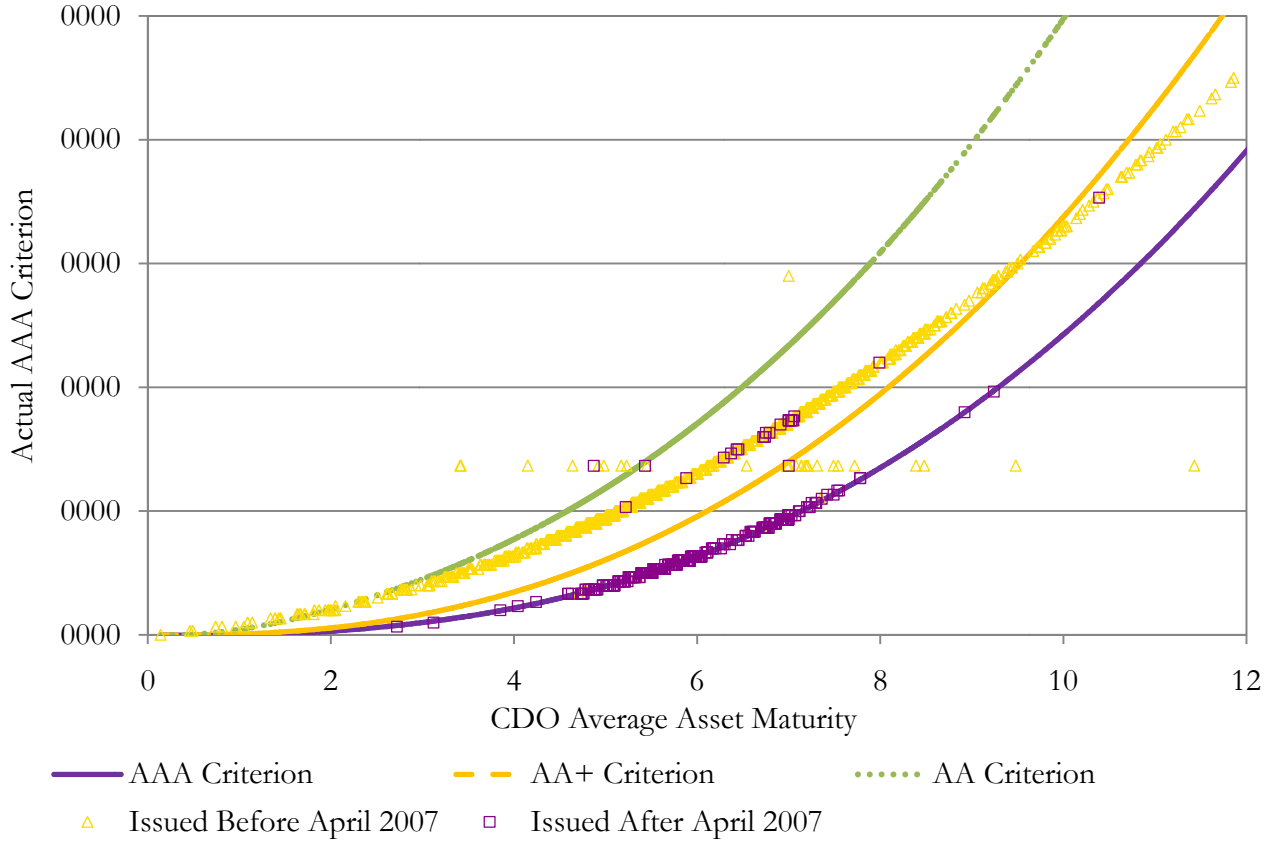


Figure 6. Publicized and Actual CDO Credit Rating Criteria in First Surveillance Report for A-, BBB+, BBB and CCC Credit Ratings, Issued in 1997-2007. This figure graphs the actual criteria against the collateral average maturity, using data from the first CRA surveillance report after the completion of the ramp-up period, along with the publicized criterion in the rating software and handbooks. The numbers on the y-axis are not shown to keep the anonymity of the data source.

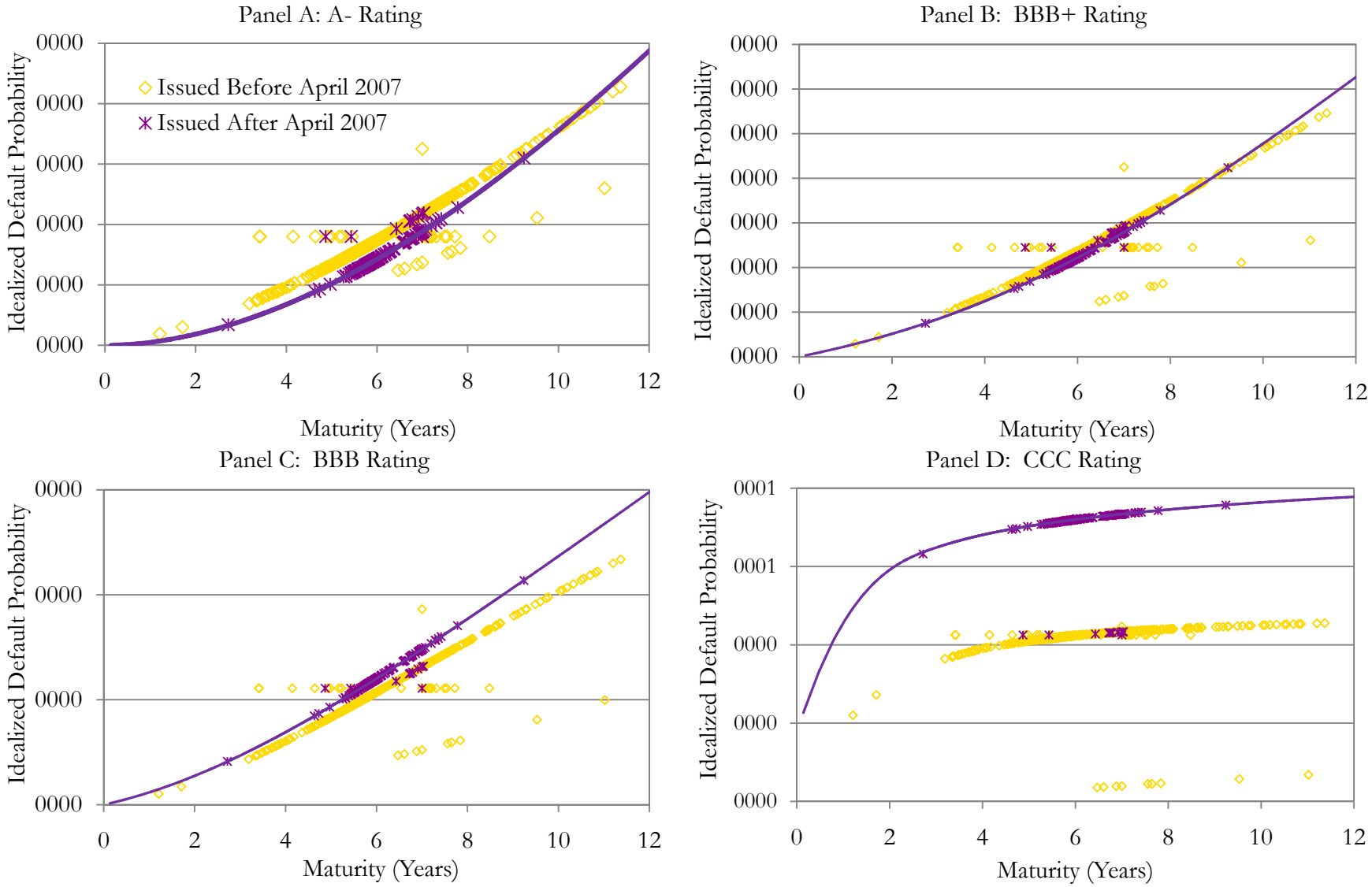


Figure 7. Scenario Default Rate According to Publicized Idealized Default Probabilities and Actual Default Probabilities: An Illustrative Example. This figure illustrates a hypothetical CDO portfolio with real rating default probabilities. The dotted lines denote the scenario default rate (SDR) for the publicized idealized default probabilities for each rating level, shown in the shaded text from AAA to CCC-. The solid lines denote SDRs for the actual default probabilities used by the CRA for each rating level, shown in the boxed text from AAA to CCC-. Scenario Default Rate is determined by the point with upper tail area under the portfolio loss rate distribution curve equal to the corresponding default probability.

