Sneak Peek 9

Reading: Coval, J.; Jurek, J.; and Stafford, E., "The Economics of Structured Finance", The Journal of Economic Perspectives, American Economic Association, Winter 2009, Vol. 23, No. 1.

Synopsis: This is a fairly quick reading which is divided into two related topics. It first introduces the concept of collateralized debt obligations (CDOs) and CDOs of CDOs (CDO^2). You'll learn to calculate the default probabilities of these structured finance products. The second topic covers the 2008 subprime financial crisis, looking at the role CDOs played in the run up to the market crash.

Contents

Study Tips

- Focus on knowing the calculations well. They're easy points on the exam.
- This reading pairs well with *Cummins.CATBonds*; try revisiting each of these readings in tandem a few weeks after you complete them both.

Estimated study time: 4 Hours *(not including subsequent review time)*

BattleTable

Based on past exams, the **main things** you need to know *(in rough order of importance)* are:

- Calculate **default probabilities** for junior, mezzanine, and senior tranches of CDOs and CDO^2s.
- Explain how changes in the **probability of default and correlation assumptions** alter the ratings associated with structured finance products.
- Describe the **role of structured finance in the 2008 financial crisis**.

Questions from the Spring 2019 exam are held out for practice purposes. (They are included in the CAS practice exam.)

reference	part (a)	part (b)	part (c)	part (d)
E (2018.Spring #12)	**Pricing CDO^2s** - no correlation	**Pricing CDO^2s** - perfect correlation	**Expected Return** - compare	
E (2017.Spring #14)	**Design of CDOs** - AAA-ratings	**Design of CDOs** - AAA-ratings		
E (2016.Spring #18)	**CDOs and CDO^2s** - default probabilities	**Ratings & Correlations** - impact of increase		
E (2015.Spring #14)	**CAT Bond CDOs vs CMOs** - contrast	**CAT Bond CDOs** - potential challenges	**CAT Bond CDOs** - potential regulations	
E (2014.Spring #16)	**CAT Bond CDOs vs CMOs** - preference rank	**Probability of Default** - impact of increase	**Default Correlations** - impact of increase	
E (2013.Spring #12)	**Default Probabilities** - calculate	**Default Probabilities** - role in subprime crisis		

In Plain English!

Asset Backed Securities

Structured finance involves *pooling economic assets* (such as auto loans, bonds, credit card receivables, or mortgages among others) and creating a **prioritized capital structure** for claims against the collateral pools. The layers of the capital structure are referred to as **tranches** and the collection of tranches is called a **collateralized debt obligation** (CDO) because it is backed by the underlying economic assets.

Structured finance creates "safe" assets by repackaging many risks associated with risky collateral. By design, many of the tranches are safer than the average asset in the underlying collateral pool. The process can be repeated further; a collection of CDOs can be repackaged into tranches, creating an **asset backed security** (ABS). The creation of "safe" assets from risky assets led to a rapid expansion of structured finance products and these were often viewed as *virtually risk-free* by investors and certified as such by ratings agencies. The 2008 financial crisis was centered on the discovery that these securities were far riskier than originally advertised.

Ratings agencies such as Moody's, Standard and Poor's, and Fitch analyze financial, economic and industry data to produce independent assessments (**credit ratings**) of creditworthiness for governments, corporations, and various financial instruments. They rate using a scale along the lines of AAA, AA, A, BBB, ...,. A credit rating can be thought of as a measure of the security's expected cash flow. Issuers of structured finance products wanted their securities to have ratings *on the same scale* attached as this creates the illusion that structured finance products are directly comparable to say the corporate debt of a single company. Having a well-known rating also opened up the structured finance market to investors who are constrained by the nature of the investments they're allowed to purchase.

Steps to Produce AAA-rated securities

The key idea here is to construct a cash-flow from the underlying securities which meets the required ratings agency standards for the likelihood of default and magnitude of loss given a default occurred.

