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The Economics of Structured Finance

Joshua Coval, Jakub Jurek, and Erik Stafford

The essence of structured finance activities is the pooling of economic assets like loans, bonds, and mortgages, and the subsequent issuance of a prioritized capital structure of claims, known as tranches, against these collateral pools. As a result of the prioritization scheme used in structuring claims, many of the manufactured tranches are far safer than the average asset in the underlying pool. This ability of structured finance to repackage risks and to create "safe" assets from otherwise risky collateral led to a dramatic expansion in the issuance of structured securities, most of which were viewed by investors to be virtually risk-free and certified as such by the rating agencies. At the core of the recent financial market crisis has been the discovery that these securities are actually far riskier than originally advertised.

We examine how the process of securitization allowed trillions of dollars of risky assets to be transformed into securities that were widely considered to be safe, and argue that two key features of the structured finance machinery fueled its spectacular growth. First, we show that most securities could only have received high credit ratings if the rating agencies were extraordinarily confident about their ability to estimate the underlying securities' default risks, and how likely defaults were to be correlated. Using the prototypical structured finance security—the collateralized debt obligation (CDO)—as an example, we illustrate that issuing a capital structure amplifies errors in evaluating the risk of the underlying securities.

■ *Joshua Coval is Professor of Business Administration at Harvard Business School, Boston, Massachusetts, and Jakub Jurek is Assistant Professor at Princeton University, Princeton, New Jersey, and Erik Stafford is Associate Professor of Business Administration at Harvard Business School, Boston, Massachusetts. Their e-mail addresses are ⟨jcoval@hbs.edu⟩, ⟨jjurek@princeton.edu⟩, and ⟨estafford@hbs.edu⟩.*

In particular, we show how modest imprecision in the parameter estimates can lead to variation in the default risk of the structured finance securities that is sufficient, for example, to cause a security rated AAA to default with reasonable likelihood. A second, equally neglected feature of the securitization process is that it substitutes risks that are largely diversifiable for risks that are highly systematic. As a result, securities produced by structured finance activities have far less chance of surviving a severe economic downturn than traditional corporate securities of equal rating. Moreover, because the default risk of senior tranches is concentrated in systematically adverse economic states, investors should demand far larger risk premia for holding structured claims than for holding comparably rated corporate bonds. We argue that both of these features of structured finance products—the extreme fragility of their ratings to modest imprecision in evaluating underlying risks and their exposure to systematic risks—go a long way in explaining the spectacular rise and fall of structured finance.

For over a century, agencies such as Moody's, Standard and Poor's, and Fitch have gathered and analyzed a wide range of financial, industry, and economic information to arrive at independent assessments on the creditworthiness of various entities, giving rise to the widely popular rating scales (AAA, AA, A, BBB, and so on). Until recently, the agencies focused the majority of their business on single-name corporate finance—that is, issues of creditworthiness of financial instruments that can be clearly ascribed to a single company. In recent years, the business model of credit rating agencies has expanded beyond their historical role to include the nascent field of structured finance.

From its beginnings, the market for structured securities evolved as a "rated" market, in which the risk of tranches was assessed by credit rating agencies. Issuers of structured finance products were eager to have their new products rated on the same scale as bonds so that investors subject to ratings-based constraints would be able to purchase the securities. By having these new securities rated, the issuers created an illusion of comparability with existing "single-name" securities. This provided access to a large pool of potential buyers for what otherwise would have been perceived as very complex derivative securities.

During the past decade, risks of all kinds have been repackaged to create vast quantities of triple-A–rated securities with competitive yields. By mid-2007, there were 37,000 structured finance issues in the U.S. alone with the top rating (Scholtes and Beales, 2007). According to Fitch Ratings (2007), roughly 60 percent of all global structured products were AAA-rated, in contrast to less than 1 percent of the corporate issues. By offering AAA-ratings along with attractive yields during a period of relatively low interest rates, these products were eagerly bought up by investors around the world. In turn, structured finance activities grew to represent a large fraction of Wall Street and rating agency revenues in a relatively short period of time. By 2006, structured finance issuance led Wall Street to record revenue and compensation levels. The same year, Moody's Corporation reported that 44 percent of its revenues came from rating structured finance products, surpassing the 32 percent of revenues from their traditional business of rating corporate bonds.