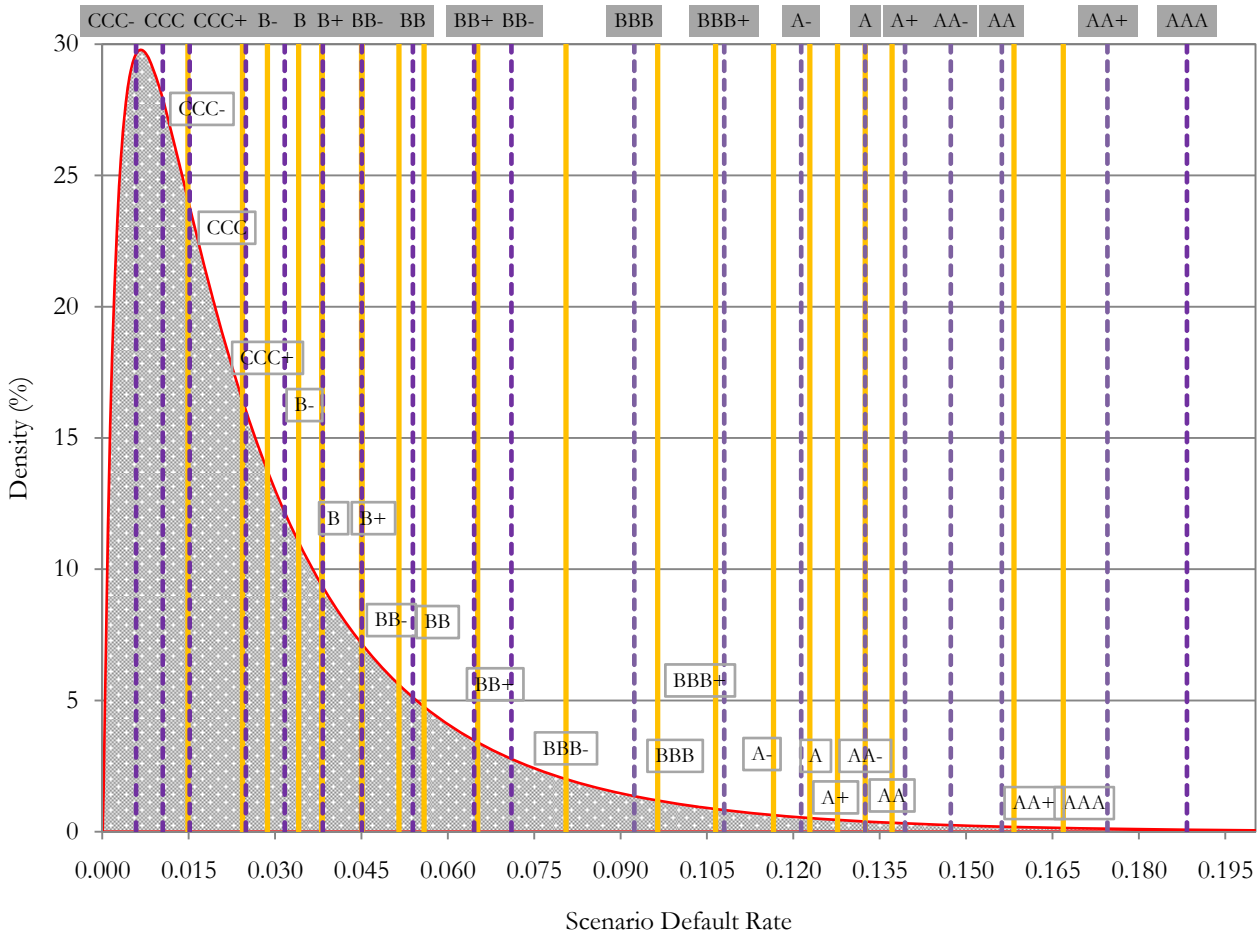


Figure 8. CDO Correlation Distribution from First Surveillance Report by CDO Collateral Asset Type. CDO correlation is directly extracted from the first CRA surveillance report after the completion of the ramp-up period. The horizontal axis is the report date.

