Did Subjectivity Play a Role in CDO Credit Ratings?

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ABSTRACT

Analyzing 916 CDOs issued from January 1997 to December 2007, we find that direct outputs from a rating agency model are more straightforward and accurate than actual ratings assigned to CDOs. Actual sizes of AAA rated tranches are on average 12.1% larger than implied by the rating agency model. These adjustments to the rating agency model are difficult to explain by possible determinants but exhibit a clear pattern of low model-implied AAA CDOs receiving larger adjustments. CDOs with larger adjustments experience worse subsequent performance. Moreover, prior to April 1, 2007, 91.2% of AAA rated notes only comply with the credit rating agency's own AA default rate standard. Had the credit rating agency followed its model and default standards AAA rated tranches would on average have been rated BBB, resulting in a 20.1% lower valuation.

In discussions regarding the causes of the recent financial crisis, the role of collateralized debt obligations (CDOs) is of central interest. Securitized instruments like CDOs are thought to be not only a driving force behind the housing market boom but also largely responsible for the damage to the banking sector.[1] Most CDO notes issued prior to mid-2007 were AAA rated. However, in mid-2007 CDOs began to experience large losses followed by massive downgrading of formerly AAA rated tranches in 2008 and 2009. How could historically trusted credit ratings suddenly become so unreliable?

In this paper we examine the CDO credit rating process in three main ways. First, we gain insight into the credit rating modeling process by comparing a credit rating agency's direct model output to a simple Monte Carlo simulation. Second, and more importantly, we examine what the rating agency does beyond its formal modeling process by analyzing 'adjustments' to its direct model outputs. We explore the relation between these adjustments and future performance. Third, we analyze the consistency of default probability standards (which are used to tranche the CDO) across time.

Rating agencies have been scrutinized and criticized by the media, regulators, members of Congress, investors, and even the CEOs of the CDO underwriting firms on their role in the recent credit crisis.[2] A central question being asked is whether credit rating agencies knowingly gave inflated CDO ratings or if they truthfully provided their best credit risk assessment based on available information at the time. Stulz (2008) argues that knowing whether a risk was mis-assessed and the

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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. Longstaff (2008) demonstrates contagion effects in 2007 from the asset-backed CDO market to the Treasury bond and stock markets. Gordon and Metrick (2009) argue that the deterioration in the subprime CDO market precedes a banking panic in the shadow banking system (dominated by securitization). Longstaff and Myers (2009) show that CDO equity and bank stock equity are mostly driven by a common factor. In terms of the boom prior to the crisis, Deng, Gabriel, and Sanders (2009) link the CDO market to lower spreads of subprime mortgage backed securities (MBS) and Shivdasani and Wang (2009) and Benmelech, Dlugsov, and Ivashina (2009) find that CLOs provided dominant financing at a low cost for the leverage buyout boom.

[2] For a discussion of the controversies surrounding rating agencies in CDO ratings see Mason and Rosner (2007), CESR (2008), and Bank for International Settlements (2008).

nature of the mistake is crucial for risk management practice. It seems apparent that understanding the CDO rating process is an integral part of learning economic lessons from the crisis. While there is no shortage of opinions and commentary, there has been relatively little empirical examination of the structured finance credit rating process around the time of the crisis.[3]

Several interesting problems with CDO valuation have been raised. First, Coval, Jurek, and Stafford (2009a) show that the most senior tranches of CDOs should demand a much higher risk premium than the observed value. Second, it is conceivable that an 'economic catastrophe' simply occurred, though compelling evidence from Longstaff and Rajan (2008) would indicate that this possibility is improbable.[4] Third, CDO market participants may have held unrealistic assumptions regarding key model inputs such as housing market prospects and default correlations.[5] Coval, Jurek, and Stafford (2009b) demonstrate that CDO valuation models hinged on a high degree of confidence in the parameter inputs. Fourth, lax standards (Keys, Mukherjee, Seru, and Vig (2008), and Mian and Sufi (2008)), fraud (Ben-David (2008)), or increasing reliance on hard information (Rajan, Seru, and Vig (2009)) in the mortgage origination process can inflate the collateral quality of mortgage related CDOs. Finally, rating analysts could make coding errors.[6] In contrast to these papers, our goal is to systematically examine fundamental mechanics of the actual rating process and separate some of the qualitative from the quantitative (model-driven) aspects.

[3] Important exceptions which we will discuss in more detail include Coval, Jurek, and Stafford (2009a, 2009b) and Benmelech and Dlugosz (2009a, 2009b), for CDO credit ratings, and for MBS credit ratings, An, Deng, and Sanders (2008) and Ashcraft, Goldsmith-Pinkham, and Vickery (2009).

[4] Deven Sharma, President of S&P explains the deterioration as a rare unanticipated event and states, "Virtually no one — be they homeowners, financial institutions, rating agencies, regulators, or investors — anticipated what is occurring." [Testimony of Deven Sharma before U.S. House of Representatives, Oct. 22, 2008.] Longstaff and Rajan (2008) find that the CDX index between 2003 and 2005 was priced such that CDO losses of 35% could occur every 763 years. Hence, 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] Sanders (2008) demonstrates the sudden increased comovement and delinquency of housing markets since 2005. Demyanyk and Van Hemert (2009) argue that subprime loan quality has been decreasing for six years before the crisis.

[6] The Financial Times uncovered computer modeling error for constant proportion debt obligations (CPDO), a type of CDO with high leverage, at Moody's [Jones, Tett, and Davies (*Financial Times*, March 20, 2008)] and S&P has disclosed some limited admission of CPDO computer error for five deals [Duyn and Chung (*Financial Times*, June 13, 2008)]. CPDOs are not in our sample.

A recent U.S. Securities and Exchange Commission (SEC, 2008) report discusses potential conflicts of interest in the credit rating agency (CRA) industry, but stops short of calling for any major policy changes. In congressional testimony on October 22, 2008 the views of the major CRAs can largely be summed up by, "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] Despite accusations, the statement seems correct in that any evidence of mishandling is mainly limited to a few embarrassing emails in an SEC examination of over two million emails.[8]

To analyze rating practices, we compile a database of 916 CDOs originally issued between January 1997 and December 2007. The data contains comprehensive information used in the rating process from one of the three major credit rating agencies. To gauge a rough, but useful, benchmark for what the credit rating agency's model is producing, we first compare the CRA model output for the fraction allocated for the 'AAA'[9] tranche to that from a simple Gaussian Copula Monte Carlo simulation model. In the simulation we use the same collateral asset information (average collateral quality, correlation, maturity) provided by the CRA, but our output should not match exactly as we are not privy to individual asset information and recovery rates. Nevertheless, we find a correlation of 0.82 between our simple simulation and the CRA model.

After ascertaining the formal modeling process outputs are fairly standard, we move on to examining that beyond the formal CRA model. Interestingly, the proportion of the CDO eligible for

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7 Direct quotes of Deven Sharma, President of Standard and Poor's, from testimony before U.S. House of Representatives on October 22, 2008.

8 Probably the most well known and quoted email in the press 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.'"

9 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.

AAA status under the CRA model exhibits a correlation of only 0.49 with the actual proportion rated AAA—formal modeling is only half the story for the determination of credit ratings. We define as the AAA 'adjustment' the difference between the proportion of a CDO rated 'AAA' in actuality and the proportion assigned AAA according to the CRA model. Adjustments can be positive or negative but we find that 84% of adjustments are positive and that, on average, adjustments amount to an additional 12.1% of AAA at the time of issue.

We examine whether manager experience and credit enhancements such as insurance, liquidity provisions, and overcollateralization can explain the AAA adjustment. We find that they do not. However, over half of the cross-sectional variation in adjustments can be simply explained and negatively related to the AAA proportions assigned by the CRA model. For the smallest quintile of 'AAA' implied by the CRA model, the model yields 42.6% AAA, but the adjustment adds another 26.8% for a total issuance amount of 69.4% AAA. In the top quintile the adjustment is essentially zero and the CDO has 85.3% AAA. Adjustments can help explain why 'AAA' CDO tranches are large and similar in size despite varying CDO structures. Ordered logit and probit regressions indicate that the amount of adjustment at the time of CDO issuance is positively related to future downgrades through July 31, 2009—adjustments to the CRA model appear to have been harmful for future CDO performance.

Are adjustments to the AAA tranche size the only problem of CDO credit ratings? We scrutinize CRA model inputs including rating default probability criterion, e.g., whether AAA ratings have the appropriate level of default risk. We document an empirical irregularity: Only 1.4% of AAA CDOs closed between January 1997 and March 2007 met the rating agency's reported AAA default standard. The rest fell short. We find that the shortcoming was systematic and in 92.4% of cases, the AAA CDOs only met the AA threshold for the default probability criterion. This practice changed around April 1, 2007 when most CDOs began to comply exactly with the stated default criterion. This pattern is for all CDO first-time surveillance reports. For CDOs issued prior to April 1, 2007, their follow-up reports (after April 2007) continued to adhere to the old pattern of criterion deviations. This difference amounts to an extra 2.7% AAA but is potentially additionally important because CDOs are often rated at the edge.

Finally, we assess dollar value of adjustments and default standards by examining what ratings would have been on AAA tranches in the absence of adjustments, given actual expected default probabilities. We estimate that the AAA tranches would have been rated BBB on average. Given the average BBB to AAA yield differential, this rating effect would have led to approximately a 94.13 million dollar value 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, it is a potential understatement as we scrutinize only one aspect of the credit rating process.

Our study adds to several strands of literature. Longstaff and Rajan (2008) present the first set of empirical evidence on CDO valuation. An, Deng, and Sanders (2008) find that CMBS ratings are hard to fully explain. Benmelech and Dlugosz (2009a) provide a detailed account of CLO rating features and Benmelech and Dlugosz (2009b) find evidence of potential CDO rating shopping.[10] Our empirical focus complements recent theoretical models of credit ratings[11] and is related to the more general debate regarding rating standards.[12]

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[10] There is also a broader literature on securitization. Ashcraft and Schuermann (2008) meticulously explain the MBS securitization process and its potential drawbacks. Duffie (2007) discusses the costs and benefits of CDOs and other credit risk transfer tools. Stulz and Johnson (1985), DeMarzo (2005), Leland (2007), Parlour and Plantin (2008), and Brennan, Hein, and Poon (2009) provide theoretical justifications for securitization.

[11] This recent but growing body of work includes: Bolton, Freixas, and Shapiro (2009), Damiano, Li, and Suen (2008), Farhi, Larner, and Tirole (2008), Mathis, McAndrews, and Rochet (2009), and Skreta and Veldkamp (2009), Opp and Opp (2009), and Sangiorgi, Sokobin, and Spatt (2009).

[12] In bond ratings, Cheng and Neamtiu (2009) find that rating agencies have been improving in their accuracy, timeliness, and volatility post Sarbanes-Oxley Act; Jorion, Shi, and Zhang (2009), in contrast to Blume, Lim, and MacKinlay (1998), find no evidence of tightening standards after controlling for accounting quality. Bongaerts, Cremers, and Goetzmann

The rest of this paper is organized as follows. Section I provides the industry background of CDO credit rating. Section II describes the data, descriptive statistics, and compares a simple simulation approach to the CRA model. Adjustments to the credit rating agency model are analyzed and related to subsequent downgrades in Section III. A deviation from the publicized default criterion is discovered in Section IV, and Section V calculates the economic importance. Section VI concludes.

I. The CDO Rating Process

A. Issuance and Rating Process

CDOs operate like highly leveraged investment companies with multi-layer debt structures of different seniorities and a nominal 'equity' tranche.[13] Issuers borrow capital from debtholders to purchase credit-related assets: which are lightly managed, used as collateral, and overseen by a trustee. Underwriters are often in charge of both structuring the deal and arranging the notes placement but the two functions are occasionally separate. CDO tranche notes are offered to investors through private placements in the primary market. Unlike conventional security issuances in which investors focus on price and quantity, CDO notes offerings have three distinctive features. First, the entire deal structure (i.e., size of each tranche, coupon rate, priority, etc.) is subject to substantial modification before issuance. Second, the success of issuance is contingent on obtaining a minimum rating for each tranche of the CDO. Third, CDO structurers have free access to rating agency software, so probable rating model outcomes are often known to the structurers prior to the solicitation of ratings.

(2009) find that multiple CRAs provide certification and Becker and Milbourn (2009) argue that competition has hurt rating quality.

[13] Longstaff and Rajan (2008), Benmelech and Dlugosz (2009a), and Sanders (2009) present overviews of CDO structure. Like corporate equity, CDO equity holders are residual claimants. Unlike corporate equity, CDO equity holders usually do not have all control rights. CDO equity is often called 'preference share', among other names.

Ratings are a focal point of primary offerings for CDO notes. Many CDO investors have a limited amount of reliable information before the deal closing and uncertain expectations about the going-concern value of CDO notes after closing. Ratings provide useful references for primary market transactions (and secondary market trading). It is almost always critical for issuers to secure target ratings before the notes issuance. Indeed, CDO prospectuses typically specify minimum ratings from particular rating agencies as preconditions to the issuance.[14] These ratings requirements can pose challenges to the issuance. If the underwriter is unable to obtain desired ratings from specified rating agencies then it must change the deal structure, such as the tranche size and control rights.

Simultaneous to the road shows for investors by the sales/marketing team, usually the structuring team of the underwriter (on behalf of the issuer) submits the CDO term sheet to the business manager of one or multiple credit rating agencies. The business manager then forwards the rating request to a rating analytical manager for preliminary evaluation. These two groups will decide whether to rate the deal. If the rating agency agrees to rate the deal, the underwriter will provide more detailed information to the rating committee for formal assessment. At this stage, the collateral asset pool is often incomplete and the rating analyst will conduct credit risk analysis based on projected collateral characteristics.[15] The CRA and underwriter may engage in discussion and iteration over assumptions made in the valuation process. If the underwriter and CRA cannot agree, then the underwriter can pay a small contract breaking fee and potentially use ratings from another rating agency.

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[14] For example, the offering memorandum for a cash flow ABS CDO called *Independence III CDO, Ltd.* states, "It is a condition of the issuance of Offered Securities that the Class A Notes be rated at least "AAA" by Standard & Poor's, a division of the McGraw-Hill Companies ("Standard & Poor's"), and "Aaa" by Moody's Investors Service, Inc." (Summary of Term, Ratings Section, page 14).

[15] 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.

Once the rating committee is ready to release preliminary ratings, a pre-sale report will be published on the deal and distributed to potential investors. At the closing date, the deal will be priced and allocated to investors according to the bids accumulated during the book-building process.[16] After closing, the CDO manager uses the proceeds raised from investors to 'ramp up' the collateral pool. The trustee oversees the operation of the CDO and keeps relevant parties informed. The surveillance analyst assigned by the rating agency will monitor the performance of the CDO using data from the trustee and the manager. Ratings are adjusted if necessary over the life of the CDO.

B. Credit Rating Methodology

Rating agencies assign individual corporate credit ratings according to expected probability of default or expected loss rate. A similar concept is applied to CDO ratings. Generic CDO models are public knowledge and discussed in detail in Sanders (2009).[17] To judge the probability of default for each tranche, one needs to compare future cash inflows generated by assets to the liability payments. Default occurs when cash inflows cannot cover the payments on time for a tranche. However, there are no assets specifically referring to a particular tranche but rather all assets as the entire collateral asset pool.[18] Next, the rating analyst needs to make assumptions on a recovery rate for each individual collateral asset, and, more importantly, the default correlation among collateral asset obligors. Equipped with these assumptions, rating analysts can derive an expected loss rate distribution associated with the collateral pool under different scenarios through simulations such as

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[16] 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. The CRA will typically release a new issue report shortly after the closing date (usually when the collateral assets are fully ramped).

[17] Our descriptions are primarily based on CRA published documents, Moody's (1998), S&P (2002), and Fitch (2006), as well as conversations with industry insiders.

[18] The rating analysts will need to supplement unrated collateral or missing asset information.

the Gaussian Copula method described in Supplementary Appendix A.[19] Hence, these scenarios are known as scenario default rates (SDR) and are analogous to finding Value-at-Risk (VaR) at a given confidence level.

The rating analyst will use the collateral asset pool's expected loss rate distribution to define a set of scenario default rates (SDRs) that will occur with expected frequencies of default. For a desired cumulative probability of portfolio loss rate, denoted D, one can back out the scenario default rate (SDR) such that $\Pr(\text{loss rate} \geq SDR) = D$ using the loss rate distribution. For example, the 'AAA' scenario is the rarest scenario with an extremely low D. Each rating agency derives its own default rate criteria from proprietary historical default databases. CDO rating software (such as Fitch's VECTOR, Moody's CDO ROM, and S&P's CDO Evaluator) specifically incorporates these "default criteria" (D) as inputs. They are presumably the same across CDOs and only vary with maturity.

Supplementary Appendix Table AI contains the AAA CDO "default criterion" for maturities from one to ten years from Fitch, Moody's, and S&P.[20] For example, Fitch's 7-year cumulative AAA CDO default criterion is 0.08%. Hence, the AAA scenario default rate is chosen such that the probability of the collateral portfolio loss rate exceeding the SDR is no more than 0.08% over the next seven years. A 30% 'AAA' SDR would mean that the collateral portfolio is very unlikely to lose more than 30% according to a historical corporate bond default experience. Although the AAA default criterion is fixed for a given maturity, the scenario default rate will vary across CDOs with different expected loss rate distributions.

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[19] S&P and Fitch always use the Gaussian Copula simulation method. Moody's initially uses the Binomial Expansion Technique which captures default correlation through its diversity score (DS) framework. In 2004, Moody's adopted the simulation method as well. Vasicek (1987) provides analytical measures of portfolio credit risk.

[20] Note that the criteria across different CRAs are not directly comparable as Moody's and Fitch criteria refer to Weighted Average Rating Factor (WARF), which corresponds to rating and default probability but S&P uses default probability directly. (The rating factors correspond to the ten-year idealized default probabilities for Moody's and Fitch.) Additionally, the actual default rate criteria tabulated in the CDO valuation tools provided by credit rating agencies are not identical to historical corporate bond default rates.

Apart from the credit risk modeling over the collateral pool, each tranche must undergo a separate cash flow analysis. The underwriter conducts cash flow simulations to obtain projected risk levels for each tranche of the CDO.[21] Many scenarios with various market conditions such as default timing patterns, interest rates, and recovery rates are considered for the cash flow simulations.[22] Under each scenario, simulations, say 10,000 runs, will produce 10,000 sets of loss rates for the collateral assets and for the specific tranche. Those 10,000 collateral asset loss rates are ranked. The highest collateral pool loss rate associated with a zero loss rate for the tranche is the break-even default rate (BDR) for the referred tranche under this scenario.[23] If 64 scenarios are considered, then the minimum of the 64 BDRs is the maximum loss rate the tranche can withstand under any scenario. In other words, the BDR is the highest loss rate resulting from the worst cash flow scenario under which the tranche will still receive timely interest payments and ultimate principal.

The key requirement for the credit rating agencies to issue a rating on a tranche is that the break-even default rate from the cash flow analysis is greater than the scenario default rate from the CRA risk analysis (BDR>SDR). For example, if a tranche can withstand a 30.72% (BDR^{AAA}) loss according to the cash flow analysis, but the collateral pool is not expected to lose more than 30% under the AAA scenario (SDR^{AAA}), then the tranche can obtain an AAA rating.[24] Rating updates for existing CDO tranches (upgrade, downgrade, affirmation) are conducted in a similar fashion. However, the triggers to initiate a rating update are the threshold values for overcollateralization

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21 Although it is the underwriters' responsibility to provide the cash flow risk assessment, tools for cash flow analysis are freely provided by the rating agencies and available to CDO investors and underwriters.

22 The rating agencies often specify certain scenarios, including stressed ones, for the deal structurer to include in the cash flow analysis. If four default timing patterns, four interest rates, and four recovery rates are considered then a total of $4 \times 4 \times 4 = 64$ cash flow scenarios will be run.

23 We follow S&P's terminology. Other rating agencies such as Moody's, Fitch, and DBRS use similar approaches. S&P relaxed the procedure on June 19, 2006 and used the 5% percentile instead of the minimum for AAA rating Break-even Default Rate.