First, Assemble a large collection of *credit-sensitive assets* in a type of portfolio called a **special purpose vehicle**. The special purpose vehicle is off of the originator's balance sheet so the originator can isolate the credit risk arising from the tranches. A **pass-through securitization** is a special purpose vehicle which doesn't prioritize claims. It pays out fractional claims based on the payoff of the underlying portfolio (the cash flow of the underlying assets). The expected loss on the underlying portfolio is the mean expected loss on the underlying securities (credit sensitive assets). Hence, the portfolio is given the average rating of the underlying pool of securities and the pass-through securitization inherits this rating. This means there's no improvement in credit rating through using pass-through securitization so we need a different approach.

To construct securities with varying risk profiles it's necessary to alter the cash flows by prioritizing claims against the cash flow of the underlying collateral pool via tranches. In a perfect world there are no defaults or prepayments the security would perform as advertised and achieve the set rate of return. Since deviations from a perfect world result in a lower rate of return (potentially no return!), we say the tranches are prioritized according to how they *absorb losses*. The **senior tranches** only absorb losses once the junior tranches have been exhausted. This means the senior tranches are less likely to take a loss than the junior tranches and so the senior tranches receive a higher credit rating than the junior tranches. These ratings can be achieved even if the underlying asset pool consists of higher risk assets.

Overcollateralization is the degree of protection offered by the junior tranches. It plays a key role in determining the credit rating of a more senior tranche because it measures the largest portfolio loss which can be realized before the senior tranche is impacted.

> **Example (from source):**
>
> Suppose an asset backed security (ABS) consists of two identical bonds, each having a 10% probability of default, p_D. Assume the probabilities of default are uncorrelated. Each bond pays $1 unless it defaults in which case it pays $0.
>
> There are three possible payoffs (outcomes): Namely, $2 if neither bond defaults, $1 if exactly one of the bonds defaults, and $0 if both bonds default.
>
> We can securitize this portfolio by dividing it into a senior tranche and a junior tranche. The **junior tranche** absorbs the first dollar of loss and the **senior tranche** absorbs the second dollar of loss.
>
> The probability of the senior tranche defaulting is $10\%^2 = 0.01$ while the probability of the junior tranche defaulting is the probability that **at least** one bond defaults which is $10\%^2 + \binom{2}{1} \cdot 10\% \cdot (1 - 10\%) = 0.19$.

The **correlation coefficient** is defined generally as $\rho_{ij} = \dfrac{Cov(X_i, X_j)}{\sqrt{Var(X_i)}\sqrt{Var(X_j)}}$. Let p_{D_A} and p_{D_B} be the default probabilities for securities A and B respectively. Further, let $p_{D_{AB}}$ be the probability of both securities defaulting. This is not necessarily equal to $p_{D_A} \cdot p_{D_B}$. Then the **default correlation parameter** for securities A and B is $\rho_{AB} = \dfrac{p_{D_{AB}} - p_{D_A} \cdot p_{D_B}}{\sqrt{p_{D_A}(1 - p_{D_A})}\sqrt{p_{D_B}(1 - p_{D_B})}}$. When both securities are identical, the default correlation parameter is given by $\dfrac{p_{DD} - p_D^2}{p_D(1 - p_D)}$.

> **Question:**
>
> Suppose the default correlation parameter for securities A and B is 25% while each security has an individual probability of default of 10%. Again, assume each security pays $1 unless it defaults and divide the portfolio into a senior tranche and junior tranche. Calculate the default probability for each tranche.

Solution:

Both securities must default for the senior tranche to default. Rearranging the default correlation parameter yields $p_{D_{AB}} = 25\% \cdot \sqrt{10\% \cdot (1-10\%)} \cdot \sqrt{10\%(1-10\%)} + 10\% \cdot 10\% = 0.0325$ which is a 3.25% chance of defaulting.