By 2008, everything had changed. Global issuance of collateralized debt obligations slowed to a crawl. Wall Street banks were forced to incur massive write-downs. Rating agency revenues from rating structured finance products disappeared virtually overnight and the stock prices of these companies fell by 50 percent, suggesting the market viewed the revenue declines as permanent. A huge fraction of existing products saw their ratings downgraded, with the downgrades being particularly widespread among what are called "asset-backed security" collateralized debt obligations—which are comprised of pools of mortgage, credit card, and auto loan securities. For example, 27 of the 30 tranches of asset-backed collateralized debt obligations underwritten by Merrill Lynch in 2007 saw their triple-A ratings downgraded to "junk" (Craig, Smith, and Ng, 2008). Overall, in 2007, Moody's downgraded 31 percent of all tranches for asset-backed collateralized debt obligations it had rated and 14 percent of those initially rated AAA (Bank of International Settlements, 2008). By mid-2008, structured finance activity was effectively shut down, and the president of Standard & Poor's, Deven Sharma, expected it to remain so for "years" (*Financial Week,* 2008).

This paper investigates the spectacular rise and fall of structured finance. We begin by examining how the structured finance machinery works. We construct some simple examples of collateralized debt obligations that show how pooling and tranching a collection of assets permits credit enhancement of the senior claims. We then explore the challenge faced by rating agencies, examining, in particular, the parameter and modeling assumptions that are required to arrive at accurate ratings of structured finance products. We then conclude with an assessment of what went wrong and the relative importance of rating agency errors, investor credulity, and perverse incentives and suspect behavior on the part of issuers, rating agencies, and borrowers.

Manufacturing AAA-rated Securities

Manufacturing securities of a given credit rating requires tailoring the cash-flow risk of these securities—as measured by the likelihood of default and the magnitude of loss incurred in the event of a default—to satisfy the guidelines set forth by the credit rating agencies. Structured finance allows originators to accomplish this goal by means of a two-step procedure involving pooling and tranching.

In the first step, a large collection of credit-sensitive assets is assembled in a portfolio, which is typically referred to as a "special purpose vehicle." The special purpose vehicle is separate from the originator's balance sheet to isolate the credit risk of its liabilities—the tranches—from the balance sheet of the originator. If the special purpose vehicle issued claims that were not prioritized and were simply fractional claims to the payoff on the underlying portfolio, the structure would be known as a pass-through securitization. At this stage, since the expected portfolio loss is equal to the mean expected loss on the underlying securities, the portfolio's credit rating would be given by the average rating of the securities in the underlying pool. The pass-through securitization claims would inherit this rating, thus achieving no credit enhancement.

By contrast, to manufacture a range of securities with different cash flow risks, structured finance issues a capital structure of prioritized claims, known as *tranches*, against the underlying collateral pool. The tranches are prioritized in how they absorb losses from the underlying portfolio. For example, senior tranches only absorb losses after the junior claims have been exhausted, which allows senior tranches to obtain credit ratings in excess of the average rating on the average for the collateral pool as a whole. The degree of protection offered by the junior claims, or overcollateralization, plays a crucial role in determining the credit rating for a more senior tranche, because it determines the largest portfolio loss that can be sustained before the senior claim is impaired.

This process of pooling and tranching, common to all structured securities, can be illustrated with a two-asset example. Consider two identical securities—call them "bonds"—both of which have a probability of default p_D, and pay \$0 conditional on default and \$1 otherwise. Suppose we pool these securities in a portfolio, such that the total notional value of the underlying fund is \$2, and then issue two tranches against this fund, each of which pay \$1. A "junior" tranche can be written such that it bears the first \$1 of losses to the portfolio; thus, the junior tranche pays \$1 if both bonds avoid default and zero if either bond defaults. The second, "senior" claim, which bears losses if the capital of the junior tranche is exhausted, pays \$1 if neither bond defaults or if only one out of two bonds defaults; it only defaults if both bonds default. It should be intuitively clear that to compute the expected cash flows (or default probabilities) for the tranches, we will need to know the likelihood of observing both bonds defaulting simultaneously. In this example, the default dependence structure can be succinctly described by means of a single parameter—either the joint probability of default, or the default correlation.[1]

What makes this structure interesting is that if the defaults of the two bonds are imperfectly correlated, the senior tranche will pay either \$1 or \$0—just like the individual bonds—except that it will be less likely to default than either of the underlying bonds. For example, if the two bonds have a 10 percent default probability and defaults are uncorrelated, the senior tranche will only have a 1 percent chance of default. This basic procedure allows highly risky securities to be repackaged, with some of the resulting tranches sold to investors seeking only safe investments. Obviously, junior tranches, being risky, will have low prices and high

[1] If we assume that both securities are identical and denote the probability of observing both claims default simultaneously by p_{DD}, the *default correlation* parameter can be computed as $(p_{DD} - p_D^2)/(p_D{*}(1 - p_D)$.

promised returns, while the senior tranches, being relatively safe, will have relatively higher prices and lower promised returns.