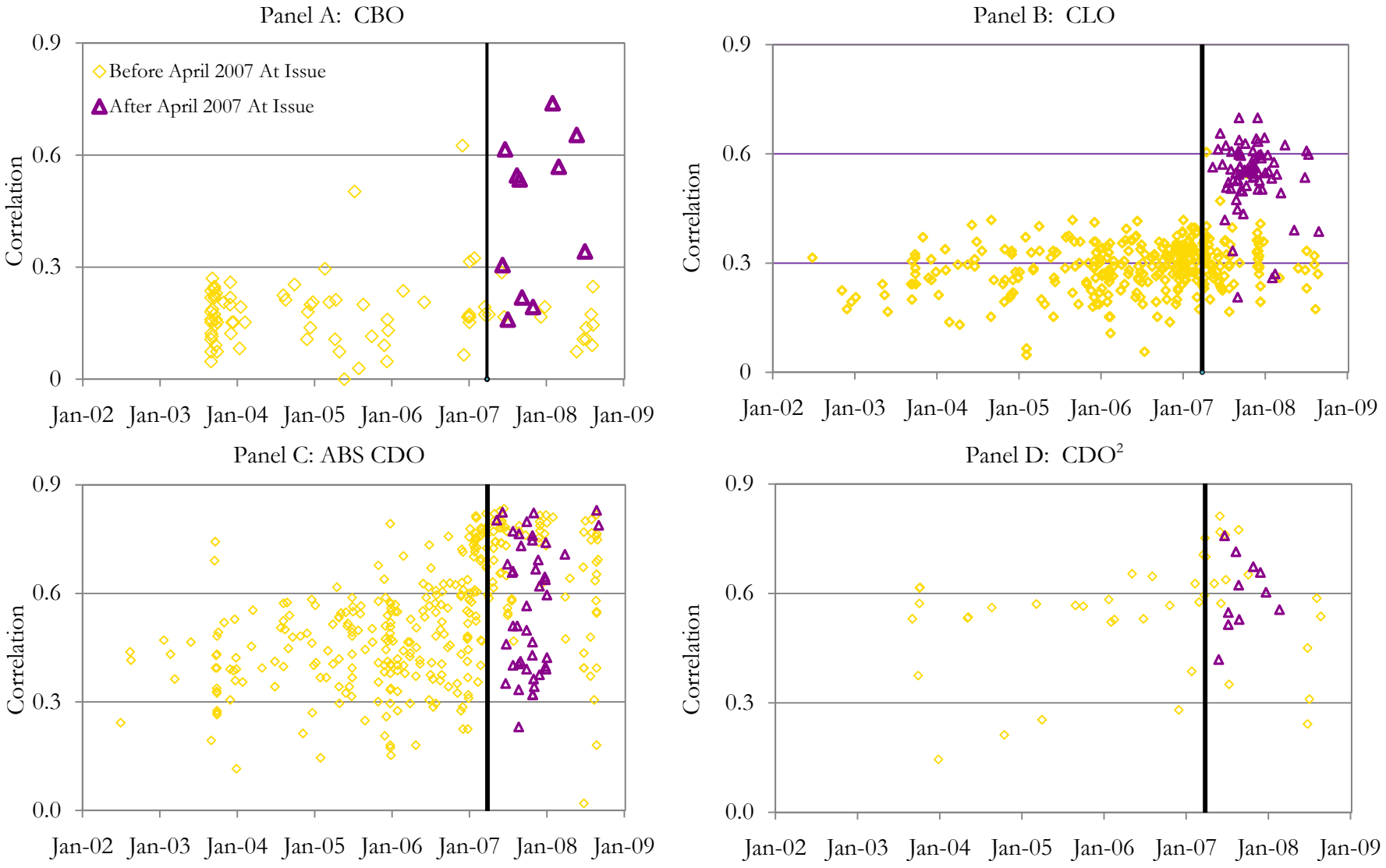


Figure 9. Correlation of CLOs Issued after April 1, 2007 against Correlation of Characteristics Matched CLOs Issued before April 2007. Panel A graphs the correlations of the CLOs issued after April 1, 2007 against the correlations of CLOs issued before April 1, 2007 with the same maturity, collateral asset rating, and collateral portfolio size. Panel B graphs average CDO correlation by collateral asset type and closing date before and after April 1, 2007.

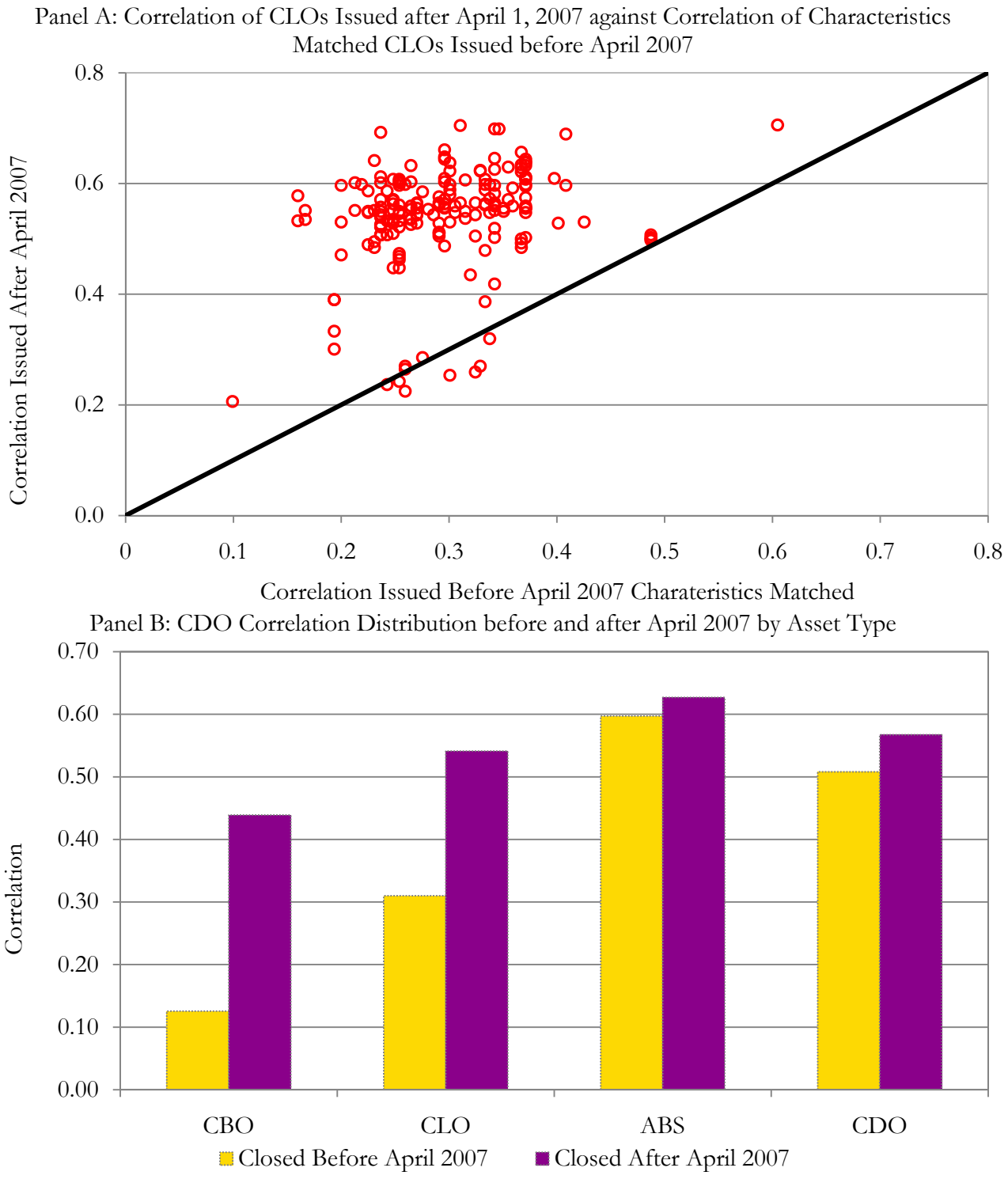
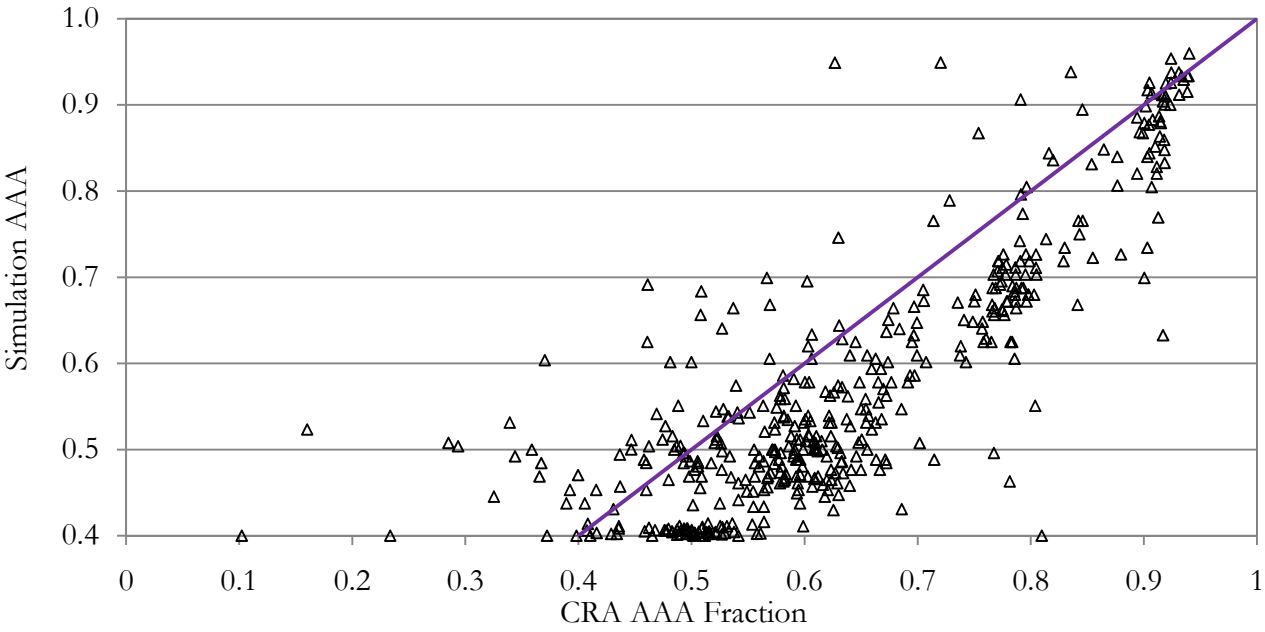