For the junior tranche to default we must have at least one of the securities default. This is given by $p_{D_A} + p_{D_B} - p_{D_{AB}} = 10\% + 10\% - 3.25\% = 16.75\%$ (draw the Venn diagram to help remember this).

Repeating the above problem with different correlation assumptions produces a table of default probabilities like the one below.

Correlation	0%	25%	50%	75%	100%
Senior Tranche	1.00%	3.25%	5.50%	7.75%	10.00%
Junior Tranche	19.00%	16.75%	14.50%	12.25%	10.00%

The key here is with ***modest correlation*** the default probability for the senior tranche is much lower than the default probability for underlying securities. So we can take higher risk assets and repackage them into something attractive to low risk investors. Of course, we do need someone to be willing to buy the junior tranche which has considerably higher risk than the underlying securities but presumably such an investor would be adequately compensated for taking on the risk via a lower price.

Structured finance relies on the law of large numbers — as we add more securities to the portfolio we can increase the number of tranches offered and increase the proportion of tranches with higher credit ratings than the average rating of the underlying securities (lower default probability than the average default probability of the underlying securities).

Example:

Suppose an asset backed security consists of three identical bonds, each having a 10% probability of default. Assume there is no correlation between any pair of bonds. Each bond pays $1 unless it defaults in which case it pays $0. There are now four possible payoffs ($3, $2, $1, or $0) so we can securitize the portfolio by dividing into three tranches as follows:

- Junior: Receives $0 if at least one bond defaults. ($1 if none default.)
- **Mezzanine**: Receives $0 if at least two bonds default. ($1 if at most one defaults.)
- Senior: Receives $0 if all bonds default. ($1 if at most two default.)

The probability of default for the senior tranche is $10\%^3$ = 0.1%. The probability of the mezzanine tranche defaulting is $10\%^3 + \binom{3}{2} \cdot 10\%^2 \cdot (1-10\%) = 2.8\%$. Lastly, the probability of the junior tranche defaulting is $10\%^3 + \binom{3}{2} \cdot 10\%^2 \cdot (1-10\%) + \binom{3}{1} \cdot 10\% \cdot (1-10\%)^2 = 27.1\%$

The key takeaway here is we're able to repackage two-thirds of the capital into securities which are less risky than the average default probability of the portfolio (10%).

Alice: "Let's explore the above example but now supposing there is a partial recovery when a bond defaults."

Expected Tranche Payouts with Recoveries

CDO-squared

It can be challenging to sell the junior and sometimes mezzanine tranches of an asset backed security due to the higher default risk. One way around this is to take a portfolio of junior or mezzanine tranches and securitize them in the same way. This is known as a **CDO-squared** (sometimes written CDO^2).

Example:

A portfolio consists of two junior asset backed securities. Each pays $1 if it doesn't default and $0 otherwise. The probability of default for each junior asset backed security is 19% and the securities are assumed to have zero correlation. Again, we have three possible payoffs for the portfolio ($2, $1, $0) and so we can repackage this portfolio into a senior and junior tranche.

The senior tranche of the CDO-squared will default only if both junior asset backed securities default. Tracing this back further means the senior tranche of the CDO-squared will only default if at least one of the underlying bonds in each of the portfolios forming the underlying asset backed securities defaults.

The default probability for the senior tranche is $19\%^2 = 3.61\%$ while the default probability for the junior tranche is $19\%^2 + \binom{2}{1} \cdot 19\% \cdot (1-19\%) = 34.39\%$.

The key takeaway is we're able to repackage half of the portfolio into a security which has a considerably lower probability of default than the underlying securities in the portfolio.

As we've seen in the examples, assuming no correlation can result in very safe senior tranches. At the other extreme, perfect correlation confers no benefit to the senior tranche. As the securities/assets become more correlated the senior tranches become more risky.

The Challenge of Rating Structured Finance Assets

Question: Identify a purpose of credit ratings.

Solution:
Credit ratings are designed to measure the ability of issuers/entities to meet their future financial commitments such as principal and interest payments.