A central insight of structured finance is that by using a larger number of securities in the underlying pool, a progressively larger fraction of the issued tranches can end up with higher credit ratings than the average rating of the underlying pool of assets. For example, consider extending the two-bond example by adding a third \$1 bond, so that now three \$1 claims can be issued against this underlying capital structure. Now, the first tranche defaults if any of the three bonds default, the second tranche defaults if two or more of the bonds default, and the final, senior-most tranche only defaults when all three bonds default. If bonds default 10 percent of the time and defaults are uncorrelated, the senior tranche will now default only 0.1 percent of the time, the middle tranche defaults 2.8 percent of the time, and the junior tranche defaults 27.1 percent of the time. Thus, by including a third bond in the pool, two-thirds of the capital—as measured by the tranche notional values—can be repackaged into claims that are less risky than the underlying bonds.

Another way to increase the total notional value of highly-rated securities produced is to reapply the securitization machinery to the junior tranches created in the first round. For example, in the two-bond case in which defaults were uncorrelated, the \$1 junior tranche defaults with 19 percent probability. However, if we combine this \$1 junior tranche with an identical \$1 junior tranche created from another two-bond pool, we can again tranche the resulting \$2 of capital into two prioritized \$1 claims. If there continues to be no correlation among underlying assets, the resulting senior tranche from this second round of securitization—a tranche that defaults if at least one bond defaults in *each* of the two underlying pools—has a default probability of 3.6 percent, which is once again considerably lower than that of the underlying bonds. The collateralized debt obligations created from the tranches of other collateralized debt obligations are typically called CDO-squared—that is, CDO^2.

A key factor determining the ability to create tranches that are safer than the underlying collateral is the extent to which defaults are correlated across the underlying assets. The lower the default correlation, the more improbable it is that all assets default simultaneously and therefore the safer the senior-most claim can be made. Conversely, as bond defaults become more correlated, the senior-most claims become less safe. Consider, for example, the two-bond case in which defaults are perfectly correlated. Since now both bonds either survive or default simultaneously, the structure achieves no credit enhancement for the senior tranche. Thus, in the two-bond example, while uncorrelated risks of default allow the senior claim to have a 1 percent default probability, perfectly correlated risks of default would mean that the senior claim inherits the risk of the underlying assets, at 10 percent. Finally, intermediate levels of correlation allow the structure to produce a senior claim with default risk between 1 and 10 percent.

The Challenge of Rating Structured Finance Assets

Credit ratings are designed to measure the ability of issuers or entities to meet their future financial commitments, such as principal or interest payments. Depending on the agency issuing the rating and the type of entity whose creditworthiness is being assessed, the rating is either based on the anticipated likelihood of observing a default, or it is based on the expected economic loss—the product of the likelihood of observing a default and the severity of the loss conditional on default. As such, a credit rating can intuitively be thought of as a measure of a security's expected cash flow.[2] In the context of corporate bonds, securities rated BBB− or higher have come to be known as *investment grade* and are thought to represent low to moderate levels of default risk, while those rated BB+ and below are referred to as *speculative grade* and are already in default or closer to it.

Table 1 reports Fitch's estimates regarding the 10-year default probabilities of corporate bonds with different ratings at issuance and gives their corresponding annualized default rates. These estimates are derived from a study of historical data and are used in Fitch's model for rating collateralized debt obligations (Derivative Fitch, 2006).[3] It is noteworthy that within the investment grade range, there are ten distinct rating categories (from AAA to BBB−) even though the annualized default rate only varies between 0.02 and 0.75 percent. Given the narrow range of the historical default rates, distinguishing between the ratings assigned to investment grade securities requires a striking degree of precision in estimating a security's default likelihood. By contrast, the ten rating categories within the speculative grade range (from BB+ to C) have default rates ranging from 1.07 to 29.96 percent.