Figure 10. Monte Carlo Simulation AAA Fraction and Actual AAA Fraction against CRA CDO Model AAA Fraction. This figure graphs actual CDO AAA fraction and the AAA fraction from the Monte Carlo simulation against the CRA model, using data from CRA surveillance reports. CRA model AAA fraction is defined as 1-SDR. Data includes all CDOs issued from January, 1997 to December, 2007 in a major CRA CDO database.

Panel A: Monte Carlo Simulation AAA Fraction against CRA CDO Model AAA Fraction



Panel B: Actual AAA Fraction against CRA CDO Model AAA Fraction

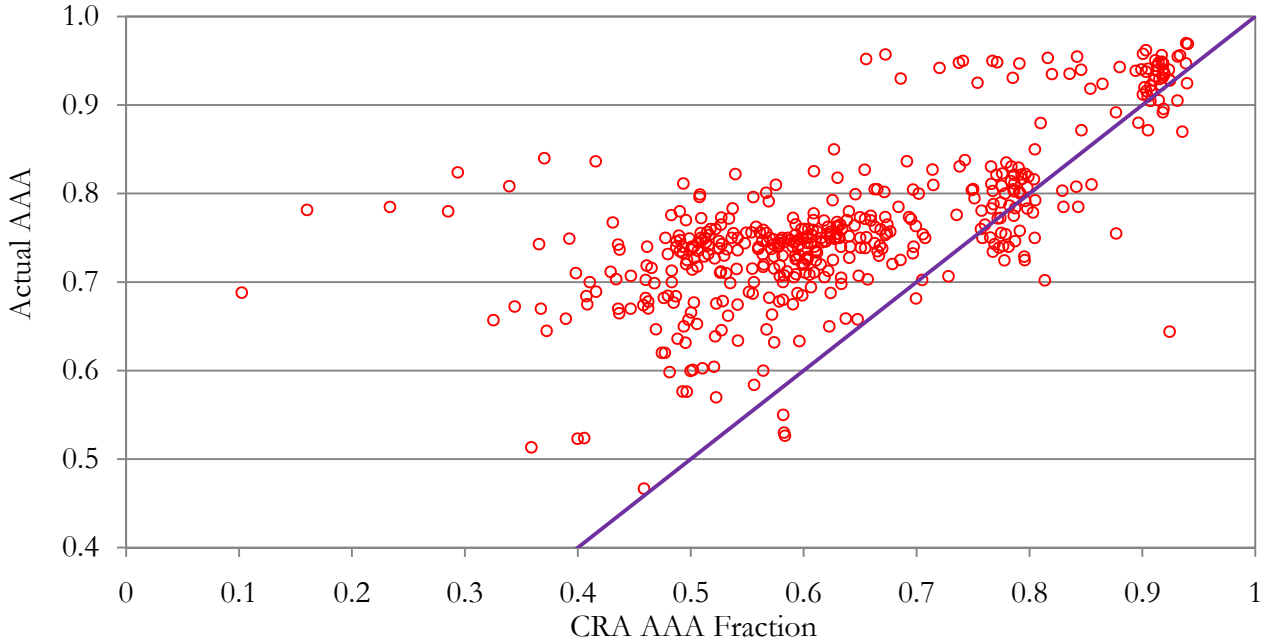


Figure 11. Credit Rating Agency Model Predicted AAA Fraction and Initial Adjustments by Collateral Asset Type and Credit Rating. This figure graphs AAA fraction from the CRA model (defined as 1-SDR) and the adjustment (difference between actual CDO fraction rated AAA and CRA model AAA fraction) by collateral asset type and credit rating. The bottom bars are CRA model AAA and the top bars are adjustments. Data includes all CDOs issued from January, 1997 to December, 2007 in a major CRA CDO database.