Credit ratings may be based on either the anticipated likelihood of default or the **expected economic loss** which is the product of the likelihood of defaulting and the severity of the loss given a default occurs.

Securities rated as BBB- or higher are called **investment grade** as they are thought to have low to moderate levels of default risk. Securities rated as BB+ or lower are called **speculative grade** and are either already in default or near to it. The Fitch's ratings agency has ten rating categories within its investment grade range. The 10-year default probabilities for corporate bonds with these categories range from 0.02% to 0.75%. It's important to note since this is a narrow range, distinguishing between different investment grade categories requires very precise estimates of the default probability for a security.

Fitch's ratings agency also has ten categories in their *speculative grade* range whose 10-year corporate bond default probabilities range from 1.07% to 29.96%.

Question: Explain why ratings agencies experienced greater difficulty assigning ratings to asset backed securities (collateralized debt obligations) compared to their traditional single-name rating business.

Solution:

- Ratings agencies were experienced at assessing single-name issues (e.g. Boeing or Wal-Mart corporate debt issues) separately without consideration about the extent of any default correlations between them.
- To rate asset backed securities, the ratings agencies had to address the challenge of modeling the entire *joint* distribution of payoffs for the underlying collateral pool.
- ABS (CDOs) are sensitive to the default correlation parameter between underlying securities because they rely on diversification to drive down the risk for the more senior tranches. Increasing the default correlation parameter reduces diversification.
- CDO-squared securities magnify the effect of default correlations.
- Modeling errors due to mis-parameterizing the default correlation are amplified with multiple rounds of securitization.
- The end result is a small change in the underlying default probabilities can result in a large change in the credit rating for a security.

Question: Briefly describe an unintended consequence of the fine-scale nature of the investment grade ratings.

Solution:
Since the investment grade ratings cover a narrow range, even a small change in the model assumptions may be enough to significantly change the assigned rating.

The authors performed some simulations to illustrate the sensitivity of CDOs and CDO^2s to parameter estimate errors. They used 40 pools of 100 bonds apiece. Each bond had a five-year default probability of 5 percent and a recovery rate of 50% of face value. They initially assume the default correlation between any pair of securities is 20%. They create a CDO for each pool of bonds by dividing the pool into three tranches. The junior tranche takes the first 6% of losses, the mezzanine tranche absorbs losses in the range 6% to 12%, and the senior tranche absorbs losses over 12%. The 40 mezzanine CDOs are then used to construct a CDO^2 with junior, mezzanine, and senior tranches which the same absorption points.Figure 1 below shows their results as they vary the default correlation.

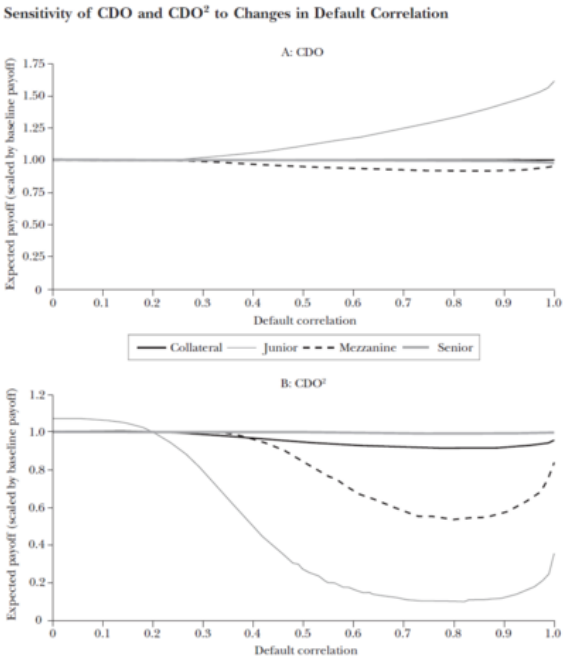

Figure 1

For a CDO (top image), as the correlation increases there is no change in the expected payoff on the collateral. However, the probability of default shifts from the junior tranche to the senior tranche until all tranches see the same default probability of the average underlying security when all underlying securities are perfectly correlated. The graph shows the junior tranche payoff as rising because it is relative to the payoff of the underlying portfolio which, as the default correlation increases, performs increasingly worse.