In the single-name rating business, where the credit rating agencies had developed their expertise, securities were assessed independently of each other, allowing rating agencies to remain agnostic about the extent to which defaults might be correlated. But to assign ratings to structured finance securities, the rating agencies were forced to address the bigger challenge of characterizing the entire *joint* distribution of payoffs for the underlying collateral pool. As the previous section demonstrated, the riskiness of collateralized debt obligation tranches is sensitive to the extent of commonality in default among the underlying assets, since collateralized debt obligations rely on the power of diversification to achieve credit enhancement.

The structure of collateralized debt obligations magnifies the effect of impre-

[2] Credit rating agencies stress that their ratings are only designed to provide an ordinal ranking of securities' long-run ("through-the-cycle") payoff prospects, whereas the expected cash flow interpretation takes a cardinal view of ratings.

[3] A comprehensive description of Fitch's rating model for collateralized debt obligations—the Default VECTOR Model—including assumptions regarding default probabilities, recovery rates, and correlations is available online. An Excel spreadsheet implementation of the model can be downloaded from ⟨http://www.fitchrating.com/jsp/corporate/ToolsAndModels.faces?context=2&detail=117⟩.

Table 1
Historical Default Experience of Bonds Rated by Fitch

	Investment-grade Bonds									
Rating at issuance	*AAA*	*AA+*	*AA*	*AA−*	*A+*	*A*	*A−*	*BBB+*	*BBB*	*BBB−*
10-year default probability	0.19%	0.57%	0.89%	1.15%	1.65%	1.85%	2.44%	3.13%	3.74%	7.26%
Default rate (annualized)	0.02%	0.06%	0.09%	0.12%	0.17%	0.19%	0.25%	0.32%	0.38%	0.75%
	Speculative-grade Bonds									
Rating at issuance	*BB+*	*BB*	*BB−*	*B+*	*B*	*B−*	*CCC+*	*CCC*	*CC*	*C*
10-year default probability	10.18%	13.53%	18.46%	22.84%	27.67%	34.98%	43.36%	48.52%	77.00%	95.00%
Default rate (annualized)	1.07%	1.45%	2.04%	2.59%	3.24%	4.30%	5.68%	6.64%	14.70%	29.96%

cise estimates of default likelihoods, amounts recovered in the event of default, default correlation, as well as model errors due to the potential misspecification of default dependencies (Tarashev and Zhu, 2007; Heitfield, 2008). These problems are accentuated further through the sequential application of capital structures to manufacture the collateralized debt obligation (CDO) tranches commonly known as CDO^2. With multiple rounds of structuring, even minute errors at the level of the underlying securities that would be insufficient to alter the security's rating can dramatically alter the ratings of the structured finance securities.

To illustrate the sensitivity of the collateralized debt obligations and their progeny, the CDO^2, to errors in parameter estimates, we conduct a simulation exercise. First, we simulate the payoffs to 40 collateralized debt obligation pools, each comprised of 100 bonds with a five-year default probability of 5 percent and a recovery rate of 50 percent of face value conditional on default.[4] Using the annualized default rates reported in Table 1 as a guide, each bond in our hypothetical collateral pool would garner a just-below investment grade rating of BB+. Finally, we fix the pairwise bond default correlation at 0.20 within each collateral pool and assume the defaults of bonds belonging to different collateral pools are uncorrelated. Our simulation methodology relies upon a simplified version of the model that is the industry standard for characterizing portfolio losses.[5]

[4] Recovery rates can vary by type of security, seniority, and the country of origin. Historical recovery rates are between 40 and 50 percent for senior unsecured corporate bonds in the United States (Derivative Fitch, 2006; Altman, 2006).

[5] The common method for modeling the joint incidence of defaults is known as the copula method (Schonbucher, 2003). This approach draws a set of N correlated random variables $\{X_i\}$ from a pre-

Within each collateral pool, we construct a capital structure comprised of three tranches prioritized in order of their seniority. The "junior tranche" is the first to absorb losses from the underlying collateral pool and does so until the portfolio loss exceeds 6 percent, at which point the junior tranche becomes worthless. The "mezzanine tranche" begins to absorb losses once the portfolio loss exceeds 6 percent and continues to do so until the portfolio loss reaches 12 percent. Finally, the senior tranche absorbs portfolio losses in excess of 12 percent. We also construct a CDO^2—to be called "CDO^2 [6–12]"—by issuing a second capital structure of claims against a pool that combines the mezzanine tranches from the 40 original collateralized debt obligations.