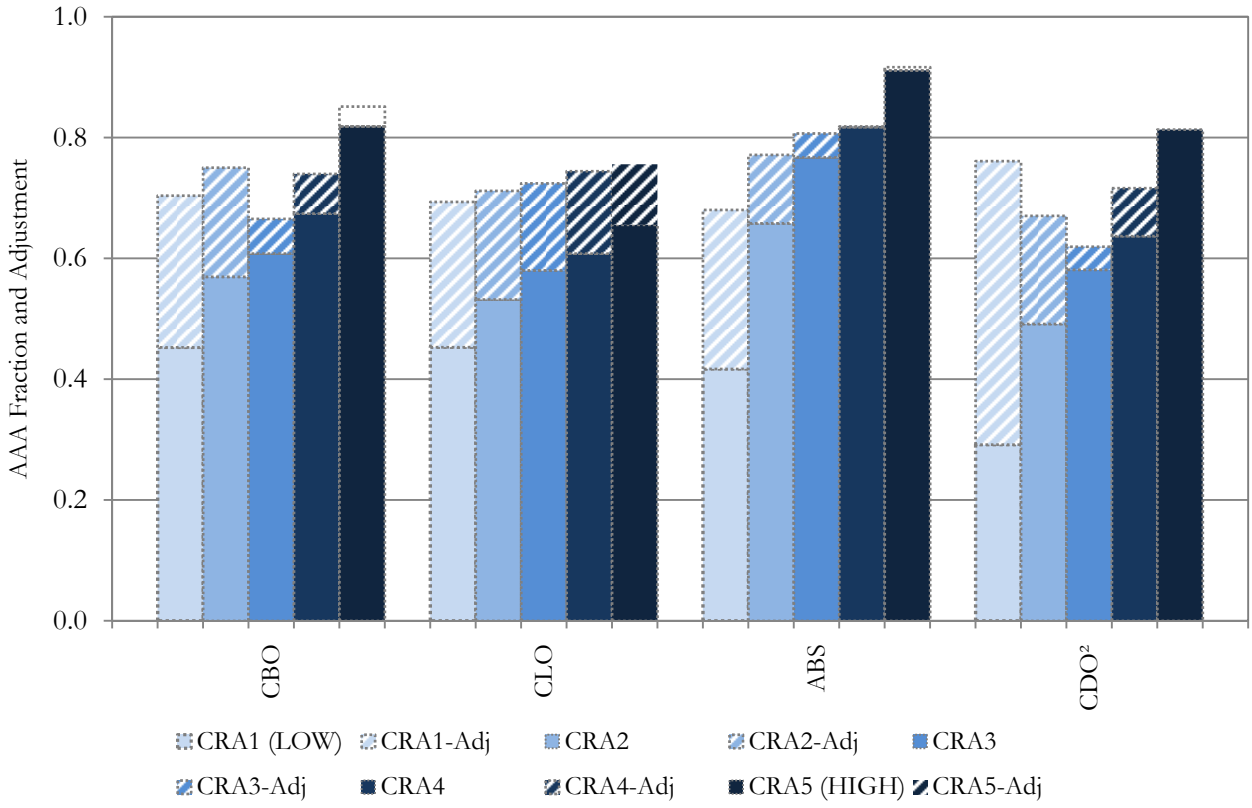


Table I

CDO Sample Description

This table reports the mean value (Panel A) and correlations (Panel B) of the collateral asset characteristics and liability structure for CDOs in our sample. Data is from a major CRA's CDO surveillance reports and CDO rating database. CDOs are issued over the period from January 1997 to December 2007. Reporting dates are from January 2002 to September 2008. Presale reports, new issue reports, deal prospectus, and SDC Platinum are used to cross validate CDO characteristics data. Data is grouped by collateral asset type (CBO for collateralized bond obligations, CLO for collateralized loan obligations, ABS CDO for CDOs of Asset-Backed Securities, and CDO² for CDO of CDOs) and report date (first report versus continuing reports). *Col. Rating* is the collateral asset average credit rating. *Correlation* is the collateral asset weighted average correlation. *Col. Maturity* is the collateral asset weighted average maturity. *Col. Size* is the total principal value of collateral assets. #. *Assets* is the number of assets in the collateral pool. #. *Obligors* is the number of distinctive obligors for the collateral assets. *Synthetic Dummy* equals to 1 if the CDO is structured synthetically (using credit default swaps, CDS, contracts) and 0 if the CDO is a cash deal. *AAA Fraction* is the fraction of the CDO liability rated AAA, non-rated super senior tranche is not included. *AAA Fraction (SS)* is the fraction of the CDO liability rated AAA counting super senior tranches as AAA. *Overcollateralization* is the ratio of total collateral asset principal value over total liability principal value. *Insurance Dummy* equals to 1 if the AAA tranche of the CDO is insured and 0 otherwise. *Liquidity Dummy* equals to 1 if the CDO has liquidity facility (such as a revolving credit line or hedging agreements) and 0 otherwise.

Panel A: Average CDO Characteristics

Variables	All		CBO		CLO		ABS CDO		CDO²	
	First	Cont'd	First	Cont'd	First	Cont'd	First	Cont'd	First	Cont'd
#. Obs.	916	2506	96	337	393	1046	373	984	54	139
Col. Rating	BB+	BB	BB-	B+	B+	B	A-	BBB	BBB	BB
Correlation	0.42	0.40	0.21	0.15	0.34	0.33	0.53	0.54	0.56	0.49
Col. Maturity(Years)	6.45	6.06	5.30	4.22	5.74	5.23	7.23	7.32	8.32	7.87
Col. Size ($millions)	634.3	547.2	394.4	265.7	479.3	473.4	865.9	736.6	589.4	444.8
#. Assets	218.3	230.2	139.2	97.8	325.9	374.1	144.7	143.8	84.02	79.71
#. Obligors	130.0	133.5	104.3	77.8	158.1	177.1	115.3	115.4	72.1	69.3
Synthetic Dummy	0.14	0.08	0.25	0.12	0.00	0.00	0.25	0.15	0.15	0.08
AAA Fraction	0.73	0.74	0.70	0.72	0.72	0.73	0.75	0.76	0.71	0.70
AAA Fraction (SS)	0.75	0.76	0.73	0.74	0.73	0.73	0.80	0.79	0.72	0.70
Overcollateralization	1.00	0.94	0.89	0.65	0.95	0.95	1.05	0.97	1.34	1.35
Insurance Dummy	0.06	0.08	0.19	0.21	0.04	0.07	0.05	0.05	0.06	0.11
Liquidity Dummy	0.23	0.25	0.47	0.42	0.11	0.14	0.28	0.27	0.37	0.47

Table I—*Continued*

Panel B: Correlation Matrix

Variables		1	2	3	4	5	6	7	8	9	10	11
Col. Rating	1											
Correlation	2	-0.41										
Col. Maturity(Years)	3	-0.42	0.47									
Col. Size ($millions)	4	-0.49	0.31	0.2								
#. Assets	5	0.36	-0.01	-0.27	-0.01							
#. Obligors	6	0.15	0.12	-0.19	0.13	0.86						
Synthetic Dummy	7	-0.18	0.38	0.24	0.19	-0.22	-0.14					
AAA Fraction	8	-0.14	-0.06	-0.06	0.09	0.04	0.09	-0.25				
AAA Fraction (SS)	9	-0.42	0.05	0.03	0.3	-0.04	0.11	-0.09	0.63			
Overcollateralization	10	-0.17	0.08	0.12	0.16	-0.05	-0.03	0.16	-0.15	-0.25		
Insurance Dummy	11	0.05	-0.16	-0.14	0.01	-0.1	-0.09	-0.09	0.11	0.1	-0.06	
Liquidity Dummy	12	-0.12	0.04	0.08	0	-0.2	-0.14	0.22	-0.09	0.04	0.05	0.04

Table II

Summary of Scenario Default Rate Differential Resulting from Criterion Deviation

This table summarizes the AAA Scenario Default Rate (SDR) differential resulting from CRA rating criterion deviation using the Monte Carlo Simulation model and Vasicek Model. Data is from CRA CDO surveillance reports and CDO rating databases. The differential is the SDR from publicized AAA criterion minus the SDR from actual criterion. CDOs are issued over the period from January 1997 to March 2007. Presale reports, new issue reports, deal prospectus, and SDC Platinum are used to cross validate CDO characteristics data. Data are stratified into multiple groups. Panel A is for the full sample. Panel B splits the sample by collateral rating. Panel C splits the sample by collateral maturity. Panel D splits the sample by CDO portfolio default correlation. Reported is the average differential in percentage by collateral type.

Panel A: Full Sample

Full Sample	Monte Carlo Simulation					Vasicek Model				
	All	CBO	CLO	ABS	CDO²	All	CBO	CLO	ABS	CDO²
SDR Difference	3.18	3.35	2.48	3.86	2.86	5.74	5.26	7.71	4.08	4.65

Panel B: By Collateral Rating

Collateral Rating	Monte Carlo Simulation					Vasicek Model				
	All	CBO	CLO	ABS	CDO²	All	CBO	CLO	ABS	CDO²
AAA and AA	3.92	—	—	4.02	1.78	2.13	—	—	2.09	3.18
A and BBB	4.19	2.65	—	4.39	3.44	4.96	10.92	—	4.70	4.53
BB and B	2.56	3.62	2.49	1.45	1.57	7.18	4.88	7.88	5.46	6.40
CCC and Below	1.43	2.10	2.11	0.00	0.00	1.89	0.51	1.57	4.12	0.21

Panel C: By Collateral Maturity

Collateral Maturity	Monte Carlo Simulation					Vasicek Model				
	All	CBO	CLO	ABS	CDO²	All	CBO	CLO	ABS	CDO²
Short	3.56	5.27	2.77	3.62	5.59	6.01	3.38	7.04	5.37	8.40
Medium	3.39	2.42	2.49	4.60	3.07	5.82	5.11	8.25	3.71	4.46
Long	2.49	2.50	2.14	3.15	-0.42	5.34	7.40	7.68	3.20	0.87