24 Although in the final version BDR must be greater than SDR, those BDR and SDR numbers could be the outcome of several iterations between the underwriter and credit rating agency. It is common that the underwriter has already estimated the SDR for the proposed deal structure prior to estimating the cash flow analysis.

(OC) ratios and interest coverage (IC) ratios which are specified in the prospectus and rating reports for different classes of the CDO tranches.[25] Tranches could be put on a watchlist with positive or negative outlook if the ratios get close to the thresholds. If the coverage tests fail, the CDO structure will unravel and affected tranches could be downgraded.

C. Beyond Modeling

For a generic credit portfolio, the tranche amount admissible for an AAA rating according to the level of expected default rate specified by the CRA credit risk model is $1-SDR^{AAA}$. Hence, we define $1-SDR^{AAA}$ for a given rating as the AAA 'CRA model fraction' since this is literally the most 'AAA' that can be justified under the rating agency's AAA default rate. Nevertheless, actual tranche structure does not always exactly correspond to the model fraction. The difference between the CRA model fraction (1-SDR) and the actual tranche size bearing such rating is not documented and does not have an industry nomenclature that we are aware of. We refer to this simply as the 'adjustment' (to the CRA model). For further clarification, we demonstrate the use of SDR, BDR, and adjustment of an actual CDO in Supplementary Appendix B.

It is unclear exactly how actual ratings can differ from CRA credit risk models. Historically, credit rating agencies do make it clear that the quality (or experience) of the collateral manager, legal documentation, structure of the cash-flow waterfall, insurance, the nature of the hedges, and liquidity considerations are all important considerations.[26] For example, the structure of the CDO may include insurance from an outside insurer ('wrap') for certain (senior) tranches, making them

[25] The overcollateralization ratio for a particular tranche is collateral par value divided by the size of this tranche and all tranches senior to it. The interest coverage ratio is the interest payments from collateral assets divided by the interest to the tranche and all tranches senior to it.

[26] See, Moody's (2003, page 11, 18), S&P (2002, pages 15-16, 54-60), Fitch (2006, pages 1, 17-19). Fitch (2006, page 1) states that "ratings are ultimately the result of a formal committee process and not simply model output." Moody's (2003, p. 18) states, "The most difficult part of rating any CDO is in reconciling the model and documentation with the risks inherent in the structure. Clearly, the relationship between the quantitative and qualitative analyses for synthetic CDOs is especially crucial." In a later document, Moody's (2009b) is more explicit and states, "we stress that the result is a 'modeled' rating; the ratings that Moody's actually assigns are determined by a rating committee and reflect both quantitative and qualitative considerations and may deviate from the 'modeled' rating."

less risky by transferring the credit risk to the insurer. The underwriter may also bring in liquidity facilities that could improve the CDO's resilience against market stress.[27]

It is important to note that the features of CDOs described above are not described as inputs into the credit rating agency risk models. Hence, there are two main possibilities for how actual AAA fractions could differ from the CRA risk model. The first alternative is that the above factors may be incorporated into the cash flow analysis (and hence BDR), potentially resulting in a large gap between the BDR results and that of the SDR (from the CRA model). If this is the case, we would expect to see a large difference between the BDR and SDR to be positively associated with large adjustments. The second alternative is that the specialized elements of the deal may be adjustments that are beyond any model or 'out-of-model.'

D. Empirical Implications

The above discussion of the CDO credit rating process points to several natural directions of empirical investigation. First, we will see how close we can replicate the CRA credit risk models with a simple Monte Carlo Simulation. This will help us determine the complexity of the credit rating agency approach. Second, we will examine adjustments to the CRA model. We can see if any differences are related to the cash flow analytics by comparing BDRs (from cash flow analysis) to SDRs from the credit rating agency model. Additionally, we examine the connection of the CDOs to some of the more quantitative structural elements such as insurance and liquidity provisions. Finally, we will examine the consistency of application of the default risk criterion (D).

[27] These include a revolving line of credit, a put option, or swap agreement. Senior tranche holders usually control collateral liquidation timing and managers have different experience and facilities.

II. Data and Approximating the Rating Agency Model

A. Data and Descriptive Statistics

CDOs are placed via private channels and hence information on the underlying collateral to value the CDO is difficult to obtain. Trustees are the book-keepers and responsible for collecting and reporting all material information to investors, underwriters, and rating agencies (or any other party not directly related to the CDO through special arrangements.) Rating agencies compile data from trustee reports and disseminate it to professionals. All three rating agencies host online CDO data services[28] that are the main investment tools for many CDO investors and managers, especially for a firm without an in-house CDO research team. Our dataset is obtained directly from one of the three major credit rating agencies. We focus only on CDOs with collateral asset information and default risk estimates (i.e., SDRs) available from credit rating models. This dataset contains asset, liability, and rating information for a set of 916 CDOs issued between January 1997 and December 2007. The most unique element of our data is the detailed description of the CDO asset pool, the inputs and parameters going into the rating agency's model, and the rating agency model outputs such as SDRs. We also obtain much coarser deal structure (tranche size, deal type, payment frequency, etc.) and ratings data from SDC.

To put the CDO data in the greater debenture universe, we also gather corporate debentures from the Fixed Income Securities Database. Panel A of Figure 1 shows the global rating distribution of corporate debentures (160,689 rated issues) and CDOs from the rating agency database (5466 rated tranches from 916 CDOs) over the same January 1997 to December 2007 period. For corporate debentures, the top rating of AAA counts for 11.6% of the total rating issuance value, non-AAA investment grade for 63.8% (13.7% AA, 29.1% A, and 21.0% BBB), and below

[28] Such as Moody's CDOCalc, S&P's CDO Interface, and Fitch's S.M.A.R.T.

investment grade 24.6%.[29] Nevertheless, over the same time period, the rating distribution for CDOs paints a starkly different picture: among all rated issuances, 84.1% AAA, 14.5% non-AAA investment grade (6.0% AA, 4.6% A, and 4.0% BBB), and 1.4% below investment grade. This highlights the prevalence of CDO AAA ratings in contrast to corporate AAA ratings.

Corporate bond AAA ratings are very stable. About 88% of AAA ratings maintain their AAA status over the one-year horizon between 1920 and 2008 (Moody's (2009a)). At their early stage, AAA CDO tranches were as stable as AAA corporate bonds (S&P (2007) and references therein). However, staggering downgrading started in August 2007. We track CDO AAA ratings from inception to July 31, 2009 and find that, as shown in Figure 1 Panel B, only 36.9% of the CDO's original AAA ratings were intact (including some CLOs in the process of being downgraded), while 31.2% were downgraded to CC, and 3.9% to D.[30] Similar large magnitudes of downgrading but with details by vintage and type are described by Benmelech and Dlugosz (2009b). A question that naturally arises is what caused AAA CDO capital to be downgraded so quickly?

Table I provides our summary statistics for all CDOs with collateral information in the first rating agency surveillance reports. 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. (ABS CDOs and CDO^2s are often referred to as structured finance CDOs.) Panel A of Table I shows that our sample is dominated by

[29] Note that these numbers do not include the unrated equity portion which is on average 8.16% of the CDO.

[30] ABS CDOs and CDO^2s are most directly related to the crisis originated in the subprime mortgage market downgraded first and continuing into early 2009. For AAA rated tranches, 78.6% of ABS CDOs and 63.0% of CDO^2s in our sample have been downgraded. CBOs are issued mostly before 2002 and some have matured. Large scale downgrading in CLOs started only in April 2009. In our data of AAA ratings, 24.0% of CBOs and 30.0% CLOs have been downgraded. Moody's is undergoing 'global rating sweep' for CLOs as of August 2009 (Moody's (2009d)).

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.

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+ which is the same collateral ratings for the CLO sample of Benmelech and Dlugosz (2009a). This is followed by CBOs with an average collateral rating of BB-. Structured finance CDOs have much higher rated collateral. ABS CDOs have collateral ratings that are A- (which is the same as in Benmelech and Dlugosz (2009b)), while CDO^2s on average have a BBB collateral rating. The correlation and maturity of the collateral also display similar patterns. CBOs and CLOs usually have a shorter maturity with a lower default correlation. ABS CDOs and CDO^2s have a longer maturity and a 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. Notwithstanding the variation in CDO compositions, the AAA portion of the CDOs is highly consistent across collateral types. The average CDO has 75.5% rated AAA when counting the super senior tranches as AAA. This portion ranges from 71.5% for CDO^2s, 72.6% for CLOs, 72.8% for CBOs, and 79.8% for ABS CDOs.

We also collect credit enhancement information such as overcollateralization (an asset-liability ratio), insurance ('wrap'), and liquidity facility.[31] Overcollateralization ratios over the entire deal are below one for CBOs and CLOs. CDO insurance could come in two forms. The first type is included in the CDO structure so that the insurance premium is paid by the CDO issuer out of asset receivables. In this case insurance premium payment is senior to AAA tranches. The second type is bought by CDO investors from the secondary markets. The premium will be paid by CDO investors directly. The latter type of insurance is similar to a credit default swap (CDS). Only the first

[31] Note that these numbers are from the first reports after ramp-up.

type of insurance matters to the CDO ratings as it is part of the structure (credit enhancement). Only a small fraction, 6.1%, of the sample CDOs is wrapped. In percentage terms, CBOs are insured more often than other CDOs. Liquidity facilities, such as a revolving line of credit are present in 23% of the sample. Panel B contains the correlation matrix of above variables. Most notably, lower quality collaterals have lower default correlations.

B. Simulation Approach to CDO Valuation

In order to peer into the CRA modeling process, we need a straightforward benchmark for comparison purposes. Because it is the most widely used by professionals, we choose to use a Gaussian Copula Monte Carlo Simulation model described in Supplementary Appendix B as the baseline model. This model is also used by Bloomberg to provide benchmark prices for traders. The inputs and parameters for the simulation are: average collateral asset default rate, average collateral asset maturity, average pair-wise correlation among assets, number of assets in the collateral pool, average recovery rate for collateral assets in the pool, and the default probability criterion. All of the above values are available in the database except for recovery rates, which we assume to be 40% for all CDOs and is common practice for both empirical research and CDS traders.[32] It is important to note that we estimate our simulation using average CDO characteristics (collateral rating and asset correlation) used by the CRA.

The primary use of the simulation model is to generate a collateral asset pool default risk measure such as the scenario default rate. For each credit rating, we can calculate the SDR given the rating default rate criterion. Because of its paramount importance for CDOs, we focus on the AAA rating.[33]

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[32] These recovery rates refer to collateral asset recovery rates. The tranche notes recovery rates are endogeneously generated in the simulations.

[33] For example, on October 20, 2006, the collateral pool of 1776 CLO I consists of 210 assets from 91 obligors with average rating B+, average default probability 3.72%, average maturity 6.24 years, average correlation 0.22. If we define

C. How Close Can Our Simulation Approximate Rating Agency Models?

Figure 2 plots the model AAA fraction (1−AAA SDR) from our Monte Carlo simulation as compared to the output from the CRA with identical (average) inputs. We categorize the results by CDO type (CBO, CLO, ABS CDO, and CDO^2) and structure (cash and synthetics). Overall, for most CDOs, the points are fairly close to the 45 degree line indicating that there is not a large deviation between our simulation and that produced by the rating agency. The observations generally fall below the line indicating that the CRA model gives slightly more AAA fraction than our simple simulation. The two models have a correlation of 0.82.[34] As shown in Table AII, on average, the credit rating agency model yields an AAA fraction of 0.63 while our Monte Carlo yields 0.58.

Overall, it appears that we can replicate outputs from the credit rating agency model reasonably well given the same set of inputs. The high correlations, despite the simplicity of our model, suggest that the CRA approach must be fairly standard. To shed light on the difference between our simple simulation model and the CRA model, we regress AAA fraction difference (CRA model over our model) on CDO structural characteristics in Table II. In regression (1), we consider CDO features directly related to our simulation approach. The 0.456 adjusted R^2 from the CDO structural variables indicates that indeed the models are systematically different. Specifications (2, 3, 5, and 6) show that the differences between the model and the CRA fraction are not largely related to manager experience or credit enhancement features (overcollateralization, liquidity, and insurance). Since our simulation does not consider these features, the regression on the differences indicates that these features are not critical considerations in the CRA model as hypothesized and

AAA default rate criterion as 0.21% and recovery rate upon default as 40% for all collateral assets, then the AAA SDR for such a collateral pool after 10,000 simulations is 0.465 which implies an AAA tranche size of 0.535.

[34] We also use the Vasicek (1987) approach as described in Supplementary Appendix A and find an average correlation of 0.43 between the Vasicek proportion of AAA and that from the CRA model.

discussed in Section II.B. This indicates that their incorporation takes place in the cash flow analysis or outside of modeling as we will analyze in the next section.

Specifications (4-6) show that CDO type is somewhat important. Since recovery rate assumptions for the CRA generally differ across CDO type and we are not privy to this information, we suspect that these differences may be proxying for unobserved differences in recovery rates. We also include year dummies in specification (6) and show that those dummy variables are insignificant in most years but increases slightly in 2007. This indicates that the CRA model likely did not change much over the period with the possible exception of 2007.

The differences between our simulation and the CRA model could be due to several factors. First, we use only average collateral characteristics rather than the more detailed characteristics that the CRA has access to. For example, imagine two deals with an average collateral rating of A. The first has all 'A' rated collateral, whereas the second has a combination of AAA and CCC rated collateral. One would expect the specificities of the collateral to lead to important differences in the final CRA model. Second, as stated previously, we are not privy to the exact asset-specific or tranche-specific recovery rate assumptions. Third, our simulation approach is rather simple in contrast to the models that credit rating agencies spend substantial resources to perfect.

Given these limitations, we are surprised that the simple Gaussian Copula Monte Carlo approach replicates the credit rating agency model closely. Moreover, nearly half of the differences between our simple approach and the rating agency model output can be explained by a linear combination of model inputs. Our results indicate that the credit rating agency modeling approach is fairly conventional but we do not rule out model error. The findings suggest that the model error is likely to be either systematic across large parts of the sample, or limited to the difference between the rating agency model and our simple benchmark.[35]

III. Beyond Rating Agency Modeling

In this section, we examine the difference between the fraction assigned as AAA for a CDO according to the credit rating agency model and the fraction of the CDO actually rated AAA. We document these adjustments by examining their magnitude, stylized features, and their efficacy and relation to subsequent CDO downgrades.

A. AAA Adjustments

Panel A of Table III shows that over the whole period for the 916 CDOs on the first surveillance report after issuance, the actual fraction of the CDO issued AAA is 75.5 percent whereas the CRA model yields 63.4 percent AAA. Hence, the difference between the amount of AAA issued and that allowed by the CRA model (the adjustment) is 12.1 percent on average. The adjustment is smallest for ABS CDOs (8.1 percent) and CBOs (10.4 percent), and largest for CDO^2s (14.7 percent) and CLOs (16.0 percent).

The adjustments are large in the early years of the sample but there are also few observations here. Adjustments are at their lowest in 2003-2004 but increase each year until the last year we have new issues, 2007. In 2007 the average adjustment is 0.182. Interestingly, the adjustments in 2007 are also higher in all the different types of CDOs as well.

Panel B shows the cross-sectional correlation between the credit rating agency model and the actual amount of AAA given. The correlation is only 0.49. Since the actual amount of AAA given and that from the CRA model differ only by the adjustment, this indicates that the adjustment

[35] Also, it is important to recognize that our approach is not subject to questions regarding key assumptions since we use the actual stated rating agencies assumptions for key standards such as the underlying asset correlations. Examining whether there was an assumption error in these key inputs is an important area for future research.

is obscuring a large part of the relation between the CRA model and the final proportion rated AAA. The adjustment exhibits a positive correlation of 0.27 with the final amount of AAA given. However, the adjustment is strongly negatively correlated (correlation coefficient -0.71) with the amount of AAA given by the CRA model. In other words, CDOs with low model implied AAA fractions receive larger adjustments.

To examine this relation in a non-linear manner, we sort each type of CDO at issuance into five groups based on the amount of AAA specified by the CRA model. Figure 3 shows a monotonic pattern where the AAA adjustment is largest in CDOs that receive the lowest 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 in the lowest quintile would have only received 29 percent AAA without the additional 47 percent adjustment enabling a total AAA rated fraction 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.

B. Explaining Adjustments

Why do adjustments exist? To understand the driver of this adjustment, in Table IV we regress the AAA adjustment on variables that credit rating agencies stress to be important but would be difficult to incorporate in a formal simulation model (as discussed in Section I.C.). Our first variable is experience in the form of a commonly discussed proxy, the past deals performed by the collateral manager. The variable enters with some statistical significance but a trivial adjusted R^2. Manager experience will become insignificant in the presence of other deal related information (specifications 5, 6, and 7). Other important CDO credit enhancements are overcollateralization, insurance, and liquidity. Specification 2 shows that of the three, overcollateralization has the most importance for explaining adjustments. However, it enters with a negative sign, suggesting that overcollateralizing the CDO would lead to less, not more, AAA; opposite to the effect hypothesized. In later specifications with more controls, the insurance variable enters with a positive sign, indicating that CDOs with insurance do receive a slightly larger adjustment.

In specification 3 we include the fraction of AAA from the CRA model (CRA AAA as shown previously in Figure 3) and here the variable enters with a strong negative coefficient and the adjusted R^2 of the model jumps to 0.503. In specification 4 we include the potential determinants of deal rating and we find that these increase the adjusted R^2 only to 0.569. Since overcollateralization enters with the opposite sign, we estimate specification 5 with the CRA AAA and overcollateralization and find an adjusted R^2 of 0.562. Hence, the incremental explanatory power of the past deals performed by the manager, insurance, and liquidity can only explain a trivial 0.007 of the cross-sectional variation in the adjustment.

It is possible that adjustments were made by comparing the CRA model with a traditional alternative such as the Vasicek model. However, including the amount of AAA predicted from the Vasicek and our Monte Carlo simulation model (specification 6) 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. We also include year-by-year dummy variables with 2004 and before as our base case. Consistent with the simple summary statistics, adjustments are larger in 2005 (0.02), 2006 (0.029), and especially 2007 (0.059). This result is potentially consistent with the declining standards in MBS ratings from mid-2005 to mid-2007 documented by Ashcraft, Goldsmith-Pinkham, and Vickery (2009). Specification 8 shows that

CDOs rated by multiple credit rating agencies receive similar-sized adjustments, possibly indicating the adjustment phenomena may be present at other brokerage houses as well.

We must note that like most analyses, our specifications cannot rule out an unknown omitted variable that is highly correlated with the amount of AAA from the CRA model.[36] Nevertheless, to the extent that there are missing variables that are quantitative in nature then they might be captured in the secondary cash flow analysis and hence show up in the break-even default rate which comes from the cash flow analysis. As discussed in Section I.B., one possibility is that the credit rating agency gives larger adjustments to CDOs where the BDR from the secondary cash flow analysis is much greater than the SDR from the credit rating agency model. In other words, it gives adjustments because they are relying more heavily on secondary cash flow simulations rather than the more standardized CRA model. It might be easier to incorporate features of the deal such as insurance, liquidity, and legal considerations in the secondary cash flow analysis. We are able to collect BDR information for a subset of 408 of our CDOs from pre-sale and new issue reports. Surprisingly, in specification (9), opposite to our prediction, we find that the relation is negative. These findings suggest that the adjustment is 'out-of-model' as it is related to neither the formal CRA model nor the cash flow simulation.

In summary, the most systematic feature we find, both economically and statistically, is that CDOs with low initial amounts of AAA receive large adjustments. However, we are unable to explain the direction of the adjustment with the main variables listed by rating agencies in terms of additional factors that they claim to take into account.

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[36] Nevertheless, we have double-checked our insurance data for completeness with another data vendor. In an optimal world, one would also want to include data on whether the portfolio assets were bought at a discount. If managers buy low quality collateral to maintain high par value, then a high model output can be a negative signal. But we do not observe the market value of the majority of collateral assets.

C. The Adjustment and Future Downgrades

Rating changes can be caused by both unpredictable market developments and inaccurate initial rating assessments. In this subsection, we examine the efficacy of the credit rating agency adjustment to increase CDO performance accuracy. We analyze the predictive power of the adjustment at the time of CDO issuance for future downgrades up until July 31, 2009 where the downgrading data stops.