While the parameter values used in our simulation do not map into any particular market, they were chosen to mimic broadly the types of collateral and securitizations commonly observed in structured finance markets.[6] After simulating the payoffs to the underlying collateral, our first step is to assign ratings to the tranches. We do this by comparing the simulated likelihood of impairment to each tranche's capital with the five-year default probability based on the annualized default rates reported in Table 1. Under our baseline parameters, the mezzanine tranche of the original collateralized debt obligation garners the lowest investment grade rating of BBB−, while the senior tranche—accounting for 88 percent of capital structure—receives a AAA rating. The collateralized debt obligation made up of mezzanine tranches, "CDO^2 ([6, 12])" in the bottom panel of Table 2, has mezzanine and senior tranches that are able to achieve a rating of AAA. Table 2 describes the default probabilities and expected payoffs (as a fraction of notional value) for the simulated tranches of both the original collateralized debt obligation and of the CDO^2 constructed from the mezzanine tranches.

Of course, these estimates of risk depend crucially on whether default correlations have been estimated correctly. Figure 1 explores the sensitivity of the

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specified distribution and then assumes that a firm defaults if its variable, $X_i = x_i$, is below the p-th percentile of the corresponding marginal distribution, $F_i(x_i)$. Under this scheme, by construction, a firm defaults p percent of the time and default dependence can be flexibly captured through the proposed joint distribution for $\{X_i\}$. A popular choice for the joint distribution function is the multivariate Gaussian (Vasicek, 2002), in which default correlation is simply controlled by the pairwise correlation of (X_i, X_j). Popular off-the-shelf CDO rating toolkits offered by credit rating agencies, such as Fitch's Default VECTOR models, Moody's CDOROM, and Standard and Poor's CDO Evaluator, all employ versions of this copula model.

[6] For example, collateralized loan obligations tend to be issued in a three-tranche structure with attachment points of 0–5 percent, 5–15 percent, and 15–100 percent. Collateralized debt obligations referencing a commonly used index of credit default swaps on corporate bonds have a more granular capital structure with two types of junior claims (0–3 percent and 3–7 percent), two types of mezzanine claims (7–10 percent and 10–15 percent), and two types of senior claims (15–30 percent and 30–100 percent). Tranches that are based on an index of residential mortgage-backed securities have a similarly granular structure with junior claims having attachment points of 0–3 percent and 3–7 percent; mezzanine claims, 7–12 percent and 12–20 percent; and senior claims, 20–35 percent and 35–100 percent.

Table 2
Summary Statistics for CDO and CDO^2 Tranches in our Simulation under Baseline Parameters

	Attachment points	*Default probability*	*Expected payoff*	*Rating*
CDO				
Junior	0%–6%	97.52%	0.59	NR
Mezzanine	6%–12%	2.07%	> 0.99	BBB−
Senior	12%–100%	< 0.00%	> 0.99	AAA
CDO^2 ([6, 12])				
Junior	0%–6%	56.94%	0.93	C
Mezzanine	6%–12%	< 0.00%	> 0.99	AAA
Senior	12%–100%	< 0.00%	> 0.99	AAA