Panel D: By Default Correlation

Default Correlation	Monte Carlo Simulation					Vasicek Model				
	All	CBO	CLO	ABS	CDO²	All	CBO	CLO	ABS	CDO²
Low	2.88	4.73	2.53	2.71	2.97	6.25	4.73	5.74	6.95	8.14
Medium	3.37	2.51	2.54	4.34	3.70	5.69	4.10	8.22	3.74	4.72
High	3.23	2.99	2.33	4.35	1.21	5.27	7.47	9.13	1.67	0.71

Table III

CDO AAA Fraction: Actual, CRA Model, Monte Carlo Simulation, and Vasicek Model

This table reports the mean value of the actual AAA fraction, CRA model predicted AAA fraction, Monte Carlo simulation predicted AAA fraction, and Vasicek model predicted AAA fraction for CDOs in our sample. Data is from CRA CDO surveillance reports and CDO rating databases. CDOs are issued over the period from January 1997 to December 2007. Presale reports, new issue reports, deal prospectus, and SDC Platinum are used to cross validate CDO characteristics data. *Actual AAA* is the actual fraction of the CDO liability rated AAA without counting non-rated super senior tranches. *Actual AAA (SS)* is the actual fraction of the CDO liability rated AAA treating super senior tranches as AAA. *CRA Model* is the fraction of the CDO that can be rated AAA according to the rating agency model, defined as 1-SDR. *MC Simulation* is the fraction of the CDO that can be rated AAA according to the Monte Carlo Simulation. *Vasicek Model* is the fraction of the CDO that can be rated AAA according to the Vasicek model. *CRA Adjustment (SS)* is the difference between actual AAA (SS) fraction and CRA model AAA fraction. Panel A displays the sample average value. Data is grouped by collateral asset type (CBO for collateralized bond obligations, CLO for collateralized loan obligations, ABS CDO for CDOs of Asset-Backed Securities, and CDO^2 for CDO of CDOs) from the first CRA surveillance report. Panel B displays the correlation matrix.

Panel A: Sample Average Value

Variables	All	CBO	CLO	ABS CDO	CDO^2
#. Obs.	916	96	393	373	54
Actual AAA	0.73	0.70	0.72	0.75	0.71
Actual AAA (SS)	0.75	0.73	0.73	0.80	0.72
CRA Model	0.63	0.62	0.57	0.72	0.57
MC Simulation	0.60	0.63	0.51	0.70	0.60
Vasicek Model	0.45	0.12	0.15	0.81	0.76
CRA Adjustment	0.10	0.07	0.16	0.04	0.14
CRA Adjustment (SS)	0.12	0.10	0.16	0.08	0.15

Panel B: Correlation Matrix

Variables	Actual AAA	Actual AAA (SS)	CRA Model	MC Simulation	Vasicek Model	CRA Adj'ment
Actual AAA						
Actual AAA (SS)	0.63					
CRA Model	0.26	0.49				
MC Simulation	0.21	0.45	0.83			
Vasicek Model	0.07	0.29	0.43	0.51		
CRA Adjustment	0.62	0.12	-0.60	-0.50	-0.29	
CRA Adjustment (SS)	0.23	0.27	-0.71	-0.56	-0.24	0.76

Table IV

Model Explicability Comparison

This table reports the OLS regression results with different dependent variables for AAA fraction. The dependent variables are the AAA fraction predicted by the Vasicek model, Monte Carlo Simulation, CRA Model, and Actual AAA fraction as described in Table IV. The independent variables are described in Table I. CLO, ABS, and CDO² are collateral asset type dummy variables. Data is from CRA CDO surveillance reports and CDO rating databases. CDOs are issued over the period from January 1997 to December 2007. Presale reports, new issue reports, deal prospectus, and SDC Platinum are used to cross validate CDO characteristics data. Data is grouped by report date (first report versus continuing reports). Robust t-statistics are in the parentheses.

	Vasicek Model		MC Simulation		CRA Model		Actual AAA	
	First	Cont'd	First	Cont'd	First	Cont'd	First	Cont'd
Intercept	0.54	0.71	1.14	0.92	1.27	1.17	0.74	0.55
	(4.81)	(12.79)	(21.19)	(29.46)	(12.83)	(24.70)	(5.03)	(7.29)
Col. Def. Prob.	0.08	0.80	0.20	0.08	-1.98	-1.57	0.86	0.34
	(0.42)	(10.04)	(2.26)	(-1.90)	(-12.15)	(-23.19)	(3.56)	(-3.10)
Avg. Col. Rating	-0.04	-0.05	-0.03	-0.03	-0.02	-0.03	-0.01	-0.01
	(-28.83)	(-62.59)	(-49.80)	(-69.20)	(-19.54)	(-48.31)	(-8.21)	(-7.27)
Correlation	0.68	0.81	-0.45	-0.46	-0.46	-0.45	-0.12	-0.04
	(33.77)	(62.89)	(-45.95)	(-62.92)	(-25.62)	(-40.94)	(-4.32)	(-2.37)
Avg. Col. Maturity	0.01	0.02	0.00	0.00	-0.01	-0.01	0.00	0.00
	(6.45)	(19.37)	(-2.23)	(-2.64)	(-5.71)	(-6.94)	(-1.41)	(0.97)
Ln CDO Size	-0.01	-0.01	0.00	0.01	-0.01	0.00	0.01	0.01
	(-0.98)	(-4.60)	(0.58)	(-7.00)	(-2.03)	(-0.02)	(1.11)	(3.37)
# Assets (×100)	0.02	0.00	0.00	0.00	0.00	0.00	-0.01	-0.02
	(3.81)	(1.44)	(0.31)	(-1.29)	(0.47)	(-0.45)	(-1.82)	(-4.57)
# Obligors (×100)	-0.03	-0.02	0.00	0.00	0.08	0.07	0.06	0.06
	(-3.45)	(-3.43)	(-0.87)	(-0.87)	(-9.70)	(15.35)	(4.96)	(7.69)
CLO	-0.03	-0.05	-0.03	-0.04	0.00	-0.01	0.01	-0.02
	(-3.01)	(-8.28)	(-6.36)	(-12.22)	(-0.43)	(-2.71)	(0.38)	(-2.08)
ABS	0.23	0.14	0.02	0.02	0.06	0.00	0.04	0.02
	(18.42)	(18.14)	(4.04)	(5.19)	(5.16)	(0.03)	(2.42)	(2.14)
CDO²	0.21	0.10	-0.01	-0.02	0.01	-0.04	0.00	-0.04
	(12.95)	(10.05)	(-0.91)	(-3.88)	(1.01)	(-4.66)	(0.22)	(-3.33)
Synthetic Dummy	-0.01	-0.01	-0.01	0.00	-0.01	-0.06	-0.03	-0.04
	(-0.88)	(-2.31)	(-1.68)	(1.27)	(-1.50)	(-11.49)	(-3.03)	(-4.22)
N	912	2478	912	2478	912	2478	912	2478
Adj. R^2	0.96	0.96	0.94	0.91	0.83	0.87	0.29	0.18

Table V

CRA AAA Fraction Adjustment and CDO Characteristics

This table shows the results of OLS regressions, where the dependent variables are CRA AAA fraction adjustment with or without super senior tranche (SS). The adjustment is defined as the difference between actual AAA fraction and CRA Model predicted AAA fraction explained in Table IV. The independent variables are described in Table I and Table IV. Data is from CRA CDO surveillance reports and CDO rating databases. CDOs are issued over the period from January 1997 to December 2007. Presale reports, new issue reports, deal prospectus, and SDC Platinum are used to cross validate CDO characteristics data. Robust t-statistics are in the parentheses.