Panel A of Table V uses an ordered logit to predict downgrades. We include type variables in all specifications since defaults are much worse in ABS and CDO^2s. If the rating agency's adjustments were made for quantitative or qualitative reasons that were helpful, then adjustments should be negatively related to future downgrades. However, specification 1 shows that the adjustment enters with a positive sign. AAA tranches with larger adjustments at issuance are more likely to be downgraded. The odds ratios on the adjustment range from 6.796 in specification (5) with the full set of control variables, to 25.587 in specification (1) controlling only for CDO type; this means that more downgrading would be 6.796 to 25.587 times more likely if the adjustment increases by one unit.

Downgrades are much more likely for securities issued in 2006 and 2007. This might be due to the quality of the collateral in these CDOs or because CDOs were given larger adjustments in later years. Nevertheless, even after controlling for the year of CDO issue as a dummy variable (specification 3), the adjustment remains highly significant. Besides the CDO type variables, the adjustment enters with the highest z-statistic (3.96), followed by the 2007 (3.24) and 2006 (3.09) dummy variables. We include the subjective features of the CDO such as the number of deals by the manager, overcollateralization, insurance, and liquidity in specification 4. Interestingly, CDOs managed by more experienced managers and CDOs with insurance have a greater probability of downgrading. The positive adjustment effect remains. We find no evidence that CDOs rated by multiple rating agencies experience less default.[37] We estimate the ordered logit within the CLO type (specification 6) and outside of the CLO type (specification 7); despite the smaller sample size we find that the adjustment is significant in both subsamples but with greater economic impact within CLOs.

In Panel B we use the full specification with ordered probit, plain probit, and OLS instead of ordered logit. We count both actual downgrades as well as CDOs placed on the downgrade watchlist in preparation for actual downgrading. The plain probit model focuses on downgrading likelihood, while the OLS model focuses linear effects of adjustment on downgrading magnitude. In all specifications AAA adjustments are strongly related to future occurrences of downgrade. Overall, the CDOs with the largest (positive) adjustments are found to be more, not less risky.

IV. Criterion Deviation

Recall that the previous analysis calculates the 'AAA' adjustment relative to the credit rating agency model. Our analysis could not assess the general question of whether the CRA model fraction was too high, despite finding that the simple simulation model correlated well with that used by the CRA. There still could be errors that are systematic across the CDOs and the analysis requires the CRA assumptions (such as correlations, asset quality). It would be difficult to analyze the validity of those assumptions. However, there is one input to CRA models that is more straightforward, the

[37] This result contrasts with Benmelech and Dlugosz (2009b), who in support of credit rating shopping, find that ABS CDOs with multiple ratings are less likely to receive recent downgrades. They do not examine adjustments. Their data include various types of structured finance securities from 2005-2007 but ABS CDOs are the only CDOs in their sample. Their set of ABS CDOs is slightly larger, whereas our data spans a longer time horizon (1997-2007) and covers all sectors of the CDO market. For our sample, the multiple CRAs dummy is significant without controlling for year dummies but not after controlling for the vintage effect. We think it is difficult to say too much in this paper on rating shopping since CDOs covered by multiple CRAs may also receive quicker downgrades if rating agencies are competing to seem more credible than their competitors. However, including the multiple ratings indicator variable in the regressions indicates that this explanation is not driving the importance of adjustments for future downgrades.

default probability criterion. Recall from Section I. B. that the default probability criterion is the maximum amount of default expected under a particular rating and maturity as shown in Table AI. In our database, we have the actual default probability criterion reported for each CDO at each rating level. Hence, we perform a simple comparison to see whether CDO credit ratings measure up to their presumed credit quality.[38]

A. Rating Default Probability Criterion

In order to examine the default probability criterion, we construct a "criterion deviation" defined as actual criterion minus publicized criterion (as shown in Table AI) with the same maturity. A zero deviation is rating at the edge, a negative deviation is being more conservative, and a positive deviation represents a default threshold that is higher than and hence not as strict as the publicized criterion. If the credit rating agency meets its publicized standards, it should never be the case that the actual default criterion is higher than that publicized. Figure 4 plots the time series of the criterion deviation for the AAA rating at CDO closing time from January 1997 to December 2007. Although we will later map to rating magnitudes, we do not report the values to keep the identity of the CRA anonymous. Only three CDOs appear to meet the criteria prior to 2007 and the rest of the deviations are positive, meaning that the riskiness of the 'AAA' tranche is higher than the publicized criterion.

Beginning in roughly April 2007 the deviations largely disappear. Panel B of Figure 4 zooms in on 2007 and shows that there are relatively few deviations after April 1, 2007. In terms of when the rating criteria changed, it is difficult to pinpoint as we only have data from the first distributed rating agency surveillance reports. The deals are structured in advance of this date. Differences in the length of time between when the deal was preliminarily rated and when the surveillance report

[38] At first, examining the criterion was not the most obvious approach for us to gain insights on CDO ratings.

appears can vary considerably and could potentially explain why a few CDOs issued after April 2007 continue to look similar to CDO reports prior to April.[39]

It is important to note that the criterion deviation in Figure 4 is an approximation since it is not adjusted by differences in maturity. We plot all actual AAA default probability criterion against maturity. Figure 5 shows that the publicized criteria are smoothly distributed on a convex curve as expected. CDOs issued prior to April 2007 are shown as a light yellow triangle. Before April 1, 2007, most of the actual default criteria lie on another distinctive curve, seemingly related to the shape of the publicized criteria but to the left meaning that the default criteria are higher than the publicized criteria. CDOs with initial surveillance reports after April 1, 2007 are in dark purple squares and mostly overlap with publicized criteria.

In order to gauge the economic impact, we also plot dashed and dotted lines for the publicized criteria of the AA+ rating and AA rating. Except for a few CDOs with long maturities which meet AA+ criteria (between AA+ and AAA publicized criterion lines), most CDO AAA ratings only meet the AA rating criterion (between AA and AA+ publicized criterion lines).

We notice one additional, less prominent but clear, irregularity: there are 27 CDOs which seem to form a straight line, independent of the maturity. Upon further investigation we notice that for those CDOs, not only are their default probability criteria constant and identical, but their scenario default rates are exactly identical for each of the 19 rating scales from AAA to CCC-. This is only possible if the CDOs have the exact same portfolio loss distribution, which would seem nearly impossible given that the CDO features differ considerably. Hence it seems hard to reconcile these results to a model but the fact that their values persist in subsequent surveillance reports also speaks against data error. We further discuss the 27 CDOs in Supplementary Appendix C and show their features in Table AIV.

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

Thus far, we have focused on a comparison of actual AAA default probabilities relative to publicized AAA default standards. We now compare the standards across all rating levels. To fully characterize this "criterion deviation" finding, we re-assign credit ratings for each tranche corresponding to the actual default criterion used for CDOs in our sample. The results for all CDOs are summarized in Table VI before April 1, 2007 (Panel A) and after (Panel B). For CDOs issued before April 1, 2007, Panel A shows that 1.3% of AAAs comply with the publicized AAA criterion, 4.8% should be rated one notch lower and comply with the publicized AA+ criterion, and 92.5% comply with the publicized AA criterion. The results are similar for AA+ to A-. Then a dramatic change occurs when 96.5% of the BBB actual default probabilities match publicized default probabilities for CDOs issued before April 1, 2007. Panel B shows that for CDOs issued after April 1, 2007, the compliance rates (actual default probability meeting publicized default probability criterion) are above 90% for all ratings.

We illustrate the difference between publicized and actual default thresholds in Supplementary Appendix Figure A3. For ratings of BBB+ and above, the actual default probabilities used are higher (more lenient) than the publicized default criterion. But for BBB capital and below, the CRA utilizes a more stringent default rate than that of the publicized rate.

To summarize, the CRA appears to have used different criteria as model inputs before and after April 1, 2007. Prior to April 1, 2007, the default probabilities used in practice are systematically higher (less stringent) than those publicized for the investment grade (BBB and above) tranches, but significantly lower (more stringent) for those tranches below investment grade. Criterion compliance occurs in most deals around April 1, 2007.

B. *Potential Explanations*

One possibility for the criterion shift in April 1, 2007 is that the criterion used by the rating agency was indeed different but we only observe the most recent publicized criterion. We first track the CRA's default probability criterion updates. The CRA's documentation, including public news releases, research reports, and presentation slides at conferences and training sessions, confirms the record of publicized criterion for CDOs as shown in Table AI at least back to 2002. Hence, we are using the right criterion.

As our analysis has been from the first surveillance report after the CDO issuance, we now examine the criteria used by the CRA after April 1, 2007 in continuing surveillance reports. In Figure 6 we label the CDOs by whether their date of issuance is before April 1, 2007 (yellow triangles) or after April 1, 2007 (purple squares). During the eighteen months from April 2007 to September 2008 (when this data stops), there are two main default probability criteria actually used by the CRA for AAA ratings. CDOs issued after April 1, 2007 (the purple squares) follow the publicized lower default probability criterion strictly. But all of the CDOs issued prior to April 2007 continue to use the same default probability criterion demonstrated at the time of issue (in Figure 5). It is not clear how a CRA model can allow two different CDO standards simultaneously. If the credit rating agency were to change rating standards then one would expect it to affect all CDOs.

Supplementary Appendix Table A4 displays CDO characteristics before and after April 1, 2007 and reveals no large shifts around April 2007, except for an increase in CLO correlations after April 2007. Interestingly, AAA model adjustments of 18.2% AAA are exactly the same as those for the entire year in Table III—while the rating agency changed the standard for the default criterion, the adjustments remained steady across 2007. Importantly, there is no disclosure of changing CDO modeling methods or varying standards in any of the credit rating agency websites regarding CDOs around April 2007 that we can locate in our extensive searches. However, there was some documented tightening of standards for MBS securities. Gorton and Metrick (2009) demonstrate the decline of the subprime mortgage market through the ABX.HE index beginning in January 2007. A most notable quote by an undisclosed market participant on March 3, 2007 states that, "the legs that power the CDO machine for the last three years have fallen off," indicating that the industry is experiencing hardship. There are also some calls for more government oversight of regulation beginning in March. We provide more detail on the credit market news and conditions in the first half of 2007 in Supplementary Appendix D and in Figure A5.

V. Measuring Economic Importance

A. Economic Analysis of the Criterion Deviation

We have noted that the criterion deviation leads to more lenient standards for ratings above BBB but tougher standards for BBB and below. While there is much more capital issued at the higher rated tranches, spreads are larger on the lower rated tranches, so the valuation impact of the criterion deviation is unclear and needs to be quantified. For the sample of CDOs issued before April 1, 2007, we calculate the valuation effect in Table VII by re-rating the CDOs according to the stated default criterion for each tranche. We can only apply the analysis to the rated tranches, not the unrated equity portion which counts 8.16% of a CDO on average. AAA rated issues account for 84.59% of the total amount of rated issuance. BBB+ to AAA rated issues (who receive a looser default probability criterion) account for 94.98% of total rated CDO issuance whereas BBB and below (which receive stricter default criterion) account for a total of only 5.02% of rated issuance. No CDO notes carry an initial CCC rating.

To quantify the valuation effect of the deviation, we use the simple duration approximation: $\frac{\Delta P}{P} \approx -D^{*} \times \Delta y$, the percentage change in the value approximately equals to the difference in yields multiplied by modified duration.[40] Using this method, we calculate the value difference for an AA rated note sold as an AAA note. In our sample, the average AAA spread is 33.60 basis points, while the AA spread is 64.84 basis points. For a note with duration 6.68 sold as AAA but with true AA quality (default probability), the percentage value difference is 2.11%. We calculate this value difference for the entire rating universe and sum up across rating groups.[41] The negative value effects for the lower B- to BBB rated tranches are small. In total, for the CDOs issued prior to April 2007, the criterion deviation increases CDO value by $12.58 million per CDO (2.08% of collateral value) on average. Because there are 788 CDOs, this sums to a non-trivial $9.789 billion.

Even though this number is large, there are other potential reasons to suggest that the difference could go well beyond the economic calculations. Another way to think about economic magnitude is that using the actual, instead of the publicized, AAA default standard amounts to a reduction in SDR (and hence more allowable AAA) of 2.7%. First, while 2.7% seems small, a 2.7% reduction in the scenario default rate (SDR) could be critical in practice when the only condition for granting a rating is that the breakeven default rate (BDR) must be greater than the SDR. Second, 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 SDR, the so-called "rating at the edge" practice (Benmelech and Dlugosz (2009a) and Brunnermeier (2009)). Third, the lower tranches are notoriously hard to place. Examining 2.7% as a fraction of the total CDO is in some sense misleading. For our sample on average 90.65% of the issuance is above BBB and 9.35% is rated

[40] Due to the lack of coupon information, we further approximate modified duration ('effective maturity') with maturity. Note that we are using collateral asset maturity rather than CDO notes legal maturity.

[41] Since spreads have variability, there are a few cases where spreads are not monotonically decreasing. For example, the AA+ spread is higher than the AA spread. Although there are a few cases with negative value effects, the principal values are very small.

BBB rated or below, or unrated. Shifting 2.7% of the CDO from below BBB to investment grade means that instead of having 12.05% of the CDO to place there is only 9.35% of non-investment grade debt—that is 22% less of hard to place debt and may mean having to find one less large buyer.[42]

B. Re- Rating the AAA tranche

To gain a sense of the economic magnitude of the AAA adjustment and given that they were harmful for CDO performance, a relevant question is: what would the top tranches of CDOs be rated if the CRA had strictly followed their model and not issued adjustments? To answer this question precisely, one would need to use the CRA model to re-rate the CDO. We do not know the CRA model, but we showed previously that our Monte Carlo yielded estimates close to that of the CRA agency model. Hence, as an approximation, we re-rate the entire CDO using the Monte Carlo Simulation for the given structure of the CDO. For example, if the actual amount of AAA capital was 80%, then we map the implied 20% SDR to the corresponding rating (expected default probability).[43] If the resulting credit rating is BBB for this top tranche then we rate and re-value the entire AAA tranche. An alternative is to value only the difference in value between the part that would withstand AAA and the part that is not revalued lower. The problem with this procedure is that it is not re-valuing the AAA tranche as it was actually cut. In other words, our question for AAA tranches is: what was the rating of tranches using a simple Monte Carlo model and no adjustments? Because we use the publicized AAA default criterion this approach also lumps together the much smaller criterion deviation effect.

[42] We thank an anonymous industry expert for brining this issue to our attention.
[43] If the model gives a SDR of 0.366 corresponding to an AAA default probability, then only the top 0.634 fraction can be granted AAA rating. If the structurer wants to make the top tranche size 0.755 of the entire CDO (12.1% larger), then the resulting SDR would need to be 0.245. This would correspond to a much larger expected default probability (say, BBB level).

We first find the rating for each of the AAA tranches of the CDOs in our sample. As shown in Table VIII, according to the Monte Carlo Simulation, the average rating across collateral type is BBB.[44] Interestingly, the average spread difference over the sample between BBB CDO tranche spreads and AAA CDO spreads is only 2.56%. We calculate the value difference of the AAA tranche and the tranches' new rating according to the simple approximation:

$$\text{Value Dif} = \text{Collateral Maturity} \times (\text{AAA Spread} - \text{Model Rating Spread}) \times \$ \text{ Value of the AAA Fraction} \quad (1)$$

According to these estimates, the value difference due to criterion deviation and adjustment amounts to 15.2% of the total CDO and 20.1% of the AAA tranche. On a dollar basis it amounts to a $94.13 million value inflation per CDO and $86.22 billion for our sample of 916 CDOs.

Overall, our findings suggest that the effect of the adjustments on the AAA tranche is substantial. Adding the effects of the adjustment to other tranches would only slightly magnify the findings as most of the CDO is in the AAA tranche.[45] Moreover, one should not view these numbers as comprehensive but rather only as some suggestive estimates. For example, moving massive amounts of capital to BBB would surely increase BBB spread differentials. Additionally, the BBB is the rating with the simple simulation method often used in practice but does not consider the systematic nature of default risk and parameter uncertainty such as pointed out in Coval, Jurek, and Stafford (2009a, 2009b). Nevertheless, consistent with Coval, Jurek, and Stafford our paper also provides another metric that indicates AAA tranches were massively mispriced. Since the Gaussian Copula simulation method we use was apparently widely used in practice, our analysis indicates that the most sophisticated market participants may have been aware of some CDO mispricing.

[44] From the CRA model directly we obtain similar rating inferences as the average SDR difference between AAA and BBB is 0.144; this is slightly less than the average adjustment of 0.121 plus the criterion deviation of 0.027. The average downgrading is about 6 notches in our AAA rated notes.

[45] This process is also computationally intensive as it requires revaluing each tranche of each CDO for all 22 possible ratings.

VI. Summary and Concluding Remarks

This paper separates the CDO modeling process from that beyond modeling, shedding light on quantitative versus qualitative practices. Using data on 916 CDOs issued from 1997 to 2007, a simple Monte Carlo simulation model using CRA inputs delivers a 0.82 correlation for the size of the AAA tranche to that produced by the CRA model—the model used by the rating agency is mostly run-of-the-mill. However, the actual size of the AAA tranche exhibits a correlation of only 0.49 with the size from the CRA model, indicating that the formal modeling process is only part of the picture. Beyond modeling, 'adjustments' to the rating agency model are positive, amounting to an additional 12.1% AAA for the average CDO. Adjustments are not explained by likely candidates such as manager experience or tranche insurance. CDOs with lower proportions of AAA implied by the CRA model received higher adjustments. The adjustments at the time of issuance are positive predictors of future 2008 and 2009 downgrades—they were not helpful in practice.

Additionally, in examining default risk criteria we document an empirical irregularity distinct from the adjustment. The AAA default risk criterion prior to April 2007 is typically a full rating lower than the stated default risk rating criterion. Thereafter, the CRA switched to the stated criteria for most of the newly issued CDOs. Nevertheless, even after April 2007, CDOs issued prior to April 2007 kept the old criterion, such that there were two default probability criteria in place simultaneously. After re-rating the AAA tranche of CDOs with no adjustments and using the publicized default risk criteria, we find that their valuations should have been approximately 20.1 % lower or $86.22 billion in total.

Our results have important implications for regulators and investors. There has been a recent movement to blame modeling and modelers; and to make the rating process more qualitative and less quantitative.[46] Our findings suggest that this step would be in the wrong direction. It would seem sensible to make data on key inputs, outputs, and the rating modeling process more and not less transparent. The modeling box could then be opened and debated. While 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 jointly at work and hope to see more research on CDO credit ratings.

Our findings also suggest that perhaps researchers should more carefully examine the claims of Akerlof and Romer (1993) (recast recently by Akerlof and Shiller (2009)) regarding linkages between financial sophistry and financial crises. The causes for the failure of the shadow banking system may be deeper than an exogenous banking sunspot.

[46] In a recent overview of proposed rating changes, in one of the two main bullet points S&P (2009) states: "We are proposing to put greater emphasis on qualitative analysis in our overall rating process." Moody's (2009c) also stresses the importance of qualitative factors in their new rating approach.

References

Akerlof, George A., and Paul M. Romer, 1993, Looting: The economic underworld of bankruptcy for profit, *Brookings Papers and Economic Activity* 2, 1-73.

Akerlof, George A., and Robert J. Shiller, 2009, *Animal Spirits*, Princeton University Press.

An, Xudong, Yongheng Deng and Anthony B. Sanders, 2008, Subordination Levels in Structured Financing. In Arnoud Boot and Anjan Thakor (eds.) *Corporate Finance, Volume 3: Financial Intermediation and Banking*. Elsevier.

Andrews, Donald, 1993, Tests for parameter instability and structural change with unknown change point, *Econometrica* 61, 821-856.

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

Ashcraft, Adam B., and Til Schuermann, 2008, Understanding the securitization of subprime mortgage credit, *Foundations and Trends in Finance* 2, 191-309.

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

Becker, Bo, and Todd Milbourn, 2009, Reputation and competition: Evidence from the credit rating industry, Working paper, Harvard Business School.

Ben-David, Itzhak, 2009, Manipulation of collateral values by borrowers and intermediaries, Working paper, Ohio State University.