Alice: "Working with correlations is tricky when there are more than two securities. So instead let's see what happens when we vary the bond default probabilities."

Varying the default probability

Key Takeaways:

- Most securities could only receive their high credit ratings if the ratings agencies were exceptionally confident in their ability to estimate the risk of default and the correlation of defaults.
- A small error in the parameter estimates can change the default risk from AAA to a reasonable likelihood of default - i.e. a small swing in the input results in a large swing in the output.
- The securitization process substitutes largely diversifiable risks for risks which are highly systemic.
- Securities produced by structured finance are much less likely to survive a severe economic downturn than traditional corporate securities.
- Default risk for senior tranches is concentrated in systemically adverse economic states. i.e. broad recession, not just one company running into trouble.
- Changing the bond default probability or default correlation assumptions slightly for a CDO-squared has a much greater impact on the security than it does for a CDO.

Question: Identify one way regulators have proposed highlighting the risk associated with structured finance ratings.

Solution:
Regulators have suggested using a "**.SF**" modifier to highlight the rating is for a structured finance product and thus is more susceptible to uncertainty in the model parameters. For example, a CDO might be rated as AAA.SF while a corporate bond may be rated as AAA.

Question: Describe an unintended consequence of credit rating agencies rating both structured finance and single-name securities on the same scale.

Solution:

- Investors who sought safe investments (think AAA or investment grade in general) entered the structured finance market without fully understanding the nature of the underlying economic risks.

Rise and Fall of the Structured Finance Market

The structured finance market evolved as a "rated" market - the risk of each tranche defaulting was assessed by ratings agencies. In mid-2007, approximately 60% global structured finance products were AAA rated vs. less than 1% of traditional corporate issues. The ability to issue highly rated (AAA) securities with attractive yields meant high demand from investors, leading to Moody's reporting as early as 2006 that more of its revenues came from rating structured finance products than from rating corporate bonds.

By 2008 the market saw numerous AAA rated (triple-A) structured finance products downgraded to junk and by mid-2008 the market for structured finance activities was viewed as "shut down for years to come".

A large portion of the CDOs issued in the run up to the 2008 financial crisis were backed by subprime residential mortgage-backed securities. This is important because many residential mortgage-backed securities are actually tranches from a securitization of a large pool of mortgages. The end result is these CDOs actually behaved more like CDO^2. Compounding this, subprime lending was relatively new at the time which meant historical data on defaults and delinquencies (late payments) was limited. This made it challenging to accurately assign default probabilities or estimate potential recoveries.

To aid the housing market, government agencies such as Fannie Mae, Freddie Mac, and Ginnie Mae purchased mortgages from local banks provided they satisfied certain size and credit quality requirements. These were repackaged into mortgage-backed securities with the implicit guarantee of the U.S. government. Non-conforming mortgages such as subprime mortgages were ineligible for government backed securitization. In response, Wall Street created "private-label" mortgage-backed securities to securitize these assets for sale in the capital markets. These subprime mortgage-backed bonds were often then re-securitized into **collateralized mortgage obligations** (CMOs) which are essentially a CDO^2.

Question: Briefly describe two reasons why investors were exposed to higher levels of default risk under private-label mortgage-backed securities.

Solution:

1. The underlying assets had higher rates of default due to the low credit quality of the borrowers.
2. There were high levels of default correlation due to pooling mortgages from similar geographic areas and vintages (points in time).

When the housing market declined, many borrowers found themselves **underwater**. That is, they owed more on their mortgage than the value of their house. Those on adjustable mortgages could no longer reset their low interest rate payments after the initial low rate ended by refinancing. This led to a significant increase in default rates.