	Dependent Variable = Adjustment				Dependent Variable = Adjustment (SS)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	0.18	0.61	0.60	0.65	0.20	0.57	0.57	0.56
	(13.52)	(27.84)	(25.90)	(20.02)	(21.36)	(41.91)	(39.87)	(28.67)
Overcollateralization	-0.07	-0.05	-0.05	-0.02	-0.08	-0.06	-0.06	-0.04
	(-6.30)	(-5.43)	(-5.34)	(-2.09)	(-10.05)	(-11.03)	(-11.59)	(-7.48)
Insurance Dummy	0.06	0.07	0.07	0.05	0.03	0.04	0.04	0.04
	(2.24)	(3.23)	(3.15)	(2.68)	(1.55)	(2.85)	(3.07)	(3.17)
Liquidity Dummy	-0.05	-0.04	-0.04	-0.02	-0.01	0.00	0.00	0.00
	(-3.54)	(-3.21)	(-3.21)	(-1.83)	(-0.64)	(0.68)	(0.13)	(0.68)
CRA AAA		-0.72	-0.72	-0.70		-0.62	-0.71	-0.65
		(-22.49)	(-12.56)	(-11.73)		(-31.02)	(-19.92)	(-18.10)
Vasicek AAA			0.00	-0.15			0.04	-0.05
			(-0.24)	(-4.40)			(3.95)	(-2.65)
MC AAA			0.01	0.01			0.06	0.07
			(0.12)	(0.10)			(1.55)	(1.56)
AA Adjustment				-0.83				-0.87
				(-6.67)				(-11.68)
Issued Before Apr07				-0.09				-0.06
				(-6.02)				(-6.00)
CLO				0.02				0.03
				(1.11)				(2.64)
ABS				0.13				0.08
				(4.80)				(4.55)
CDO^2				0.13				0.07
				(3.89)				(3.65)
Synthetic Dummy				-0.10				-0.02
				(-6.40)				(-1.90)
N	914	914	914	914	914	914	914	914
Adj. R^2	0.06	0.40	0.40	0.47	0.11	0.56	0.58	0.64

Table VI

AAA Fraction Adjustment and Subsequent Rating Downgrade as of December 2, 2008: Sorting Results

This table summarizes AAA downgrade portion and downgrade notches for CDOs grouped by CRA CDO AAA fraction adjustment (actual AAA fraction minus CRA model predicted AAA fraction) as explained in Table IV. AAA downgrade data is as of December 2, 2008. CDOs are sorted into three groups according to the lowest 25%, middle 50%, and highest 25% of adjustment with super senior tranche. Data is from CRA CDO surveillance reports and CDO rating databases. CDOs are issued over the period from January 1997 to December 2007. Presale reports, new issue reports, deal prospectus, and SDC Platinum are used to cross validate CDO characteristics data. Data is grouped by collateral asset type (CBO for collateralized bond obligations, CLO for collateralized loan obligations, ABS CDO for CDOs of Asset-Backed Securities, and CDO^2 for CDO of CDOs).

Panel A: CBO and CLO

	CBO				CLO			
	Low	M	High	H-L	Low	M	High	H-L
Number of CDOs	24	47	25		96	198	99	
Adjustment (SS)	-0.10	0.11	0.28	0.38	0.08	0.15	0.26	0.18
AAA Downgrade Portion	0.08	0.06	0.24	0.16	0.00	0.00	0.01	0.01
(t-stat)				(1.49)				(0.98)
AAA Downgrade Notch	0.17	0.11	2.36	2.19	0.00	0.00	0.02	0.02
(t-stat)				(1.83)				(0.98)

Panel B: CDO of ABS and CDO^2

	CDO of ABS				CDO^2			
	Low	M	High	H-L	Low	M	High	H-L
Number of CDOs	91	186	96		13	27	14	
Adjustment (SS)	-0.08	0.05	0.29	0.37	-0.06	0.11	0.42	0.47
AAA Downgrade Portion	0.71	0.73	0.95	0.23	0.46	0.67	0.71	0.25
(t-stat)				(4.50)				(1.33)
AAA Downgrade Notch	10.80	11.24	16.79	5.98	9.04	9.74	14.00	4.96
(t-stat)				(5.83)				(1.33)

Table VII

AAA Fraction Adjustment and Subsequent Rating Downgrade as of December 2, 2008: Regression Results

This table shows regression results where the dependent variable is the number of notches downgraded from initial AAA rating or downgrade plus rating watch negative (RWN, as of December 2, 2008) counting as a half notch downgrade. The adjustment is defined as the difference between actual AAA fraction (with and without super senior tranches) and CRA Model predicted AAA fraction. The independent variables are described in Table I and Table IV. Data is from CRA CDO surveillance reports and CDO rating databases. CDOs are issued over the period from January 1997 to December 2007. Presale reports, new issue reports, deal prospectus, and SDC Platinum are used to cross validate CDO characteristics data. The sample includes CBO, ABS CDO, and CDO^2. Panel A is for ordered probit regression where the dependent variable is AAA downgrade with RWN and AAA adjustment includes super senior. First line is the coefficient estimate. The numbers in the square bracket is the odds ratio. The numbers in the parentheses are z-stat or t-stat. Panel B is for logistic regressions and ordinary least square (OLS) regressions, in which specifications 1, 3, 5, 7 are for AAA adjustment without super senior, 2, 4, 6, 8 AAA adjustment with super senior.

Table VII—*Continued*

Panel A: Ordered Probit Regression

	(1)	(2)	(3)	(4)	(5)
AAA Adjustment	2.19	3.15	2.62	2.77	4.24
	[8.93]	[23.40]	[13.76]	[15.93]	[69.27]
	(4.53)	(6.03)	(5.07)	(4.77)	(6.06)
ABS		3.58	3.75	3.84	1.6
		[35.73]	[42.62]	[46.45]	[4.95]
		(11.32)	(10.42)	(10.73)	(2.76)
CDO^2		3.18	3.46	3.53	1.37
		[24.10]	[31.77]	[34.05]	[3.93]
		(7.04)	(6.85)	(6.73)	(1.97)
Synthetic Dummy			1.36	1.41	1.17
			[3.91]	[4.08]	[3.23]
			(6.91)	(6.66)	(4.91)
Overcollateralization				0.09	0.13
				[1.09]	[1.14]
				(0.73)	(0.92)
Insurance Dummy				0.59	0.7
				[1.80]	[2.00]
				(1.53)	(1.85)
Liquidity Dummy				-0.14	-0.09
				[0.87]	[0.92]
				(-0.73)	(-0.43)
Vasicek AAA					3.97
					[53.05]
					(6.52)
N	523	523	523	523	521
Pseudo R^2	0.01	0.09	0.11	0.11	0.14