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

Benmelech, Efraim, and Jennifer Dlugosz, 2009b, The credit rating crisis, *NBER Macro Annual*, forthcoming.

Benmelech, Efraim, Jennifer Dlugosz, and Victoria Ivashina, 2009, What lies beneath: Is there adverse selection in CLO collateral? Working paper, Harvard Business School.

Bongaerts, Dion, Martijn Cremers, and William N. Goetzmann, 2009, Multiple ratings and credit spreads, Working paper, Yale School of Management.

Brennan, Michael J., Julia Hein, and Ser-Huang Poon, 2009, Tranching and Rating, *European Financial Management*, forthcoming.

Blume, Marshall E., Felix Lim, and Craig MacKinlay, 1998, The Declining Credit Quality of U.S. Corporate Debt: Myth or Reality? *The Journal of Finance* 53, 1389-1413.

Bolton, Patrick, Xavier Freixas, and Joel D. Shapiro, 2009, The Credit Ratings Game, NBER Working Paper No. 14712.

Brunnermeier, Markus, 2009, Deciphering the Liquidity and Credit Crunch 2007-2008, *Journal of Economic Perspectives* 23, 77-100.

The Committee of European Securities Regulators (CESR), 2008, The role of credit rating agencies in structured finance, consultation paper.

Cheng, Mei, and Monica Neamtiu, 2009, An empirical analysis of changes in credit rating properties: timeliness, accuracy and volatility, *Journal of Accounting and Economics* 47, 108-130.

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

Coval, Joshua D., Jakub W. Jurek, and Erik Stafford, 2009b, The economics of structured finance, *Journal of Economic Perspectives* 23, 3-25.

Damiano, Ettore, Hao Li, and Wing Suen, 2008, Credible ratings, *Theoretical Economics* 3, 325-365.

DeMarzo, Peter M., 2005, The pooling and tranching of securities: A model of informed intermediation, *Review of Financial Studies* 18, 1-35.

Demyanyk, Yuliya, and Otto Van Hemert, 2009, Understanding the subprime mortgage crisis, *Review of Financial Studies,* forthcoming.

Deng, Yongheng, Stuart A. Gabriel, and Anthony B. Sanders, 2009, CDO market implosion and the pricing of subprime mortgage-backed securities, Working paper, NUS, UCLA, and GMU.

Duffie, Darrell, and Nicolae Garleanu, 2001, Risk and valuation of collateralized debt obligations, *Financial Analysts Journal* 57, 41-59.

Duffie, Darrell, and Kenneth J. Singleton, 2003, *Credit Risk: Pricing, Measurement, and Management*, Princeton University Press.

Farhi, Emmanuel, Josh Lerner, and Jean Tirole, 2008, Fear of Rejection? Tiered Certification and Transparency, NBER Working Paper No. 14457.

Fitch Ratings, 2006, Global rating criteria for collateralized debt obligations.

Gorton, Gary, and Andrew Metrick, 2009, The run on repo and the panic of 2007-2008, Working Paper, Yale School of Management.

Jorion, Philippe, Charles Shi, and Sanjian Zhang, 2009, Tightening credit standards: The role of accounting quality, *Review of Accounting Studies* 14, 123-160.

Keys, Benjamin J., Tanmoy Mukherjee, Amit Seru, Vikrant Vig, 2008, Did securitization lead to lax screening? Evidence from subprime loans 2001-2006**,** *Quarterly Journal of Economics*, forthcoming**.**

Leland, Hayne E., 2007, Financial synergies and the optimal scope of the firm: Implications for mergers, spinoffs, and structured finance, *Journal of Finance* 62, 765-807.

Longstaff, Francis A., 2008, The subprime credit crisis and contagion in financial markets, Working paper, UCLA.

Longstaff, Francis A., and Brett Myers, 2009, How does the market value toxic assets? Working paper, UCLA.

Longstaff, Francis A., and Arvind Rajan, 2008, An empirical analysis of the pricing of collateralized debt obligations, *Journal of Finance* 63, 529-563.

Mason, Joseph R., and Joshua Rosner, 2007, Where did the risk go? How misapplied bond ratings cause mortgage backed securities and collateralized debt obligation market disruptions?, Working paper, Drexel University.

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

Merton, Robert C., 1974, On the pricing of corporate debt: The risk structure of interest rates, *The Journal of Finance* 29, 449-470.

Mian, Atif, and Amir Sufi, 2008, The consequences of mortgage credit expansion: Evidence from the 2007 mortgage default crisis, *Quarterly Journal of Economics*, forthcoming.

Moody's Investors Service, 2003, Moody's approach to rate CDOs.

Moody's Investors Service, 2009a, Corporate default and recovery rates, 1920-2008, special comment in February 2009.

Moody's Investors Service, 2009b, Moody's Approach to rating structured finance CDOs, March 2, 2009 and August 14, 2009.

Moody's Investors Service, 2009c, V scores and parameter sensitivities in the global corporate synthetic CDO sector, Structured Finance Rating Methodology, April 29, 2009.

Moody's Investors Service, 2009d, Structured finance ratings quick, Special Report, August 31, 2009.

Opp, Christian C., and Marcus M. Opp, 2009, Rating agencies in the face of regulation: Rating inflation and regulatory arbitrage, Working paper, Chicago Booth and Berkeley Haas.

The President's Working Group on Financial Markets, 2008, Policy Statement on Financial Market Development (March 13, 2008), Washington, Treasury, Federal Reserve, SEC, CFTC.

Parlour, Christine, and Guillaume Plantin, 2008, Loan Sales and Relationship Banking, *Journal of Finance* 63, 1291-1314.

Rajan, Uday, Amit Seru, and Vikrant Vig, 2009, The failure of models that predict failure: Distance, incentives and default, Working paper, University of Chicago.

Sanders, Anthony, 2008, The subprime crisis and its role in the financial crisis, *Journal of Housing Economics* 17, 254-261.

Sanders, Anthony, 2009, A primer of CDO valuation, Working paper.

Sangiorgi, Francesco, Jonathan Sokobin, and Chester Spatt, 2009, Credit-rating shopping, selection and the equilibrium structure of ratings, Working paper, Stockholm, SEC, and CMU.

Shivdasani, Anil, and Yihui Wang, 2009, Did structured credit fuel the LBO boom?, Working paper, UNC-Chapel Hill.

Skreta, Vasiliki, and Laura Veldkamp, 2009, Rating shopping and asset complexity: A theory of rating inflation, *Journal of Monetary Economics* 56, 678-695.

Standard and Poor's, 2002, Global cash flow and synthetic CDO criteria.

Standard and Poor's, 2007, The fundamentals of structured finance ratings, August 27, 2007.

Standard and Poor's, 2009, Summary and highlights of proposed changes to our global rating methodology for corporate cash flow and synthetic CDOs.

Stulz, René M., and Herb Johnson, 1985, An analysis of secured debt, *Journal of Financial Economics* 14, 501-521.

Stulz, René M., 2008, Risk management failures: What are they and when do they happen? *Journal of Applied Corporate Finance* 20, 58-67.

Vasicek, Oldrich, 1987, Probability of loss on loan portfolio, Moody's KMV Corporation.

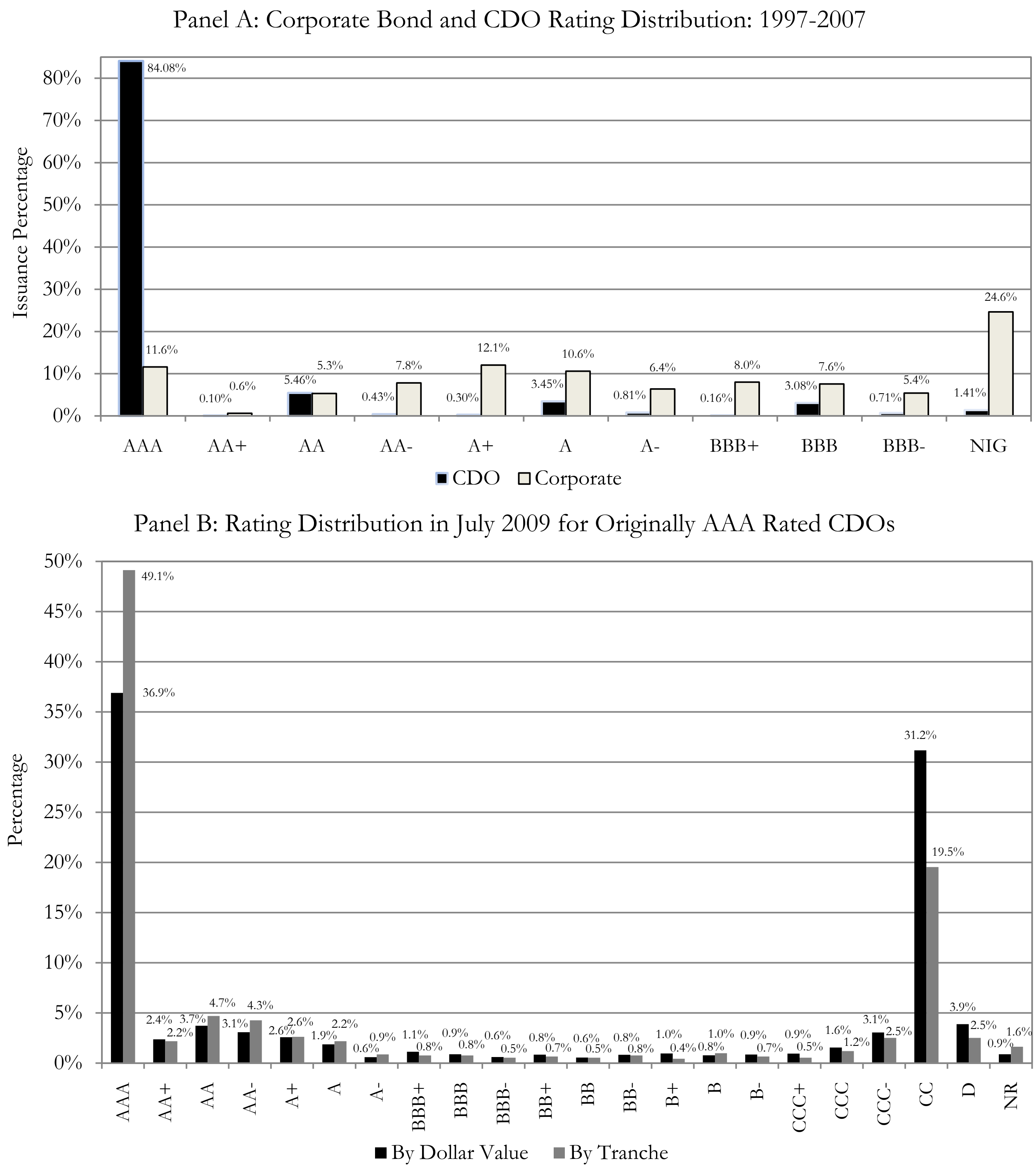


Figure 1. Credit Rating Distribution. The top figure (Panel A) plots the rating distribution for CDOs and corporate debentures issued between January 1997 and December 2007. The vertical axis is the issuance fraction with the corresponding credit rating out of all global rated debt issues in the Fixed Income Securities Database (FISD) and our sample CDOs. 'NIG' refers to non-investment grade (ratings below BBB-). The bottom graph (Panel B) illustrates the rating distribution as of July 31, 2009 (simple average and dollar value weighted) for all CDOs with initial AAA rating (issued between 1997 and 2007) from the rating agency's CDO rating database. 'NR' refers to not rated.

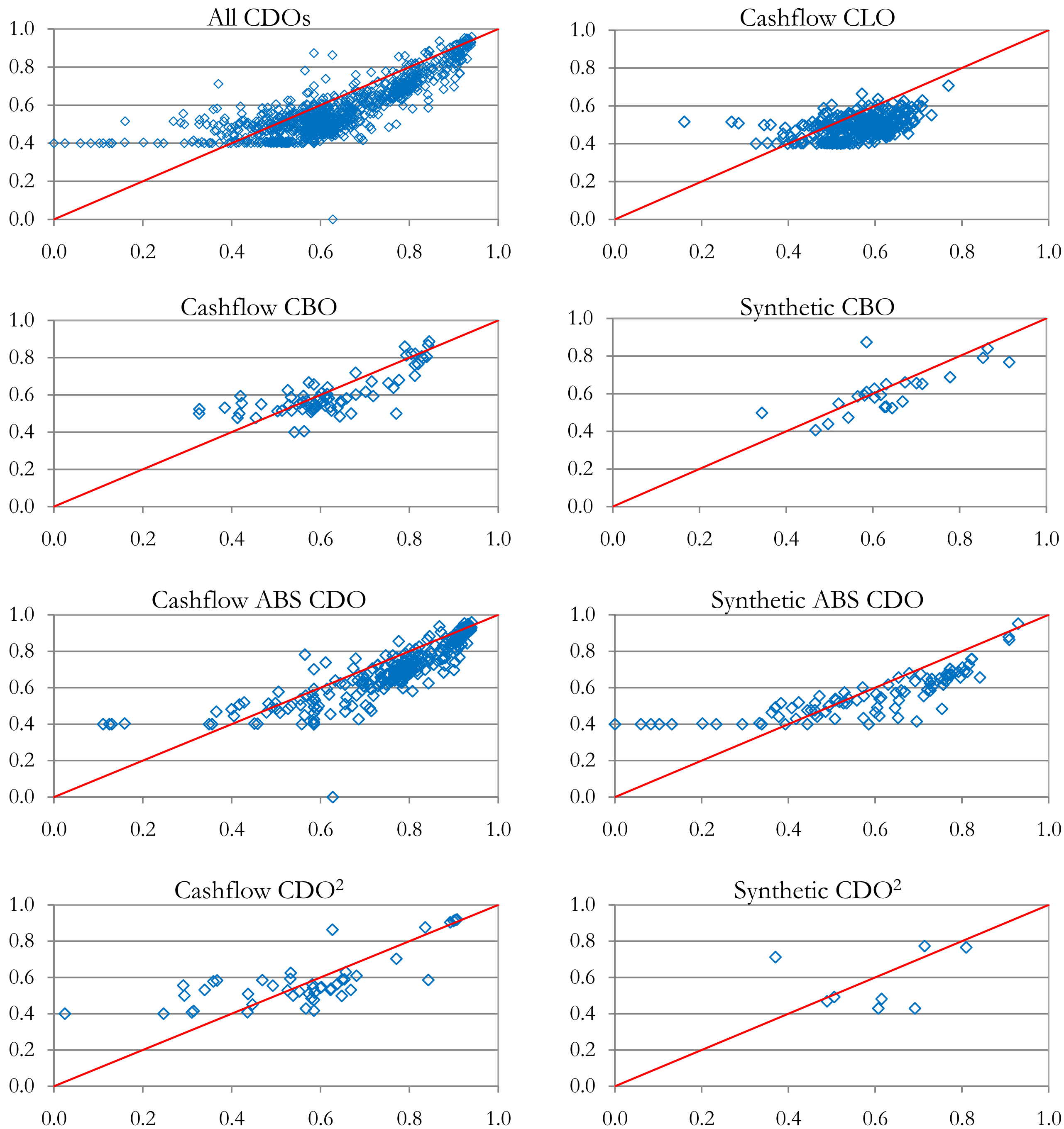


Figure 2. AAA Fraction Predicted by Credit Rating Agency Model and Our Monte Carlo Simulation. This figure graphs credit rating agency model predicted AAA fraction (x-axis) in first surveillance reports versus our Monte Carlo simulation AAA fraction (y-axis). Our Monte Carlo Simulations use publicly disclosed default rate criterion for AAA credit rating and assume a 40% recovery rate for all CDO collateral assets. The sample includes 916 CDOs issued between January 1997 and December 2007.

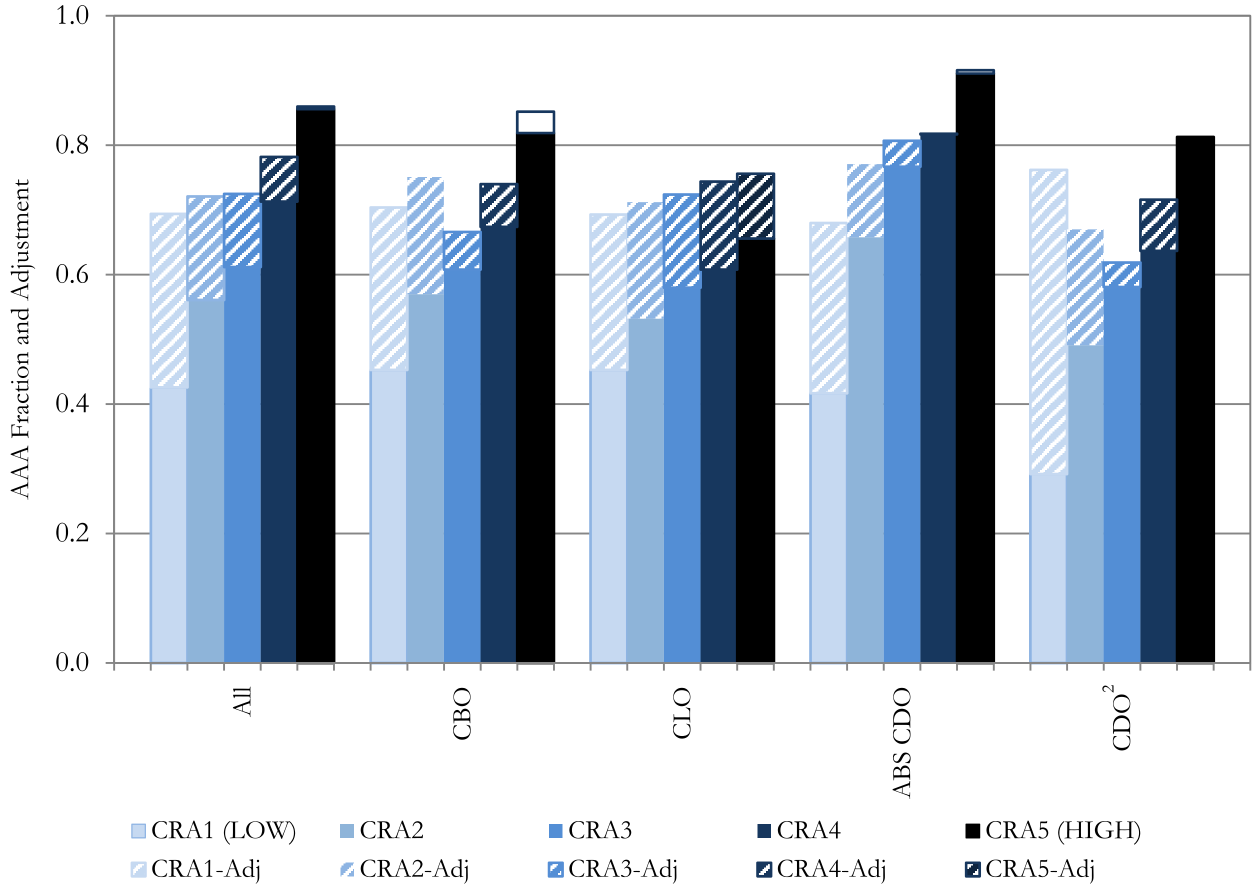


Figure 3. Credit Rating Agency Model Predicted AAA Fraction and Initial Adjustment by Collateral Asset Type. This figure graphs AAA fraction from the credit rating agency model (defined as 1-SDR) in first surveillance reports and the adjustment (difference between actual CDO fraction rated AAA and credit rating agency model AAA fraction). The bottom bars are credit rating agency model AAA fractions and the top bars are adjustments. The total length of the bars is the actual AAA fraction. Data is divided into different collateral asset types (CBO, CLO, ABS CDO, CDO^2). Within each CDO type, the data is further separated into five groups according to credit rating agency model AAA fraction, from low (group 1) to high (group 5). Empty bars represent negative adjustments. All CDOs are issued between January, 1997 and December, 2007.