Question: Briefly describe two reasons why investors experienced greater than expected losses when default levels were higher than expected.

Solution:

1. Recoveries were lower than expected because many assets were being sold-off under financial pressure at the same time (a **fire sale**).
2. The use of CMOs magnified the effect of mis-estimating the expected losses on the underlying mortgages. This is because a CDO^2 can sustain large losses when the actual default probability and correlation of the underlying assets change by only a small amount.

Pricing Systematic Risk in Structured Products

The capital asset pricing model suggests securities which are correlated with the broader market should offer higher expected returns than those with the same expected payoffs or same credit ratings but are less correlated with the market. This is because securities which are not correlated (positively or negatively) with the market can eliminate their risk through diversification. Since they can eliminate this risk, an investor is willing to pay a higher price for the security. Consequently, the expected return is lower (same payoff but higher price equals lower return on investment).

An example of a security that is uncorrelated with the market is a catastrophe bond. These bonds payout provided there is not a natural disaster. If there is a natural disaster then the bond defaults. The key assumption is a single catastrophe cannot materially impact the global economy so the risks associated with a catastrophe bond are uncorrelated with the market. For more on catastrophe bonds, see *Cummins CAT Bonds*.

When investors cannot diversify away risk they are said to be bearing **systematic risk**. As the systematic risk held increases, investors demand lower prices to ensure high returns as compensation for bearing this risk.

When a large diversified portfolio is produced through pooling, allocating the expected returns into tranches creates assets which are highly correlated with the overall market. This means investors in senior tranches of such CDOs are exposed to large amounts of systematic risk as they become increasingly likely to experience material losses when the overall market declines. Investors should require a high yield (low price) for bearing this risk. However, the nature of the credit ratings during the 2008 financial crisis meant investors perceived the risk to be similar to that of similarly rated single name securities. This meant investors demanded yields which were comparable to those for single name securities - i.e. the tranches were overpriced / the yields on the structured finance products were too low because they didn't account for the systematic exposure to the broader market environment.

Question: Briefly describe a drawback of credit ratings.

Solution:

- Credit ratings are designed to capture the expected payoff. They are not designed to reflect whether a security is likely to default at the same time as a stock market decline or a recession.

Question: Briefly describe two reasons why demand for all tranches of structured finance products was high in the run up to the 2008 financial crisis.

Solution:

1. Many investment grade structured finance products offered attractive yields when compared to single-name securities with the same credit rating. Having a credit rating that investors seemingly understood and attractive yields meant demand for these products was high.
2. The senior tranches appeared materially safer than the junior tranches because of the assumptions about default probabilities and correlations. The yields on senior tranches were lower than they should have been and this inflated the returns on the junior tranches. This incentivized participation in the "toxic" junior tranches.

Alice: "So who was to blame for all of this mess?"

- Credit rating agencies made mistakes by rating structured finance products higher than they should have. They failed to appreciate the sensitivity of their models to the default probabilities and correlation assumptions and naively extrapolated good existing economic conditions indefinitely into the future.
- Regulators also didn't appreciate the model failings. They tied bank capitalization requirements to credit ratings, incentivizing banks to invest heavily in structured finance products.
- Investors outsourced their due diligence to the ratings agencies without questioning whether structured finance and single-name securities should be rated using the same scale.
- Issuers of structured finance products paid for the ratings rather than the investor. This produced possible conflicts of interest - "rate my product as highly attractive/safe or I'll go to another rating agency...".
- Minimum capital requirements for banks (Basel I and II) meant AAA-rated securities required holding half as much capital compared to that required to hold other investment grade securities. This increased the demand for AAA-rated securities.
- Investment banks played the role of both investor and dealer/issuer. Low capital requirements for AAA-rated assets and the perception that they were "safe" meant investment banks often kept the senior tranches that they could not sell to investors.
- Everyone generally believed market forces would solve potential problems.