Table VII—*Continued*

Panel B: Plain Logistic Regression and OLS Regression

	Logit				OLS			
	Dep. Var.= AAA Downgrade		Dep. Var.= AAA Downgrade & RWN		Dep. Var.= AAA Downgrade		Dep. Var.= AAA Downgrade & RWN	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	-3.54	-4.16	-3.57	-4.15	-2.70	-3.66	-2.47	-3.43
	(-5.43)	(-5.64)	(-5.87)	(-6.05)	(-2.79)	(-3.71)	(-2.74)	(-3.71)
AAA Adjustment	1.72	4.36	1.74	4.29	7.29	12.68	7.11	12.57
	(3.27)	(4.11)	(3.23)	(4.12)	(5.30)	(6.40)	(5.25)	(6.48)
ABS	1.94	1.97	1.98	1.97	3.16	2.99	3.20	2.93
	(3.08)	(2.94)	(3.36)	(3.14)	(2.19)	(2.10)	(2.33)	(2.17)
CDO^2	1.24	1.08	1.29	1.10	1.89	1.39	1.93	1.32
	(1.76)	(1.48)	(1.94)	(1.58)	(1.14)	(0.85)	(1.21)	(0.84)
Synthetic Dummy	1.62	1.41	1.74	1.52	4.99	4.06	4.94	4.00
	(5.52)	(4.35)	(5.95)	(4.69)	(6.70)	(5.36)	(6.76)	(5.38)
Overcollateralization	-0.12	0.10	-0.11	0.10	-0.18	0.40	-0.20	0.39
	(-0.98)	(0.69)	(-0.95)	(0.66)	(-0.44)	(0.91)	(-0.48)	(0.90)
Insurance Dummy	0.99	0.96	0.98	0.95	1.33	1.29	1.36	1.36
	(1.30)	(1.34)	(1.33)	(1.37)	(1.10)	(1.09)	(1.17)	(1.19)
Liquidity Dummy	0.02	-0.08	0.05	-0.04	-0.35	-0.71	-0.31	-0.64
	(0.07)	(-0.30)	(0.19)	(-0.15)	(-0.52)	(-1.08)	(-0.47)	(-1.00)
Vasicek AAA	3.35	3.64	3.29	3.59	13.24	13.37	12.97	13.20
	(5.32)	(5.60)	(5.48)	(5.71)	(7.85)	(8.07)	(8.02)	(8.31)
N	521	521	521	521	521	521	521	521
Pseudo/Adj. R^2	0.30	0.32	0.32	0.34	0.41	0.42	0.43	0.44

Table VIII

CDO AAA Value Difference Relative to Rating from Alternative Models

This table summarizes ratings assigned by alternative models for actual CDO liability structure and corresponding value difference from actual AAA rating. *Model Rating* is the rating assigned by the Monte Carlo (MC) simulation and Vasicek model with the actual AAA fraction. *Spread* is the difference in coupon rate between the CDO AAA tranche and the corresponding tranche (market average substituted if no such tranche existed). *Value Dif* is the present value difference defined as the following:

$$Value\ Dif = Collateral\ Average\ Maturity \times (AAA - Model\ Rating\ Spread) \times Dollar\ Value\ of\ the\ AAA\ Fraction$$

Sample Dif is total value dif over the sample (Value Dif multiplied by #CDO). *Dif in AAA Portion* is the value differential in total AAA amount. *Dif in CDO Portion* is the value differential in whole CDO amount. Data is from CRA CDO surveillance reports and CDO rating databases. CDOs are issued over the period from January 1997 to December 2007. Presale reports, new issue reports, deal prospectus, and SDC Platinum are used to cross validate CDO characteristics data. Data is grouped by collateral asset type (CBO for collateralized bond obligations, CLO for collateralized loan obligations, ABS CDO for CDOs of Asset-Backed Securities, and CDO² for CDO of CDOs).

Panel A: Full Sample

	Monte Carlo Simulation					Vasicek Model				
Variables	All	CBO	CLO	ABS	CDO²	All	CBO	CLO	ABS	CDO²
#. Of CDOs	916	96	393	373	54	916	96	393	373	54
Model Rating	BBB	BBB	BBB	BBB	BBB+	A	BBB	BB+	AA	AA+
AAA Spread	0.33	0.42	0.30	0.33	0.40	0.33	0.42	0.30	0.33	0.40
Model Rating Spread	2.89	2.94	2.83	2.99	2.54	1.90	2.47	2.97	0.84	0.79
Spread Dif (%)	2.56	2.54	2.53	2.66	2.14	1.57	2.08	2.68	0.51	0.40
Value Dif ($ millions)	94.13	54.75	52.94	146.83	74.68	42.23	42.96	56.38	31.17	15.19
Sample Dif ($ billions)	86.22	5.26	20.81	54.77	4.03	38.68	4.12	22.16	11.63	0.82
Dif in AAA Portion	0.20	0.19	0.15	0.21	0.18	0.09	0.15	0.16	0.05	0.04
Dif in CDO Portion	0.15	0.14	0.11	0.17	0.13	0.07	0.11	0.12	0.04	0.03

Table VIII—*Continued*

Panel B: CDOs Issued before April 2007

	Monte Carlo Simulation					Vasicek Model				
Variables	All	CBO	CLO	ABS	CDO²	All	CBO	CLO	ABS	CDO²
#CDOs	778	85	321	329	43	778	85	321	329	43
Model Rating	BBB	BBB	BBB	BBB	BBB+	A	BBB-	BBB-	AA+	AA
AAA Spread	0.34	0.44	0.31	0.34	0.42	0.34	0.44	0.31	0.34	0.42
Model Rating Spread	2.85	3.01	2.72	3.01	2.35	1.78	2.51	2.85	0.76	0.74
Spread Dif (%)	2.51	2.59	2.42	2.67	1.93	1.45	2.10	2.55	0.43	0.32
Value Dif ($millions)	88.14	47.43	48.75	137.87	50.62	34.8	34.89	52.3	20.88	11.52
Sample Dif($billions)	68.57	4.03	15.65	45.36	2.18	27.07	2.97	16.79	6.87	0.50
Dif in AAA Portion	0.19	0.19	0.14	0.21	0.14	0.08	0.14	0.15	0.03	0.03
Dif in CDO Portion	0.15	0.14	0.10	0.17	0.10	0.06	0.10	0.11	0.03	0.02

Panel C: CDOs Issued after April 2007

	Monte Carlo Simulation					Vasicek Model				
Variables	All	CBO	CLO	ABS	CDO²	All	CBO	CLO	ABS	CDO²
#CDOs	138	11	72	44	11	138	11	72	44	11
Model Rating	BBB	BBB+	BBB	BBB+	BBB	A-	A	BBB-	AA	AA+
AAA Spread	0.30	0.30	0.29	0.30	0.35	0.30	0.30	0.29	0.30	0.35
Model Rating Spread	3.11	2.58	3.30	2.89	3.32	2.53	2.25	3.50	1.40	1.01
Spread Dif (%)	2.82	2.28	3.01	2.59	2.97	2.23	1.94	3.21	1.11	0.66
Value Dif ($millions)	124.99	92.63	70.28	210.41	168.72	81.39	81.09	73.97	106.75	28.88
Sample Dif ($billions)	17.25	1.02	5.06	9.26	1.86	11.23	0.89	5.33	4.70	0.32
Dif in AAA Portion	0.21	0.17	0.18	0.21	0.24	0.13	0.15	0.19	0.11	0.04
Dif in CDO Portion	0.16	0.12	0.13	0.18	0.18	0.10	0.11	0.14	0.09	0.03