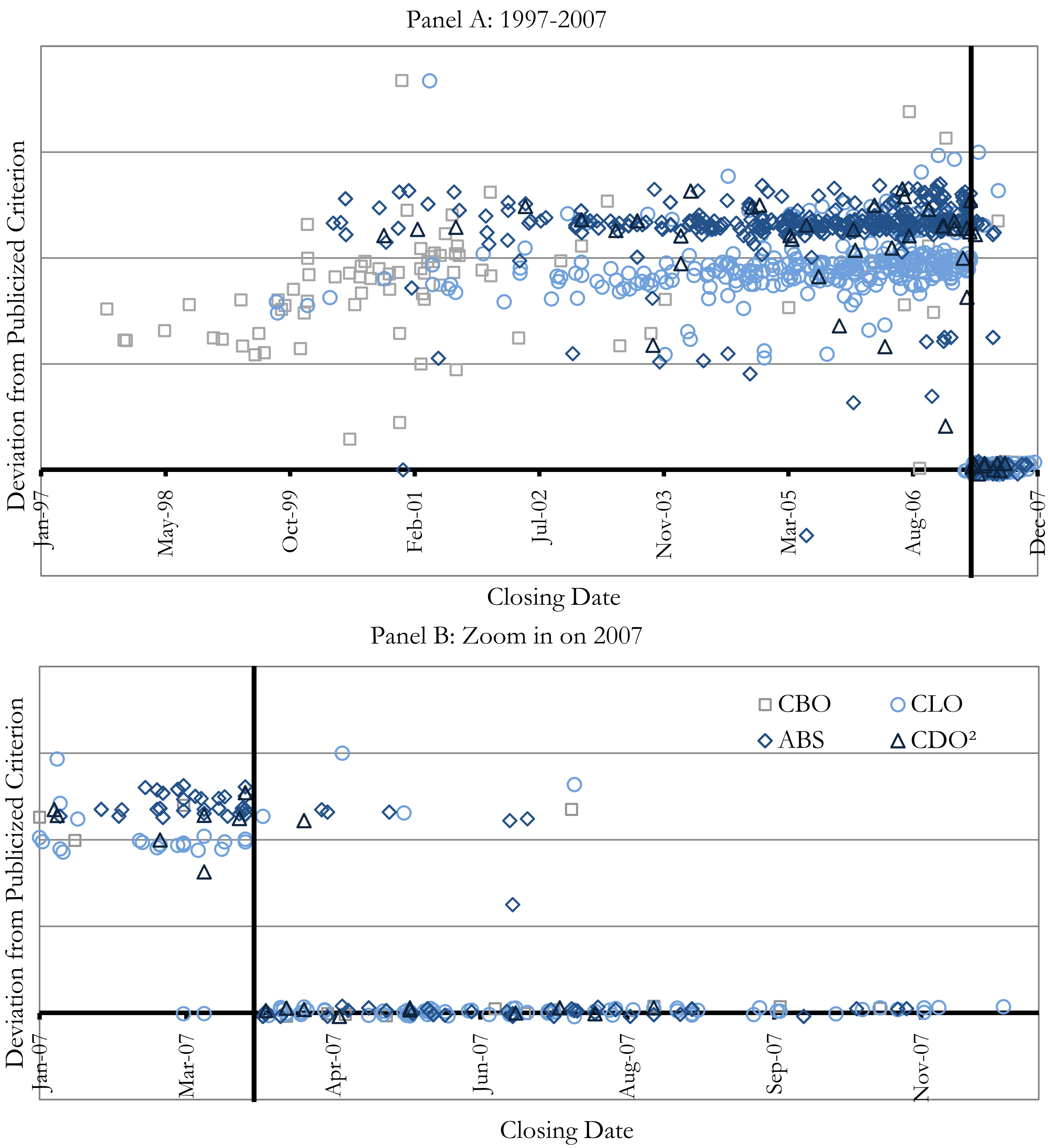


Figure 4. Difference between Actual and Publicized Default Rate Criterion for CDO AAA Credit Rating in First Reports. This figure graphs the deviation in actual default rate criterion from the publicized default rate criterion for CDO AAA credit ratings across time. The deviation is defined as the difference between the actual criterion in the first credit rating agency surveillance reports and the publicized criterion with the same maturity (actual−publicized). The magnitude of the deviation (y-axis) is not shown to keep the anonymity of the data source. The black horizontal line refers to zero deviation and the black vertical line refers to April 1, 2007.

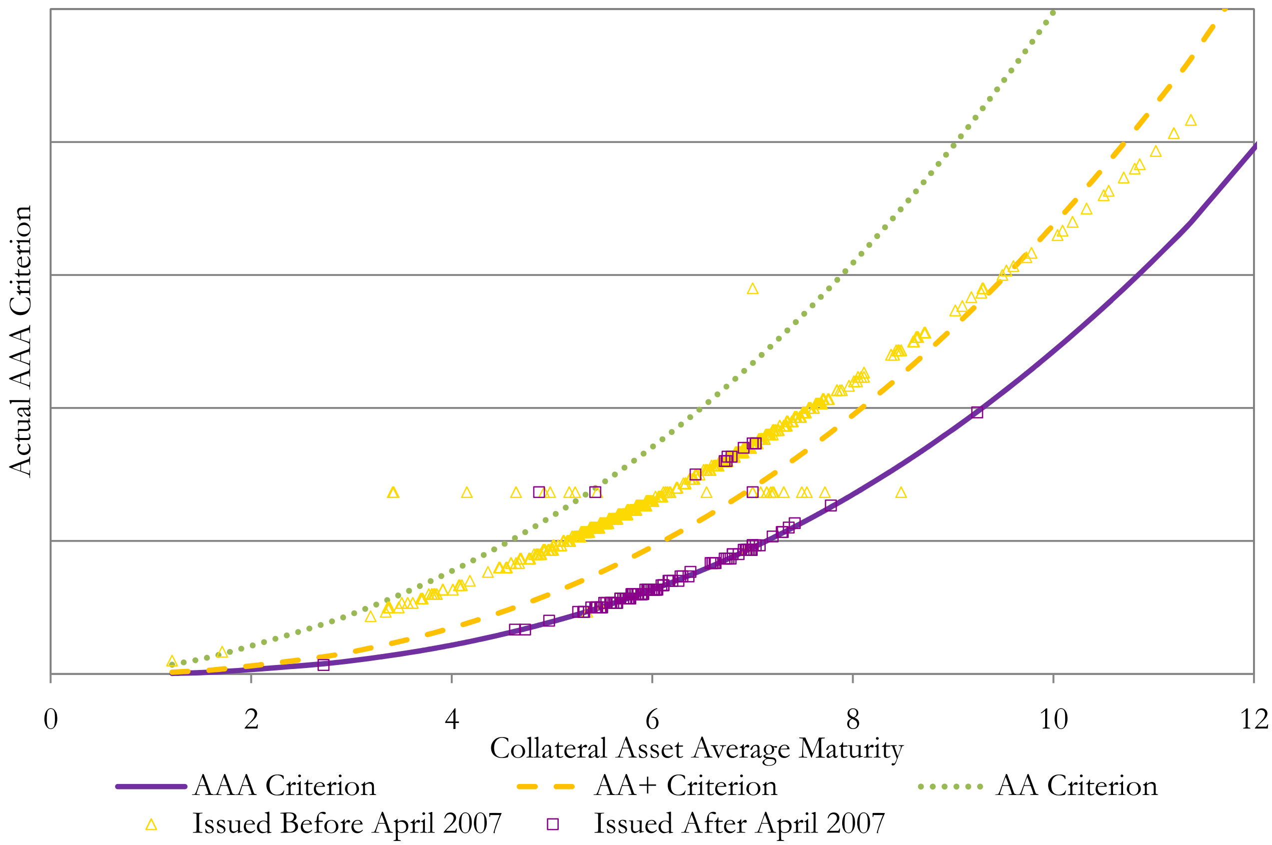


Figure 5. Actual and Publicized Default Rate Criterion for CDO AAA Credit Rating in First Reports. This figure graphs the actual default rate criterion for the CDO AAA credit rating (y-axis) against collateral asset average maturity (x-axis), using data from the first credit rating agency surveillance reports, along with credit rating agency publicized default rate criteria for AAA, AA+, and AA in rating software and manuals. The magnitude of the default rate criterion (y-axis) is not shown to keep the anonymity of the data source. The sample includes 916 CDOs issued between January 1997 and December 2007. CDOs issued before and after April 1, 2007 are plotted separately.

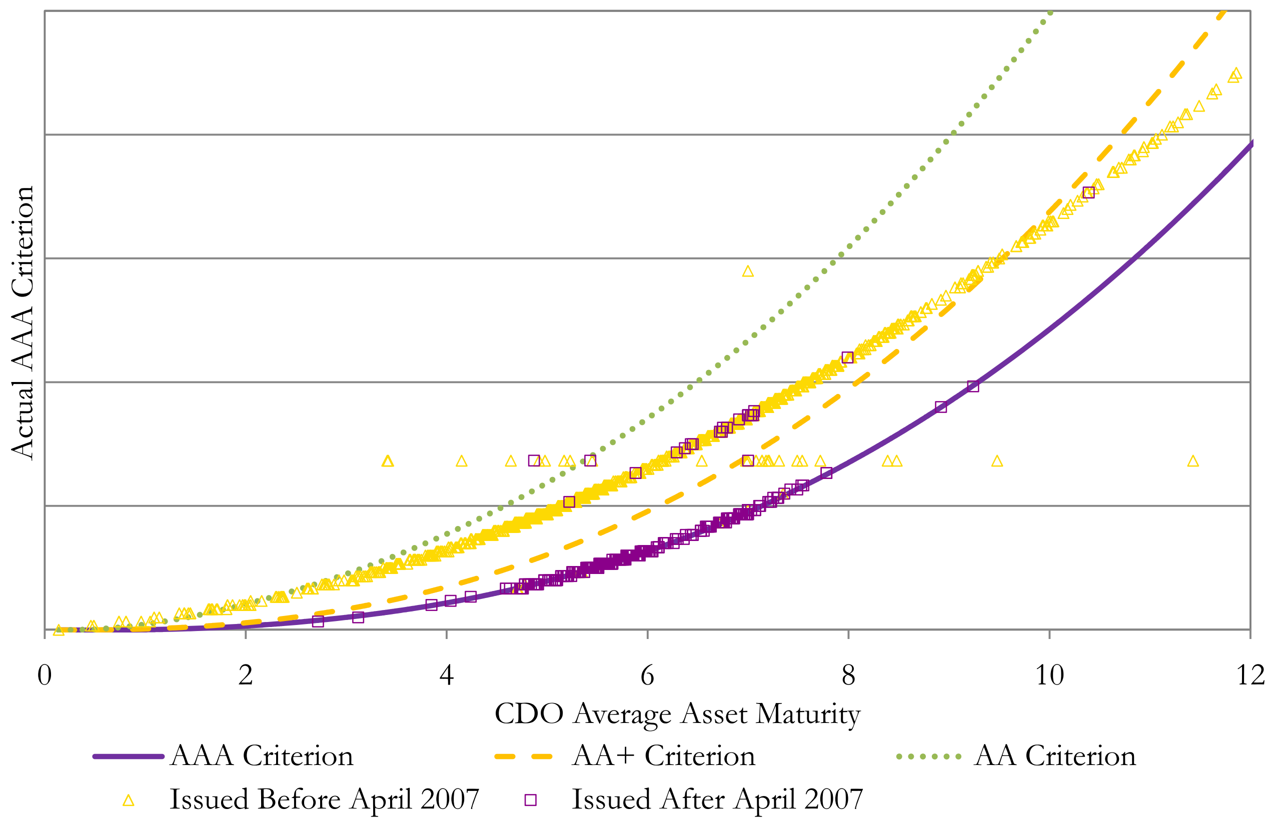


Figure 6. Actual and Publicized Default Rate Criterion for CDO AAA Credit Rating in All Reports after April 1, 2007. This figure graphs the actual default rate criterion for the CDO AAA credit rating (y-axis) against collateral asset average maturity (x-axis), using data from all credit rating agency surveillance reports from April 1, 2007 to September 30, 2008, along with credit rating agency publicized default rate criteria for AAA, AA+, and AA in rating software and manuals. The magnitude of the default rate criterion (y-axis) is not shown to keep the anonymity of the data source. The sample includes 916 CDOs issued between January 1997 and December 2007. CDOs issued before and after April 1, 2007 are plotted separately.

Table I

CDO Sample Description

This table reports the average value (Panel A) and correlations (Panel B) of the collateral asset characteristics and liability structure for CDOs in our sample. Data are from credit rating agency surveillance reports. CDOs are issued over the period from January 1997 to December 2007. Last reporting date is September 2008. 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). *Col. Rating* is the collateral asset average credit rating (average is calculated after numerical conversion AAA=1, AA+=2, AA=3, … C=21). *Col. Default Rate* is the average expected collateral asset default rate in percentage. *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 counting super senior tranches as AAA. *Mgr Deal #* is the number of CDOs the collateral manager has managed including the current CDO. *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	CDO^2
#. Obs.	916	96	393	373	54
Col. Rating	BB+	BB-	B+	A-	BBB
Col. Default Rate (%)	2.69	3.83	4.32	0.86	1.47
Correlation	0.42	0.21	0.34	0.53	0.56
Col. Maturity (Years)	6.45	5.30	5.74	7.23	8.32
Col. Size ($ millions)	634.3	394.4	479.3	865.9	589.4
#. Assets	218.3	139.2	325.9	144.7	84.02
#. Obligors	130.0	104.3	158.1	115.3	72.1
Synthetic Dummy	0.14	0.25	0.00	0.25	0.15
AAA Fraction	0.755	0.728	0.726	0.798	0.715
Mgr Deal #	7.9	4.4	8.6	7.9	8.5
Overcollateralization	1.004	0.886	0.948	1.046	1.335
Insurance Dummy	0.061	0.188	0.043	0.048	0.056
Liquidity Dummy	0.235	0.469	0.112	0.284	0.370

(*continued*)

Table I—*Continued*

Panel B: Correlation Matrix

Variables		1	2	3	4	5	6	7	8	9	10	11	12
Col. Rating	1												
Col. Default Rate	2	0.83											
Correlation	3	-0.41	-0.37										
Col. Maturity(Years)	4	-0.42	-0.43	0.47									
Col. Size ($ millions)	5	-0.51	-0.32	0.39	0.21								
#. Assets	6	0.36	0.31	-0.01	-0.27	0.08							
#. Obligors	7	0.15	0.14	0.12	-0.19	0.22	0.86						
Synthetic Dummy	8	-0.18	-0.18	0.38	0.24	0.25	-0.22	-0.14					
AAA Fraction	9	-0.42	-0.27	0.05	0.03	0.28	-0.04	0.11	-0.09				
Log(Mgr Deal #)	10	-0.08	-0.05	0.31	0.11	0.28	0.23	0.30	0.15	0.02			
Overcollateralization	11	-0.17	-0.15	0.08	0.12	0.20	-0.05	-0.03	0.16	-0.25	0.04		
Insurance Dummy	12	0.05	0.12	-0.16	-0.14	-0.02	-0.10	-0.09	-0.09	0.10	-0.11	-0.06	
Liquidity Dummy	13	-0.12	-0.13	0.04	0.08	0.00	-0.20	-0.14	0.22	0.04	-0.06	0.05	0.04

Table II

Rating Agency and Our Simulation AAA Fraction Difference Regressions

This table reports coefficient estimates from OLS regressions. The dependent variables are the difference between the CDO AAA fraction from the credit rating agency model and from a Monte Carlo Model (CRA AAA – Monte Carlo AAA). The Monte Carlo Simulation inputs are average collateral default rates, maturity, correlations, and number of assets reported by the CRA. The simulation approach is described in the Appendix. Recovery rate is assumed to be 40% for all simulations. The independent variables are described in Table I. *CLO*, *ABS CDO*, and *CDO²* are collateral asset type dummy variables. Closing year dummies for 2002-2007 are included with closing year 2001 and before as the comparison group. CDOs are issued over the period from January 1997 to December 2007. Heteroskedasticity adjusted t-statistics are in parentheses.

	Dependent Variable: CRA AAA – Monte Carlo AAA					
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	0.160	0.016	0.036	-0.006	0.137	0.201
	(1.68)	(3.17)	(5.83)	(-0.63)	(1.37)	(1.94)
Col. Def. Prob.	-2.117				-2.118	-2.169
	(-13.05)				(-12.99)	(-13.25)
Avg. Col. Rating	0.008				0.008	0.009
	(7.28)				(6.93)	(7.11)
Avg. Col. Maturity	-0.007				-0.007	-0.006
	(-4.16)				(-4.16)	(-3.68)
Correlation	-0.003				-0.005	-0.036
	(-0.18)				(-0.27)	(-1.77)
Log(CDO Size)	-0.011				-0.011	-0.015
	(-2.44)				(-2.35)	(-3.00)
# Assets	0.000				0.000	0.000
	(1.21)				(0.11)	(-0.05)
# Obligors	0.001				0.001	0.001
	(10.07)				(10.32)	(10.79)
Log(Mgr Deals)		0.009			-0.003	-0.004
		(3.13)			(-1.42)	(-1.65)
Overcollateralization			-0.002		0.003	0.004
			(-0.30)		(0.81)	(1.11)
Insurance Dummy			-0.033		0.003	0.004
			(-2.69)		(0.27)	(0.45)
Liquidity Dummy			-0.016		0.002	0.005
			(-2.31)		(0.40)	(0.90)
CLO				0.062	0.030	0.028
				(6.32)	(3.25)	(2.54)
ABS CDO				0.028	0.031	0.038
				(2.85)	(2.86)	(3.20)

(*continued*)

Table II—*Continued*

	Dependent Variable: CRA AAA – Monte Carlo AAA					
	(1)	(2)	(3)	(4)	(5)	(6)
CDO^2				-0.027 (-1.88)	0.014 (0.99)	0.016 (1.08)
Synthetic Dummy				-0.016 (-1.85)	-0.007 (-0.90)	-0.010 (-1.23)
Closing Year 2002						-0.009 (-0.68)
Closing Year 2003						0.014 (1.14)
Closing Year 2004						0.005 (0.46)
Closing Year 2005						0.010 (0.90)
Closing Year 2006						0.002 (0.19)
Closing Year 2007						0.029 (2.46)
N	902	902	902	902	902	902
Adjusted R^2	0.456	0.011	0.015	0.103	0.469	0.481

Table III

CDO AAA Fraction: Actual, Credit Rating Agency Model, and Adjustment

This table reports the average value of the actual AAA fraction, CRA model predicted AAA fraction, and the adjustment (difference between actual and CRA model) for CDOs in our sample. Data is from first CRA CDO surveillance reports and the CDO rating databases. CDOs are issued over the period from January 1997 to December 2007. *Actual AAA* 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. *CRA Adjustment* is the difference between actual AAA 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 reports. Panel B displays the correlation matrix with t-statistics of the correlation coefficients in parentheses.

Panel A: Sample Average Value

Variables	All	CBO	CLO	ABS CDO	CDO^2
#. Obs.	916	96	393	373	54
Actual AAA	0.755	0.728	0.726	0.798	0.715
CRA Model	0.634	0.625	0.566	0.717	0.568
CRA Adjustment	0.121	0.104	0.160	0.081	0.147
Positive/Total	770/916	75/96	384/393	263/373	48/54
CRA Adjustment <=2002	0.107	0.106	0.127	0.066	0.127
Positive/Total	102/131	52/65	21/25	24/36	21/25
CRA Adjustment 2003-04	0.062	0.064	0.129	0.003	0.129
Positive/Total	118/155	3/4	67/69	42/74	67/69
CRA Adjustment 2005	0.097	-0.035	0.149	0.057	0.019
Positive/Total	136/156	1/2	73/73	55/73	7/8
CRA Adjustment 2006	0.128	0.091	0.154	0.101	0.128
Positive/Total	223/261	8/11	126/127	79/110	10/13
CRA Adjustment 2007	0.182	0.133	0.206	0.153	0.219
Positive/Total	194/213	11/14	98/99	65/80	20/20

Panel B: Correlation Matrix

Variables	Actual AAA	CRA Model AAA
CRA Model	0.49 (14.09)	
CRA Adjustment	0.27 (5.34)	-0.71 (-16.34)

Table IV

CRA AAA Fraction Adjustment and CDO Characteristics

This table shows the results of OLS regressions, where the dependent variable is the CRA AAA fraction adjustment. The adjustment is defined as the difference between actual AAA fraction and CRA Model predicted AAA fraction explained in Table III. The independent variables are described in Table I except the following: *Vasicek AAA* which is the AAA fraction of the CDO predicted by the Vasicek model, *Multiple CRA* which is a dummy variable with 1 for multiple rating on the CDO and 0 otherwise, and *BDR-SDR* which is the difference between break-even default rate (BDR) and scenario default rate (SDR) in the presale or new issue reports. Data is from CRA CDO presale, new issue, and surveillance reports as well as CDO rating databases. CDOs are issued over the period from January 1997 to December 2007. Heteorsketasticity adjusted robust t-statistics are in the parentheses.

(*continued*)

Table IV—*Continued*

	Dependent Variable: AAA Adjustment									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Intercept	0.107	0.182	0.529	0.559	0.574	0.561	0.531	0.498	0.497	0.414
	(13.23)	(16.14)	(38.03)	(38.46)	(41.93)	(35.26)	(24.90)	(22.81)	(22.62)	(10.61)
Log(Mgr Deals)	0.010	0.012		0.007		0.006	0.005	0.003	0.003	0.005
	(2.21)	(2.82)		(2.44)		(1.87)	(1.60)	(0.87)	(0.87)	(1.23)
Overcollateralization		-0.079		-0.061	-0.061	-0.063	-0.063	-0.060	-0.060	-0.030
		(-10.07)		(-11.00)	(-11.03)	(-11.51)	(-11.20)	(-10.89)	(-10.85)	(-5.48)
Insurance Dummy		0.034		0.040		0.041	0.045	0.049	0.049	0.035
		(1.83)		(3.10)		(3.17)	(3.47)	(3.79)	((3.78)	(1.69)
Liquidity Dummy		-0.005		0.006		0.002	0.008	0.014	0.014	-0.002
		(-0.43)		(0.75)		(0.20)	(1.06)	(1.84)	(1.84)	(-0.21)
CRA AAA			-0.642	-0.618	-0.618	-0.711	-0.737	-0.721	-0.721	-0.596
			(-30.18)	(-30.83)	(-30.74)	(-19.88)	(-19.57)	(-19.31)	(-19.28)	(-9.91)
Vasicek AAA						0.032	0.030	-0.022	-0.022	0.054
						(3.16)	(1.46)	(-1.01)	(-1.00)	(1.48)
Simulation AAA						0.079	0.112	0.139	0.139	0.032
						(1.92)	(2.55)	(3.17)	(3.17)	(0.53)
CLO							0.035	0.025	0.025	0.073
							(2.81)	(1.97)	(1.97)	(2.31)
ABS CDO							0.031	0.054	0.054	0.032
							(1.81)	(3.09)	(3.04)	(0.83)
CDO^2							0.017	0.033	0.032	0.005
							(0.79)	(1.55)	(1.55)	(0.13)
Synthetic Dummy							-0.009	-0.025	-0.025	-0.028
							(-0.81)	(-2.20)	(-2.20)	(-1.09)
Closing Year 2005								0.020	0.020	0.027
								(2.04)	(2.03)	(2.51)
Closing Year 2006								0.029	0.029	0.045
								(3.15)	(3.12)	(4.28)
Closing Year 2007								0.059	0.060	0.069
								(5.56)	(5.51)	(4.97)
Multiple CRAs									0.001	0.021
									(0.15)	(1.70)
BDR-SDR										-0.004
										(-3.63)
N	903	903	903	903	903	903	903	903	903	408
Adjusted R^2	0.005	0.112	0.503	0.569	0.562	0.579	0.584	0.598	0.598	0.638

Table V

AAA Fraction Adjustment and Subsequent Downgrade as of July 31, 2009

This table shows regression results where the dependent variable is the number of notches downgraded from initial AAA rating or downgrade notches plus 0.5 if the tranche is on negative rating watchlist ('w/ Watch', as of July 31, 2009) for potential downgrade. AAA fraction adjustment, the first independent variable, is defined as the difference between actual AAA fraction with super senior tranches and credit rating agency model predicted AAA fraction as described in Table III. The last independent variable, *Multiple CRA,* is a dummy variable with 1 for multiple rating on the CDO and 0 otherwise. Other independent variables are described in Table I. Data is from credit rating agency CDO first surveillance reports and CDO rating databases. CDOs are issued over the period from January 1997 to December 2007. Panel A is for ordered logit regression where the dependent variable is AAA downgrade notches. Reported are the odds ratio and heteorsketasticity adjusted robust z-stat in parentheses. Panel B is for ordered probit, plain probit and OLS regressions. Dependent variables are notches downgraded from AAA for specifications (1), (3), (5) and notches downgraded plus a half notch for rating watch negative for specifications (2), (4), and (6). Reported are coefficient estimates and heteorsketasticity adjusted robust z-stat (for ordered probit and plain probit) or t-stat (for OLS) in parentheses.

(*continued*)

Table V—*Continued*

Panel A: Ordered Logit Regression							
	Dependent Variable: AAA Downgrade Notches						
	All CDOs					CLOs	Ex-CLOs
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
AAA Adjustment	25.587	15.686	7.252	7.020	6.796	88.9	5.634
	(6.66)	(5.67)	(3.96)	(3.66)	(3.60)	(2.83)	(2.83)
CLO	2.505	4.372	2.470	2.670	2.716		
	(2.70)	(3.40)	(1.92)	(2.12)	(2.16)		
ABS CDO	60.098	76.053	78.140	81.120	87.323		64.176
	(11.28)	(10.16)	(9.39)	(9.71)	(9.83)		(8.72)
CDO^2	36.207	50.290	43.064	42.271	43.123		29.218
	(6.90)	(6.64)	(6.26)	(6.05)	(6.07)		(5.46)
Synthetic Dummy		4.216	2.060	2.010	2.030		1.018
		(7.04)	(3.27)	(2.96)	(3.04)		(0.06)
Year 2007			4.905	4.567	4.092	0.735	11.005
			(3.24)	(3.24)	(3.00)	(-0.35)	(4.56)
Year 2006			4.437	4.114	3.736	1.274	5.358
			(3.11)	(3.09)	(2.88)	(0.28)	(3.48)
Year 2005			1.892	1.860	1.669	1.059	1.174
			(1.32)	(1.34)	(1.10)	(0.07)	(0.35)
Year 2004			0.681	0.643	0.603	0.957	0.376
			(-0.70)	(-0.86)	(-0.99)	(-0.05)	(-1.98)
Year 2003			1.185	1.076	1.103	2.799	0.438
			(0.26)	(0.11)	(0.15)	(1.08)	(-1.31)
Year 2002			0.228	0.230	0.222	1.112	0.115
			(-2.08)	(-2.15)	(-2.16)	(0.11)	(-3.24)
Log(Mgr Deals)				1.166	1.162	1.001	1.314
				(2.20)	(2.14)	(0.01)	(2.63)
Overcollateralization				1.058	1.042	0.862	1.117
				(0.50)	(0.37)	(-0.09)	(1.11)
Insurance Dummy				2.086	2.093	0.508	2.075
				(2.15)	(2.14)	(-0.92)	(1.44)
Liquidity Dummy				1.170	1.173	1.182	1.216
				(0.84)	(0.86)	(0.46)	(0.93)
Multiple CRAs					0.688	0.332	0.985
					(-1.46)	(-1.50)	(-0.06)
N	899	899	899	888	888	388	500
Pseudo R^2	0.143	0.157	0.188	0.189	0.190	0.015	0.193

(*continued*)

Table V—*Continued*

Panel B: Alternative Econometric Specifications						
	Ordered Probit		Plain Probit		OLS	
	Downgrade	w/ Watch	Downgrade	w/ Watch	Downgrade	w/ Watch
	(1)	(2)	(3)	(4)	(5)	(6)
AAA Adjustment	1.148	1.154	1.174	1.157	4.834	4.841
	(3.67)	(3.69)	(2.84)	(2.81)	(3.53)	(3.53)
CLO	0.451	0.400	0.831	0.776	-0.280	-0.350
	(1.82)	(1.65)	(3.29)	(3.10)	(-0.33)	(-0.42)
ABS CDO	2.450	2.417	2.328	2.267	11.354	11.371
	(9.90)	(10.01)	(9.67)	(9.51)	(13.65)	(13.68)
CDO^2	2.099	2.058	1.607	1.549	8.754	8.716
	(6.55)	(6.51)	(5.44)	(5.29)	(6.23)	(6.19)
Synthetic Dummy	0.471	0.462	0.589	0.622	2.723	2.646
	(3.58)	(3.50)	(3.72)	(3.84)	(4.59)	(4.47)
Year 2007	0.685	0.704	0.064	0.086	3.477	3.504
	(2.88)	(2.97)	(0.25)	(0.34)	(3.48)	(3.50)
Year 2006	0.617	0.645	0.223	0.259	3.274	3.318
	(2.71)	(2.85)	(0.89)	(1.04)	(3.34)	(3.38)
Year 2005	0.172	0.196	0.051	0.079	0.672	0.759
	(0.74)	(0.85)	(0.20)	(0.31)	(0.66)	(0.74)
Year 2004	-0.355	-0.335	-0.507	-0.479	-1.737	-1.700
	(-1.40)	(-1.33)	(-1.87)	(-1.78)	(-1.54)	(-1.51)
Year 2003	-0.026	-0.008	-0.303	-0.277	-0.520	-0.496
	(-0.09)	(-0.03)	(-0.99)	(-0.91)	(-0.43)	(-0.41)
Year 2002	-0.830	-0.811	-0.902	-0.875	-3.656	-3.636
	(-2.34)	(-2.29)	(-2.49)	(-2.43)	(-2.88)	(-2.85)
Log(Mgr Deals)	0.079	0.081	0.099	0.099	0.421	0.424
	(1.97)	(2.01)	(2.09)	(2.09)	(2.53)	(2.54)
Overcollateralization	0.016	0.017	0.025	0.024	0.078	0.088
	(0.24)	(0.25)	(0.34)	(0.33)	(0.24)	(0.27)
Insurance Dummy	0.328	0.326	0.454	0.447	1.478	1.486
	(1.84)	(1.83)	(1.99)	(1.98)	(2.17)	(2.18)
Liquidity Dummy	0.112	0.127	0.117	0.128	0.245	0.271
	(1.09)	(1.23)	(0.92)	(1.01)	(0.53)	(0.59)
Multiple CRAs	-0.196	-0.202	-0.271	-0.269	-0.441	-0.460
	(-1.37)	(-1.41)	(-1.66)	(-1.65)	(-0.61)	(-0.64)
Constant			-1.759	-1.729	-2.110	-2.100
			(-6.08)	(-6.10)	(-2.85)	(-2.84)
N	888	888	888	888	888	888
Pseudo/Adjusted R^2	0.190	0.178	0.274	0.272	0.614	0.616

Table VI

Actual-Publicized CDO Rating Criterion Mapping Matrix

This table reports the frequency distribution of rating default rate criterion deviations. In the row 'AAA', for the AAA rating default rate criterion actually reported in rating agency surveillance reports, we compare to the publicized default rate criterion with the same maturity in publicly distributed CDO rating software and manuals. If the actual criterion qualifies the publicized criterion, then we assign '0' notch deviated. If the actual criterion does not qualify for AAA rating according to publicized criterion but qualifies for 'AA+' ('AA', 'AA-', 'A+' and below) criterion then we assign '-1' ('-2', '-3', '-4 or less') notch deviated. We calculate the percentage for each category of notch deviations so all numbers in each row add up to one. This procedure is done for all ratings from 'AAA' to 'CCC-'. A default probability can qualify for a certain rating if the actual default probability is less than 1.05 times publicized default probability of such a rating. The default probabilities are rounded to four decimal points. CDOs are issued over the periods from January 1997 to March 2007 (Panel A) and from April 2007 to December 2007 (Panel B).

Panel A: CDOs Issued Before April 1, 2007

	Number of Notches Deviated							
	3 or more	2	1	0	-1	-2	-3	-4 or less
AAA	-	-	-	0.013	0.048	0.925	0.009	0.005
AA+	-	-	0.005	0.017	0.951	0.015	0.008	0.004
AA	-	0.001	0.001	0.022	0.018	0.135	0.717	0.106
AA-	0.000	0.001	0.017	0.010	0.041	0.447	0.461	0.023
A+	0.001	0.001	0.008	0.015	0.066	0.860	0.046	0.003
A	0.001	0.003	0.012	0.021	0.735	0.225	0.004	0.000
A-	0.001	0.004	0.014	0.049	0.923	0.006	0.003	0.000
BBB+	0.004	0.009	0.008	0.408	0.568	0.004	0.000	0.000
BBB	0.004	0.009	0.009	0.965	0.013	0.000	0.000	0.000
BBB-	0.012	0.001	0.008	0.976	0.004	0.000	0.000	0.000
BB+	0.012	0.001	0.015	0.959	0.010	0.003	0.000	0.000
BB	0.012	0.003	0.006	0.964	0.013	0.003	0.000	0.000
BB-	0.013	0.001	0.073	0.909	0.004	0.000	0.000	0.000
B+	0.013	0.006	0.906	0.071	0.004	0.000	0.000	0.000
B	0.014	0.012	0.499	0.467	0.008	0.000	0.000	0.000
B-	0.019	0.031	0.866	0.080	0.004	0.000	0.000	-
CCC+	0.022	0.059	0.875	0.044	0.000	0.000	-	-
CCC	0.022	0.492	0.483	0.004	0.000	-	-	-
CCC-	0.013	0.637	0.346	0.004	-	-	-	-

(*continued*)

Table VI — *Continued*

Panel B: CDOs Issued After April 1, 2007								
	Number of Notches Changed							
	3 or more	2	1	0	-1	-2	-3	-4 or less
AAA	-	-	-	0.913	0.008	0.072	0.007	0.000
AA+	-	-	0.000	0.913	0.072	0.007	0.007	0.000
AA	-	0.000	0.000	0.913	0.000	0.007	0.065	0.014
AA-	0.000	0.000	0.000	0.913	0.007	0.058	0.014	0.007
A+	0.000	0.000	0.000	0.913	0.007	0.065	0.014	0.000
A	0.000	0.000	0.000	0.913	0.072	0.014	0.000	0.000
A-	0.000	0.000	0.000	0.920	0.072	0.007	0.000	0.000
BBB+	0.000	0.000	0.000	0.957	0.043	0.000	0.000	0.000
BBB	0.000	0.000	0.000	0.986	0.014	0.000	0.000	0.000
BBB-	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
BB+	0.000	0.000	0.000	0.986	0.014	0.000	0.000	0.000
BB	0.000	0.000	0.000	0.986	0.014	0.000	0.000	0.000
BB-	0.000	0.000	0.007	0.993	0.000	0.000	0.000	0.000
B+	0.000	0.000	0.072	0.928	0.000	0.000	0.000	0.000
B	0.000	0.000	0.072	0.928	0.000	0.000	0.000	0.000
B-	0.000	0.000	0.072	0.928	0.000	0.000	0.000	-
CCC+	0.000	0.000	0.087	0.913	0.000	0.000	-	-
CCC	0.000	0.065	0.022	0.913	0.000	-	-	-
CCC-	0.000	0.072	0.014	0.913	-	-	-	-

Table VII

Valuation Effect of the Criterion Deviation

This table describes the valuation effects due to actual CDO credit rating default rate criterion deviation away from publicized default probability criteria. Each rating from the credit rating agency using actual criterion is converted into a rating according to publicized criterion with the same maturity, as shown in Table VI. *Avg. Maturity* is the average maturity of the collateral assets. *Avg. Spread* is the average spread for CDO notes with the same rating. *Percentage Dif.* is the present value difference in percentage due to the spread difference defined as the following:

$$\text{Percentage Dif} = \text{Average Maturity} \times (\text{Actual-Publicized}) \text{ Spread}$$

Value Dif. is the total value difference in dollars:

$$\text{Value Dif} = \text{Percentage Dif} \times \text{Amount}$$

CDOs are issued over the period from January 1997 to March 2007, totaling 788 CDOs. An asterisk indicates numbers are from a larger sample due to lack of data for sample CDOs.

Rating	# Tranches	Amount ($Bn)	Fraction (%)	Avg. Maturity	Avg. Spread	Percentage Dif. (%)	Value Dif. ($mm)
AAA	1739	379.68	84.59%	6.68	33.60	2.11	8013.49
AA+	13	0.37	0.08%	6.66	84.60	-1.31	-4.84
AA	648	23.74	5.29%	7.03	64.84	3.59	852.71
AA-	49	2.05	0.46%	6.98	64.57	4.90	100.59
A+	42	1.44	0.32%	6.84	81.34	4.79	69.21
A	556	14.25	3.17%	6.56	124.29	3.33	474.42
A-	177	4.12	0.92%	6.45	147.97	7.81	321.76
BBB+	35	0.66	0.15%	6.34	278.51	-0.54	-3.60
BBB	713	13.81	3.08%	6.56	268.48	-0.05	-7.46
BBB-	153	2.96	0.66%	7.15	296.60	-0.13	-3.75
BB+	83	0.71	0.16%	7.77	598.43	-0.57	-4.08
BB	300	3.96	0.88%	6.10	464.90	-0.12	-4.95
BB-	54	0.84	0.19%	6.45	443.61	-0.01	-0.09
B+	—	—	—	—	366.14*	—	—
B	4	0.24	0.05%	6.93	467.61*	-3.40	-8.18
B-	4	0.03	0.01%	5.70	850.00	-20.67	-5.79
Sum	4570	448.87	100.00%				9789.44

Table VIII

CDO AAA Value Difference Relative to Rating from Monte Carlo Simulation

This table summarizes ratings assigned by alternative models for actual CDO liability structure and the corresponding value difference from actual AAA rating. *Model Rating* is the rating assigned by the Monte Carlo (MC) simulation with the actual AAA fraction. *AAA 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 ×(AAA-Model Rating Spread) ×Dollar Value of the AAA Fraction,

where *Model Rating Spread* is the historical spread corresponding to the rating implied by the model. *Sample Dif.* is the total value difference 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 the whole CDO amount. Data is from credit rating agency CDO first 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).

	All	CBO	CLO	ABS CDO	CDO^2
#. Of CDOs	916	96	393	373	54
Model Rating	BBB	BBB	BBB	BBB	BBB+
AAA Spread	0.33	0.42	0.30	0.33	0.40
Model Rating Spread	2.89	2.94	2.83	2.99	2.54
Spread Dif. (%)	2.56	2.54	2.53	2.66	2.14
Value Dif. ($ millions)	94.13	54.75	52.94	146.83	74.68
Sample Dif. ($ billions)	86.22	5.26	20.81	54.77	4.03
Dif. in AAA Portion	0.20	0.19	0.15	0.21	0.18
Dif. in CDO Portion	0.15	0.14	0.11	0.17	0.13

Supplementary Appendices

Supplementary Appendix A: CDO Valuation Models

This appendix provides a brief introduction to portfolio credit risk analysis. Two valuation approaches are discussed: the Gaussian Copula Monte Carlo Simulation approach and Vasicek granular portfolio approach. More detailed explanations can be found in Duffie and Garleanu (2001) or Duffie and Singleton (2003).

A. 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:

$$p_i = F(X_i). \tag{2}$$

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*:

$$\rho_{ij} = \frac{\mathrm{Cov}(p_i,p_j) - \mathrm{Var}(p_i) - \mathrm{Var}(p_j)}{\sqrt{\mathrm{Var}(p_i)\mathrm{Var}(p_j)}} = \frac{p_{ij} - p_i - p_j}{\sqrt{p_i(1\text{-}p_i)p_j(1\text{-}p_j)}} \tag{3}$$

This structural approach is economically sensible. The Vasicek (1987) model 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:

$$C_\rho\left(p_i, p_j\right) = F_\rho\left(F^{-1}(p_i), F^{-1}\left(p_j\right)\right) \tag{4}$$

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:

$$P = \begin{bmatrix} 1 & \cdots & \rho \\ \vdots & \ddots & \vdots \\ \rho & \cdots & 1 \end{bmatrix} \quad (5)$$

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. This simulation is repeated many times.

The main inputs and parameters for the simulation are portfolio average collateral default rate, maturity, correlation, number of asset, recovery rate, and the rating default probability criterion from which a scenario default rate will be derived. Note that controlling for the other model inputs and parameters, there is a one-to-one correspondence between rating default probability criterion and SDR. We focus on the AAA ratings.

B. 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

$$p_T = \Pr(V_T \leq X | V_0 > X) \quad (6)$$

Assume asset value follows a geometric Brownian motion

$$dV_t = \mu V_t dt + \sigma V_t dW \quad (7)$$

Then the probability of default can be solved analytically

$$p_T = N\left(-\frac{\ln\left(\frac{V_0}{X}\right) + \left(\mu - \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}}\right) \quad (8)$$

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

Vasicek (1987) applies the Merton model to the 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:

$$p_i = N(-c_i) \equiv p \quad (9)$$

and each individual stochastic variable can be decomposed as follows:

$$W_i = \rho X + \sqrt{1-\rho^2} Z_i \quad (10)$$

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

$$F_N(\alpha) = \sum_{k=0}^{[\alpha N]} P_k \quad (11)$$

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

$$F_\infty(\alpha) = N\left(\sqrt{\frac{1-\rho}{\rho}}\, N^{-1}(\alpha) - \sqrt{\frac{1}{\rho}}\, N^{-1}(p)\right) \quad (12)$$

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 out α given $F_\infty(\alpha)$.

Supplementary Appendix B: A CDO Rating Example

The following example illustrates the derivation of ratings for *Independence III CDO*, which is a cash ABS CDO closed on May 9, 2002. The arranger is Bank of America and manager is Independence Fixed Income (renamed Declaration Research and Management in 2003). Its senior tranches consist of $186 million of Class A-1 notes and $62 million of Class A-2 notes out of the $300 million total liabilities (targeting $302 million of collateral assets). So the total A-class notes targeting AAA rating count for 82.67% and the subordination level is 17.33%.

S&P's new issue report dated July 9, 2002 provides a SDR estimate of 21.11% for 'AAA' rating scenario. That is, under the 'AAA' scenario, the collateral asset pool is expected to lose no more than 21.11% of its value. The same report also states a Class A BDR of 22.72%. That is, under all cash flow scenarios considered, Class A notes will make timely interest and principal payments even if the portfolio loses 22.72% of its value. Because the collateral pool is not expected to lose more than 21.11% under AAA scenario but Class A notes (tranche A-1 and tranche A-2) can withstand 22.72% portfolio loss, hence Class-A tranches can obtain AAA rating.[47] Those Class A tranches will maintain AAA rating as long as the overcollateralization ratio is above 120% and interest rate coverage ratio is above 115%.

For a generic credit portfolio, the tranche amount admissible for AAA rating according to the CRA credit risk model is $1-SDR^{AAA}$. In the *Independence III CDO* example above, the 'AAA' scenario is

[47][47] Although in the final version BDR must be greater than SDR, those BDR and SDR numbers could be the outcome of several iterations. Note that if the underwriter presented a BDR of 22.72% but the rating agency calculated a higher SDR, say 23.00%, then the underwriter would need to restructure the deal (for example, cut AAA tranche size or add credit enhancement to it) or change the correlation to persuade the rating agency to calculate a lower SDR. It is common that the underwriter would have already estimated the rating agency model and known the 21.11% SDR for the proposed structure.

expected to lose no more than 21.11% of its value at the AAA default probability. A CDO rated at the edge could then receive 78.89% AAA and hence this is the 'CRA model fraction'. The difference between the actual rated tranche size and the CRA model fraction (1-SDR) is referred to as the 'adjustment.' In our example of Independence III CDO the adjustment is 82.67%−(1−21.11%)=3.78%. S&P states the rationale for "the ratings assigned to the Independence III CDO Ltd.'s class A, B, and C notes reflect the credit support provided by excess spread and subordination of cash flow to more junior classes of notes, diversification in the pool of assets securing the transaction, and protection provided by various early-amortization triggers." Moody's assigned the same ratings after it "evaluated the characteristics of the underlying collateral, the transaction's performance under various default scenarios and related stress-test analyses, the legal structure, and the expertise of the collateral manager." A more general statement from S&P explains the rationale for CDO ratings assigned "reflect the credit enhancement provided by excess spread, the subordinated classes of notes, the cash flow structure (which is subject to various stresses by Standard & Poor's), the experience and performance of the collateral manager, the transaction's interest rate hedges, diversification in the pool of assets securing the transaction, and protection provided by various early amortization triggers" (New Issue Report, Centurion CDO VI Ltd., October 17, 2002).

Supplementary Appendix C: A Discussion of Coincidental CDOs

From our main finding in Figure 5, we notice that a number of CDOs seem to use the same constant default probability criterion for each of the 19 rating scales regardless of their maturities. In Appendix Table AII, we list the 27 CDOs with the same constant default probability criterion. We further discovered that, not only are their default probability criteria constant and identical, their scenario default rates are identical for each of the 19 rating scales from AAA to CCC- across all 27 CDOs. This result will only be possible if they are all drawn from the same portfolio loss distribution or the CDOs refer to the same collateral asset pool. However, Appendix Table II shows that these 27 CDOs are very different from one another such that it would seem extremely improbable that all 27 CDOs could have the same SDRs across all tranches. The closing dates range from December 28, 2000 to July 19, 2007. One interesting finding is that all but one of the CDOs are rated by a group of credit analysts located in New York City and monitored by one surveillance analyst. This group of credit analysts rated 171 CDOs in our sample. So these 26 deals represent 15.2% of those 171 deals. Interestingly, 24 of the 27 CDOs are rated by multiple CRAs.

Supplementary Appendix D: Events around April 1, 2007

A. Summary of Market Events

We are unable to find any documentation of a shift in credit rating standards in early 2007 on any of the credit rating agency websites. In recent testimony before Congress the Moody's CEO did indicate a tightening of standards for MBS securities in early April 2007 associated with bad news regarding mortgage securities.[48] To understand market conditions around early 2007, we search through relevant news related to subprime housing and other major credit events. Sanders (2008) shows that Arizona, California, and Nevada house prices began to move together starting in 2005 and in the second-half of 2006 subprime loan defaults began to increase. In Figure A4 we plot subprime loans in foreclosure (using data provided by Loan Performance HPI) as well as relevant news for the first half of 2007 to shed light on our finding of April 1, 2007 as the ending time of the criterion deviation.

Figure A4 shows that the delinquency rate on subprime mortgages increased from 4.92% in January to 5.97% by June (with further increases of another point occurring in August). There were a number of subprime mortgage lenders either declaring or heading for bankruptcy in January and February of 2007. Gorton and Metrick (2009) document the decline of the subprime mortgage market, as measured by the ABX.HE index beginning in January 2007. On March 6, Ben Bernanke calls for a "stronger regulatory framework" for Fannie Mae and Freddie Mac. On March 22, Senator Shelby of the Senate banking committee calls for testimony of organizations including credit rating agencies involved in securitizing mortgages. Since industry insiders claim that the credit rating agencies have long feared government oversight, one must wonder if credit rating agencies were aware of such testimony. Moody's announces revision of its "loan-by-loan" mortgage data fields on April 3. On June 23, 2007 Bear Sterns announces it will bail out a credit hedge fund focusing on subprime mortgage CDOs.

The above events indicate that the crisis was looming in the beginning of 2007, well before conditions worsened considerably in August 2007 (allegedly after BNP Paribas froze redemption of two funds on August 9). 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.

B. Did other CDO features change?

In Table A4, we show key characteristics of CDOs issued before and after April 1, 2007. Beginning in April 2007, CLOs represent most of the newly issued CDOs (72 out of 138). A key parameter to CDO rating and the main free parameter for the CRA in modeling is the default correlation.

[48] In discussing MBS securities, Raymond McDaniel, Chairman and CEO of Moody's, 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].

Overall, the most noticeable change is the increase in correlation and CDO deal size. Focusing on CLOs, correlations increase from 0.29 to 0.54. Average collateral rating quality, maturity, and synthetics remain the same. Because CLOs issued after April 1, 2007 may be different from CLOs issued before April 1, 2007, we also 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. Still, default correlations of the new CLOs are much higher than the matched seasoned CLOs. Moreover, the average default correlation is higher after April 1, 2007 for each CDO type than before April 1, 2007 with the same reporting time, though the difference is 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.

Table AIV also shows that prior to April 2007 the CRA model assigns 0.64 of the CDO as AAA whereas our simulation yields 0.62. Beginning in April 2007 the CRA model yields 0.58 AAA but our model yields 0.51 AAA. Hence, despite the tougher AAA criterion there is still a disconnect between our Monte Carlo model and that of the CRA.

C. Was April 2007 Special?

Our evidence suggests that the criterion and correlation assumptions by the CRA have become tougher after April 1, 2007. However, less is known about the ultimate effects on CDO ratings (e.g., AAA fraction). The model, namely, the functional form transforming parameters and inputs into outputs, can potentially reinforce or offset effects from criterion and correlation assumptions. We first analyze the difference between CRA model AAA fraction and our simulation model output separately before and after April 1, 2007. We find that the model difference is less explained by CDO structural variables after April 1, 2007 (0.38 adjusted R^2) than before (0.47 before).[49]

In order to formally test possible structural breaks in the CRA CDO model around April 1, 2007, we conduct Chow tests for structural breaks following Andrews (1993). We report results in Table AIV. The dependent variable is the difference between the CRA model output and our simulation model output. Across all three specifications, Table AIV shows that April 2007 is the most evident break point. Since there is no structural break in the simulation model by construction, any structural break will come from the CRA model.

[49] Here we use the full set of CDO characteristics as in Table II, specification (5) except that the number of deals by the manager is excluded.

Supplementary Appendix: Figures and Tables

Figure A1. 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.

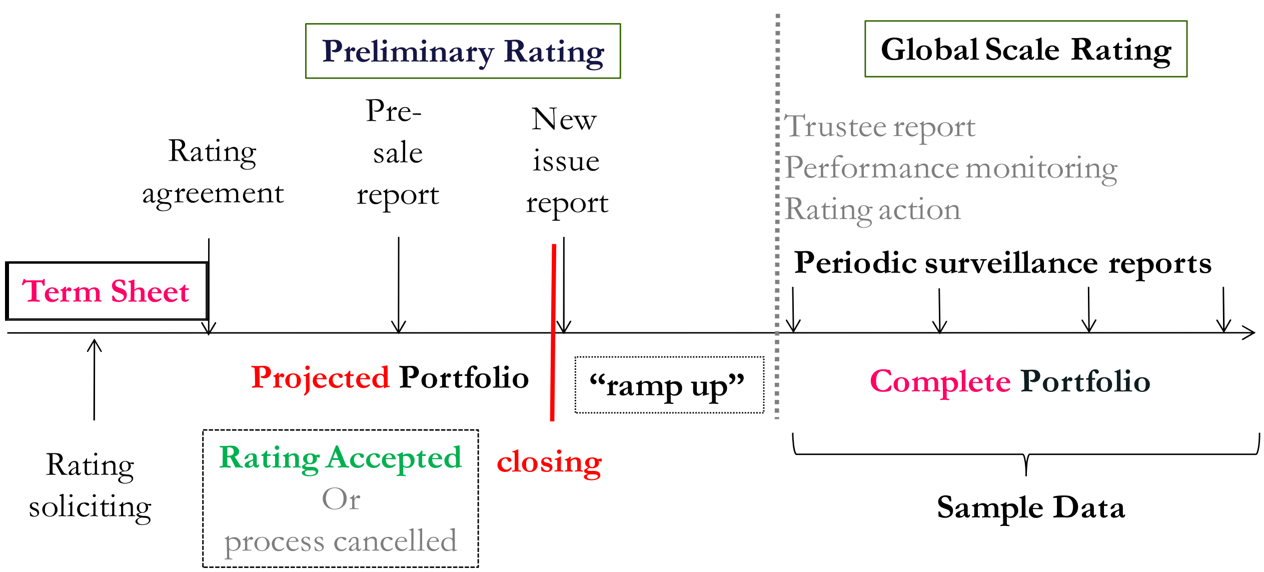
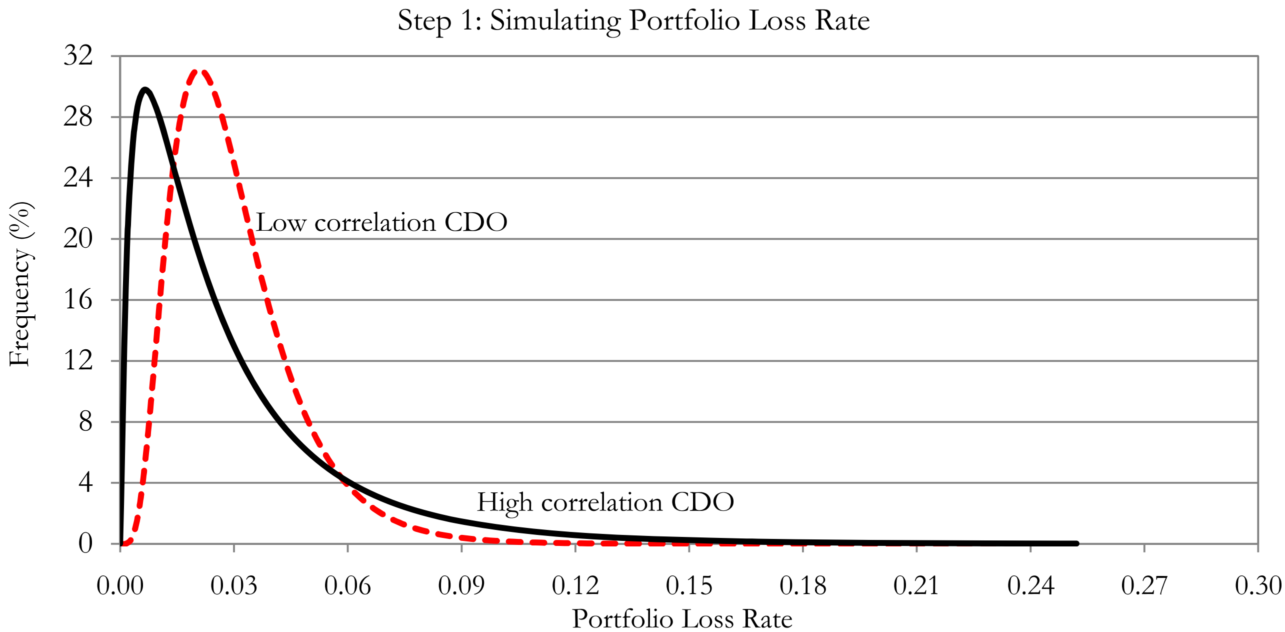


Figure A2. CDO Credit Rating Approach. This figure illustrates the CDO rating approach commonly used by major CRAs. Using CDO collateral asset information, the CRA first simulates portfolio loss rates and draws the histogram. This histogram is then used in the second step to map the "idealized default 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.



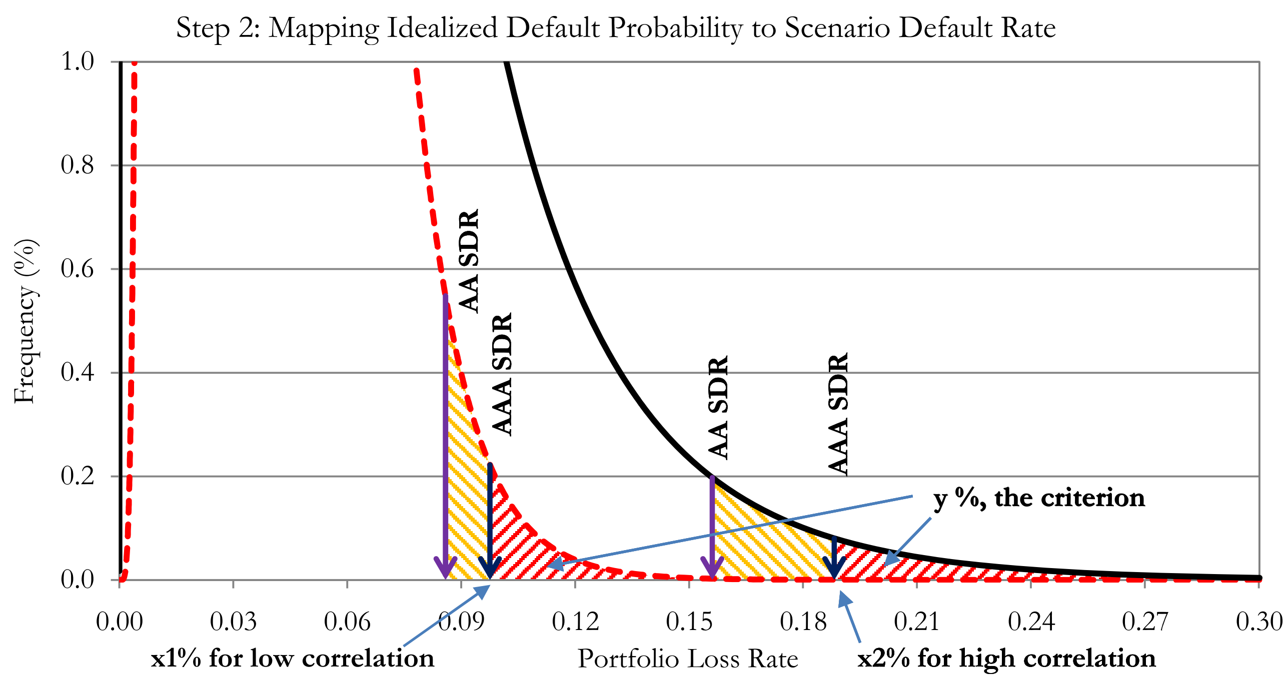


Figure A3. Scenario Default Rate According to Publicized Idealized Default Probabilities and Actual Default Probabilities: An Illustrative Example. This figure illustrates a hypothetical CDO portfolio with real rating default probabilities. The dotted lines denote the scenario default rate (SDR) for 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.

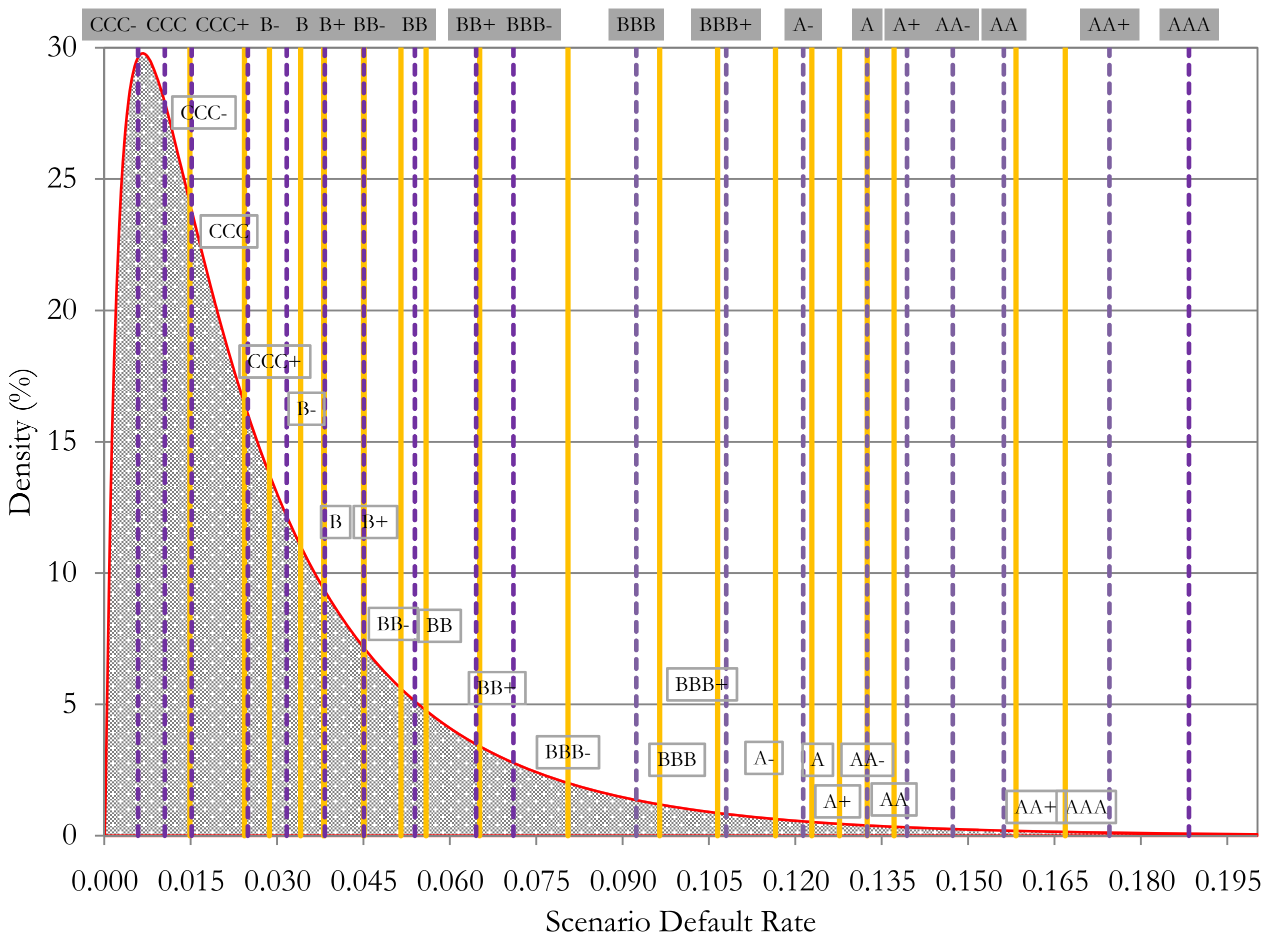
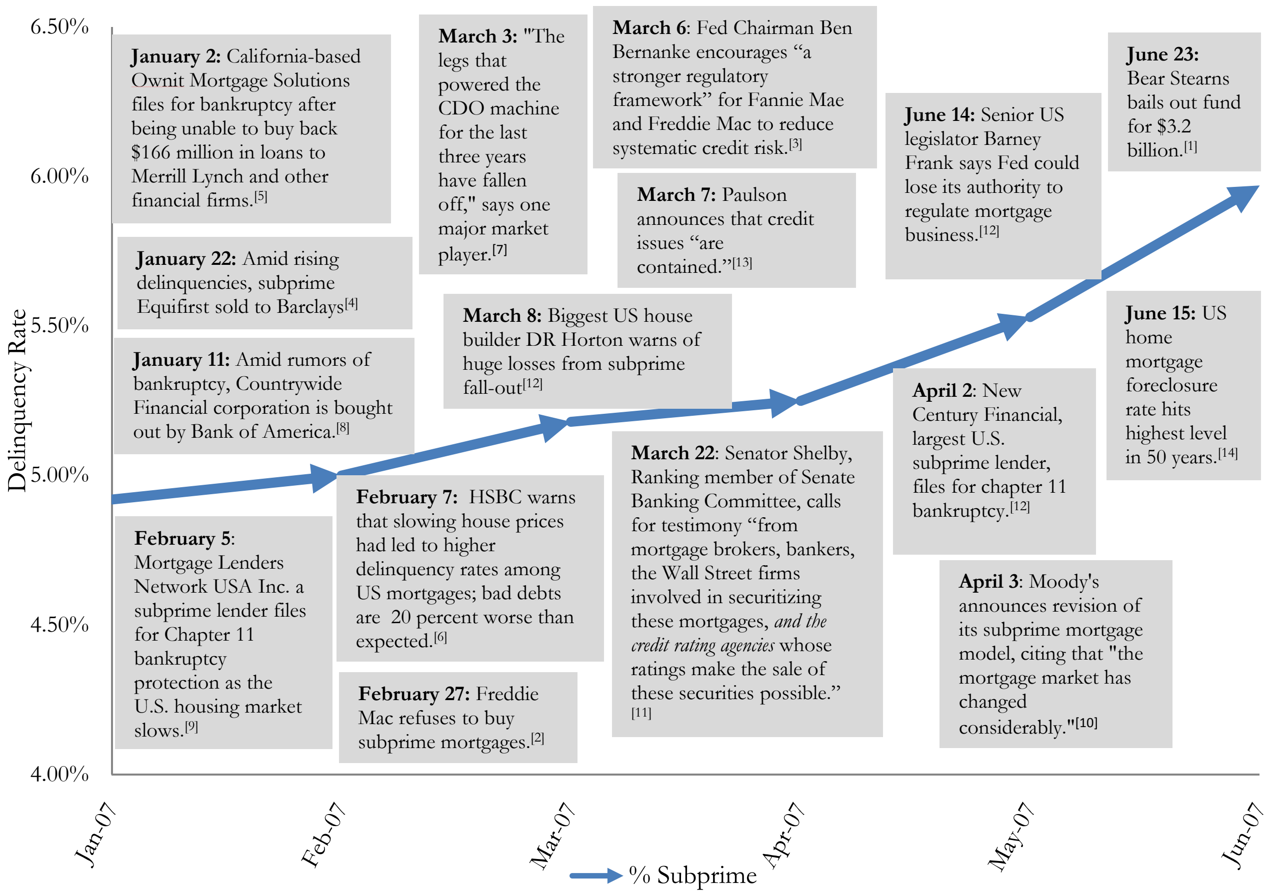


Figure A4. Timeline Leading into the Crisis. This timeline is constructed from various news sources that details the events leading up to the subprime crisis and is accompanied by a plot of the delinquency rates of subprime mortgages for the period Jan. 1-June 31, 2007. Total foreclosures include REOs.



1. Bajaj, J. C. (2007, June 23). $3.2 Billion Move By Bear Stearns To Rescue Fund. The New York Times.
2. Bajaj, V. (2007, February 28). Freddie Mac Tightens Standards. The New York Times.
3. Bernanke, B. (2007, March 6). GSE Portfolios, Systematic Risk, and Affordable Housing. Speech before the Independent Community Bankers of America's Annual Convention. Honolulu, Hawaii.
4. Board, L. (2007). Barclays buys EquiFirst for $225M. TheDeal.com.
5. Keoun, B. (2007, January 2). bloomberg.com. Retrieved April 29, 2009, from Bloomberg News Inc.: http://www.bloomberg.com/apps/news?pid=conewsstory&refer=conews&tkr=MER:US&sid=akwzqnZA.euU
6. King, I. (2009, March 3). The Spark That Ignited A Blaze. The Times, p. 1.
7. Mitchell, D. (2007). Wider AAA' subprime levels weaken nearterm rebound hopes. SourceMedia.
8. National Public Radio. (2008, January 11). Bank of America to Buy Countrywide. Retrieved April 29, 2009, from NPR.org: http://www.npr.org/templates/story/story.php?storyId=18018024
9. Reuters. (2007, February 5). Mortgage Lender Network Files for Chapter 11. Retrieved April 29, 2009, from Reuters Web Site: http://www.reuters.com/article/companyNewsAndPR/idUSN0546894120070205
10. Romer, J. (2008, June 9). Cuomo Rewards the Rating Agencies. Retrieved April 29, 2009, from RGE Monitor: http://www.rgemonitor.com/financemarkets-monitor/252748/cuomo-rewards-the-rating-agencies/
11. Shelby, R. C. (2007). Mortgage Market Turmoil: Causes and Consequences. Washington, DC: Senate Committee on Banking, Housing, and Urban Affairs.
12. The British Broadcasting Channel. (2008, May 19). Timeline: Sub-prime losses. Retrieved April 29, 2009, from BBC.co.uk: http://news.bbc.co.uk/2/hi/business/7096845.stm.
13. The Evening Standard. (2007). Paulson says mortgage crisis in US is contained. London.
14. Trejos, D. E. (2007). Foreclosure Rate Hits Historic High. Washington Post.

Table AI

AAA CDO Rating Default Rate Criterion from Fitch, Moody's, and S&P

This table reports the AAA rating default rate criterion for CDOs for maturities from 1 to 10 years. Fitch and Moody's report "idealized default probabilities" (the 10-year idealized default probabilities correspond to their rating factors) while S&P reports actual expected default rate. Fitch and S&P state that their default probabilities are cumulative. The choice of decimal point for reporting is directly from the rating agencies.

	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

Table AII

CRA Model and Monte Carlo Simulation

This table provides the mean and standard deviation of the statistics for the AAA fraction obtained from a leading credit rating agency (CRA Model) and from a Gaussian Copula Monte Carlo Simulation model (MC AAA). The correlation between the two is also reported. The summary statistics are reported for collateralized bond obligations (CBOs), collateralized loan obligations (CLOs), CDOs collateralized with asset-backed securities (ABS CDO), and CDOs consisting of notes of existing CDOs (CDO^2). Results are further divided by whether the CDO is a cash deal or synthetic deal with CDS contracts. The CDOs are issued from January 1997 to December 2007. The Monte Carlo Simulation inputs are average collateral default rates, maturity, correlations, and number of assets reported by the CRA. The default rate criterion for AAA scenario is taken from the CRA's manual. The simulation approach is described in the Appendix. For our simulation's recovery rate assumptions, a fixed 40% recovery rate is used for all CDOs.

	All	Cash				Synthetic			
		CBO	CLO	ABS CDO	CDO^2	CBO	CLO	ABS CDO	CDO^2
N	916	72	393	281	46	24	0	92	8
CRA AAA	0.63	0.62	0.57	0.76	0.56	0.63	-	0.59	0.60
Std. dev.	0.16	0.13	0.076	0.15	0.19	0.13	-	0.20	0.14
MC AAA	0.58	0.60	0.49	0.70	0.58	0.61	-	0.56	0.57
Std. dev.	0.14	0.11	0.06	0.14	0.14	0.12	-	0.12	0.15
Correlation	0.82	0.76	0.44	0.86	0.73	0.72	-	0.82	0.23

Table AIII

Model Explicability Comparison

This table reports the OLS regression results with different dependent variables for AAA fraction. The dependent variables are the AAA fractions predicted by the Vasicek model, Monte Carlo Simulation, CRA Model, and Actual AAA fraction. The independent variables are described in Table I of the text. CLO, ABS CDO, and CDO^2 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. Data is grouped by report date (first reports versus continuing reports). Heteroskedasticity and autocorrelation adjusted 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)
Log(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 CDO	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)
CDO^2	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 AIV

Characteristics of CDOs with Constant Criterion and Identical Model Output

This table summarizes the characteristics of 27 CDOs with constant default probability criterion (independent of maturity) and identical SDR across all ratings. Variable definitions are in Table I. Manager (Mgr), underwriter (UW), and analyst names are coded with a number. # *Raters* is the number of rating agencies rating the CDO. *AAA dng* is the number of notches the AAA tranche of the CDO was downgraded as of July 31, 2009.

CDO #	Closing Date	Rating Date	Structure	Type	Mgr #	UW #	Report Date	WAM	WAR	# Assets	Corr.	Credit Analyst #	Surveillance Analyst #	Original Amt	# Raters	AAA Spread	AAA Dng
1	12/28/00	12/29/00	Cash	CBO	7	8	8/15/08	3.41	BB-	117	0.15	14	**1**	500	2	50	0
2	2/6/01	2/7/01	Cash	ABS CDO	6	11	8/18/08	6.54	B-	94	0.31	5	**1**	300	2	48	3
3	4/19/01	5/7/01	Cash	CLO	9	14	8/13/08	3.42	B	333	0.30	7	**1**	438	3	50	3
4	5/24/01	6/4/01	Cash	ABS CDO	12	6	8/29/08	7.18	B-	38	0.18	4	**1**	240	3	48	0
5	12/18/01	1/3/02	Cash	CBO	7	1	8/15/08	5.45	B+	142	0.25	7	**1**	327	2	50	0
6	11/14/02	11/20/02	Cash	ABS CDO	6	18	8/22/08	7.14	BB	306	0.64	7	**1**	300	3	55	4
7	10/29/03	10/29/03	Cash	ABS CDO	8	2	8/29/08	7.21	BBB-	88	0.39	2	**1**	400	3	12	0
8	4/22/04	4/27/04	Cash	ABS CDO	1	5	7/31/08	7.20	BBB-	104	0.48	7	**1**	410	2	60	3
9	7/29/04	9/1/04	Cash	ABS CDO	14	16	8/29/08	7.14	A	318	0.55	7	**1**	2442	2	NA	3
10	7/30/04	8/4/04	Cash	CLO	7	9	8/18/08	5.23	B+	105	0.17	7	**1**	216	2	43	0
11	10/26/04	11/1/04	Cash	ABS CDO	1	10	9/2/08	7.31	B+	221	0.75	7	**1**	550	2	36	19
12	6/9/05	7/1/05	Cash	ABS CDO	15	13	8/29/08	8.48	BB-	135	0.55	11	**1**	382	2	27	9
13	12/15/05	12/23/05	Cash	ABS CDO	1	15	9/5/08	7.54	B+	136	0.69	7	**1**	500	1	27.5	19
14	4/20/06	4/25/06	Cash	CDO^2	5	4	8/28/08	7.08	BB+	92	0.54	6	**2**	287	2	15	0
15	7/27/06	8/3/06	Synthetic	CBO	1	11	8/7/08	4.15	B+	89	0.17	3	**1**	301	2	24	0
16	9/13/06	9/28/06	Cash	CLO	3	15	7/3/08	5.17	B+	168	0.28	5	**1**	300	2	NA	0
17	10/26/06	11/1/06	Synthetic	ABS CDO	11	12	8/29/08	7.49	CCC+	214	0.82	9	**1**	1504	2	30	19
18	11/21/06	12/4/06	Cash	CLO	2	3	8/13/08	4.92	B	442	0.32	13	**1**	399	1	NA	0
19	12/14/06	12/29/06	Cash	CLO	10	7	6/11/07	6.15	B+	232	0.25	10	**1**	400	2	24	0
20	12/15/06	12/21/06	Cash	ABS CDO	1	7	8/29/08	7.00	B-	95	0.65	2	**1**	350	2	43*	14
21	12/19/06	12/29/06	Cash	CDO^2	5	4	8/10/08	7.72	BB-	103	0.59	12	**1**	334	2	15	11
22	12/21/06	12/28/06	Synthetic	CBO	1	9	8/11/08	4.64	BBB-	100	0.09	9	**1**	1000	2	20	0
23	1/10/07	1/18/07	Cash	ABS CDO	1	17	8/31/08	7.00	CCC-	105	0.76	1	**1**	500	2	32	19
24	1/24/07	2/1/07	Cash	CLO	2	3	7/10/08	4.98	B	453	0.33	13	**1**	484	2	NA	0
25	5/1/07	5/21/07	Cash	CLO	4	5	7/18/08	4.87	B	331	0.60	13	**1**	400	2	22.5	0
26	6/28/07	7/2/07	Synthetic	ABS CDO	3	7	9/8/08	7.00	B-	178	0.79	5	**1**	1000	1	45	19
27	7/19/07	8/1/07	Cash	CLO	13	12	9/2/08	5.43	B	91	0.39	8	**1**	309	2	29	0

Table AV

Characteristics of CDOs Issued Before and After April 1, 2007

This table reports the mean value of deal characteristics for CDOs issued before and after April 1, 2007. CDOs are issued over the period from January 1997 to December 2007. *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. *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. *CRA AAA* is the AAA fraction from CRA model. *Simulation AAA* is the AAA fraction from the simulation model. *AAA Adjustment* is the difference between the actual AAA fraction and the CRA AAA. The summary statistics are reported for collateralized bond obligations (CBOs), collateralized loan obligations (CLOs), CDOs collateralized with asset-backed securities (ABS CDO), and CDOs consisting of notes of existing CDOs (CDO^2).

Variables	All		CBO		CLO		ABS CDO		CDO^2	
	Before	After	Before	After	Before	After	Before	After	Before	After
#. Obs.	778	138	85	11	321	72	329	44	43	11
Col. Rating	10.97	11.89	13.48	11.91	14.41	14.79	7.15	7.93	9.23	8.73
Correlation	0.39	0.55	0.18	0.44	0.29	0.54	0.53	0.56	0.54	0.60
Col. Maturity	6.49	6.23	5.14	6.56	5.72	5.82	7.29	6.79	8.83	6.31
Col. Size	605.6	796	347.9	754	466.8	535	821.5	1198	499.8	940
#. Assets	210.2	264	125.9	242	318.9	357	142.6	161	82.3	91
#. Obligors	127.7	143	102.0	122	155.6	169	114.6	121	71.0	76
Synthetic Dummy	0.11	0.25	0.19	0.73	0.00	0.00	0.21	0.50	0.07	0.45
Overcollateralization	1.01	0.98	0.88	0.96	0.95	0.96	1.05	1.00	1.40	1.09
Insurance Dummy	0.06	0.04	0.21	0.00	0.05	0.00	0.04	0.14	0.07	0.00
Liquidity Dummy	0.25	0.14	0.48	0.36	0.12	0.06	0.30	0.18	0.40	0.27
Actual AAA	0.753	0.761	0.738	0.729	0.726	0.726	0.794	0.828	0.706	0.751
CRA AAA	0.643	0.579	0.626	0.610	0.581	0.498	0.720	0.695	0.556	0.616
Simulation AAA	0.622	0.511	0.646	0.541	0.531	0.412	0.706	0.652	0.605	0.566
AAA Adjustment	0.110	0.182	0.102	0.119	0.145	0.228	0.074	0.133	0.150	0.135

Table AVI

Tests of Structural Breaks in Rating Agency Model

This table reports the F values from the Chow test for structural breaks in the rating agency model of selected known break points. The break points separate the whole sample into two groups: one dated before the break point and the other after. The dependent variables are the difference between the CDO AAA fraction from the CRA model and from a Monte Carlo Model (CRA AAA – Monte Carlo AAA). The Monte Carlo Simulation inputs are average collateral default rates, maturity, correlations, and number of assets reported by the CRA. The simulation approach is described in the Appendix. Recovery rate assumptions are fixed at 40% for all specifications. Model specifications (1), (2), (3) are considered as follows:

$$\text{AAA Dif} = \alpha + \beta_1 \times \text{Col. Def. Prob.} + \beta_2 \times \text{Avg. Col. Rating} + \beta_3 \times \text{Avg. Col. Maturity} + \beta_4 \times \text{Correlation} + \beta_5 \times \text{Ln Col Size} + \varepsilon \quad (1)$$

$$\text{AAA Dif} = \alpha + \beta_1 \times \text{Col. Def. Prob.} + \beta_2 \times \text{Avg. Col. Rating} + \beta_3 \times \text{Avg. Col. Maturity} + \beta_4 \times \text{Correlation} + \beta_5 \times \text{Ln Col Size} + \beta_6 \times \text{\# Assets} + \beta_7 \times \text{Overcollateralization} + \beta_8 \times \text{Insurance Dummy} + \beta_9 \times \text{Liquidity Dummy} + \beta_{10} \times \text{CLO Dummy} + \beta_{11} \times \text{ABS CDO Dummy} + \beta_{12} \times \text{CDO Dummy} + \beta_{13} \times \text{Synthetic Dummy} + \varepsilon \quad (2)$$

$$\text{AAA Dif} = \alpha + \beta_1 \times \text{Col. Def. Prob.} + \beta_2 \times \text{Avg. Col. Rating} + \beta_3 \times \text{Avg. Col. Maturity} + \beta_4 \times \text{\# Assets} + \beta_5 \times \text{ABS CDO Dummy} + \varepsilon \quad (3)$$

Variable definitions are in Table I. CDOs are issued over the period from January 1997 to December 2007.

	Model Specifications		
Break Point	(1)	(2)	(3)
Jan-04	1.96	1.63	2.18
Jan-05	1.22	1.37	0.84
Jan-06	2.87	1.45	1.96
Feb-06	3.14	1.58	2.04
Mar-06	3.62	1.92	2.46
Apr-06	4.79	2.48	3.27
Jul-06	6.94	3.62	4.96
Oct-06	9.26	4.90	6.12
Jan-07	9.38	4.91	5.53
Feb-07	9.04	5.43	4.40
Mar-07	9.00	5.36	4.80
Apr-07	10.96	7.03	8.01
May-07	8.81	5.18	6.03
Jun-07	7.32	4.37	5.66
Jul-07	6.44	4.16	5.63
Aug-07	2.56	1.94	2.67
Sep-07	2.37	1.62	1.94