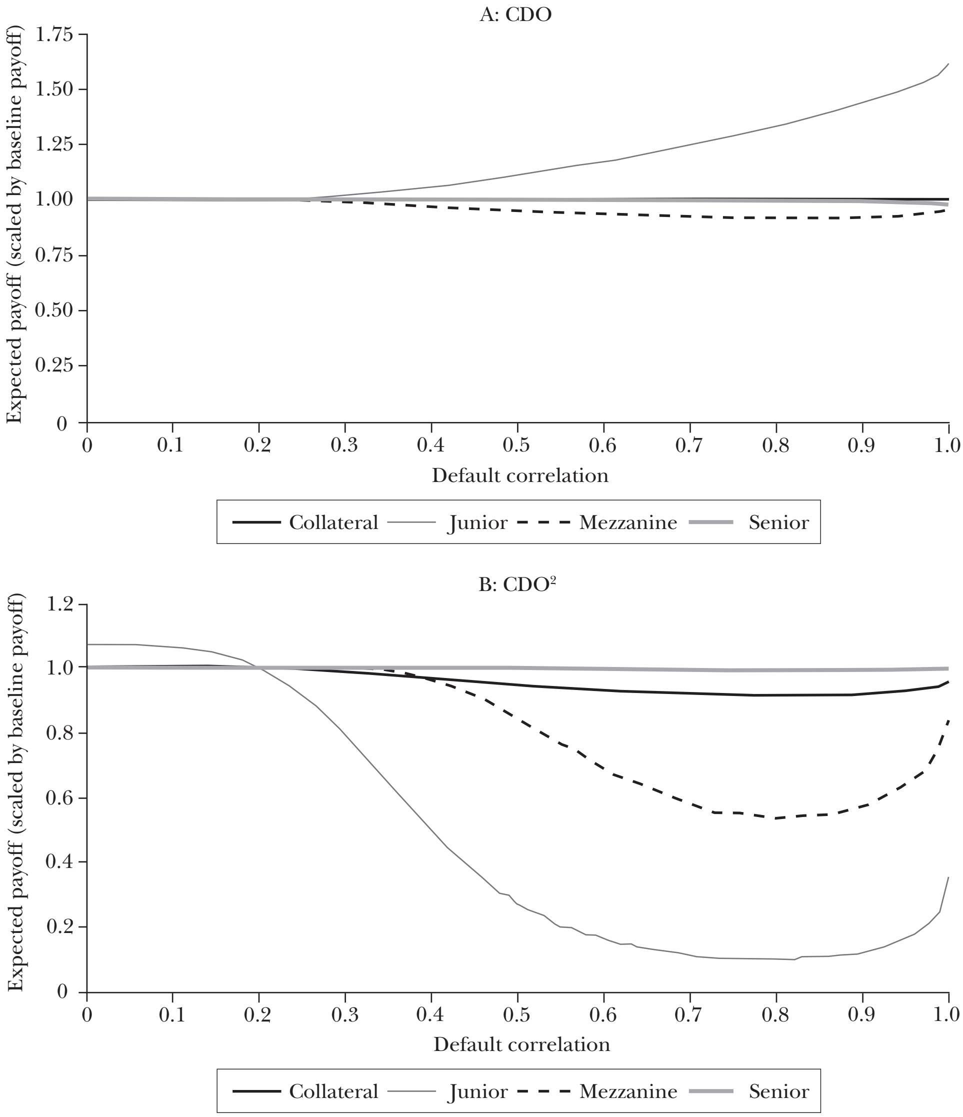
Note: While the parameter values used in our simulation do not map into any particular market, they were chosen to mimic broadly the types of collateral and securitizations commonly observed in structured finance markets.

original collateralized debt obligation and the CDO^2 tranches to changes in default correlation for bonds *within* each collateralized debt obligation. The correlation in defaults for bonds belonging to different collateral pools remains fixed at zero. The figure displays the expected payoff as a function of the default correlation, normalized by the expected payoff under the baseline calibration. These values can be thought of as illustrating the impact of either an error in the modeling assumptions or an unexpected realization of the default experience on the value of a $1 investment in each tranche.

The top panel shows that the expected payoff of the underlying collateral pool does not depend on the default correlation. As the default correlation increases from its baseline value of 0.20, indicating default risk is less diversified than expected, risk shifts from the junior claims to the senior claims. Consequently, the expected payoff on the junior tranche rises relative to the baseline value, while the expected payoff on the mezzanine tranche falls. The effect of changes in default correlation on the mezzanine tranche of the collateralized debt obligation is nonmonotonic. The expected payoff declines until the default correlation reaches a value of 0.80, where the tranche has lost approximately 10 percent of its value relative to the baseline calibration, and then rises as defaults become perfectly correlated and risk is shifted toward the senior tranche. In the limit of perfect default correlation, each tranche faces the same 5 percent chance of default over five years as we assigned each of the individual securities in the underlying portfolio.

The bottom panel of Figure 1 shows how shifts in the valuation of the mezzanine tranche of the collateralized debt obligation are amplified by the second-generation capital structure of the CDO^2. For example, as the pairwise default correlations within the underlying collateral pool of bonds increase from

Figure 1
Sensitivity of CDO and CDO^2 to Changes in Default Correlation



Note: Figure 1 explores the sensitivity of the original collateralized debt obligation and the CDO^2 tranches to changes in default correlation for bonds *within* each collateralized debt obligation. The correlation in defaults for bonds belonging to different collateral pools remains fixed at zero. The figure displays the expected payoff as a function of the default correlation, normalized by the expected payoff under the baseline calibration.

20 to 60 percent, the expected payoff on the mezzanine claim of the CDO^2, which is an investment grade security under the baseline parameters, drops by a staggering 25 percent.

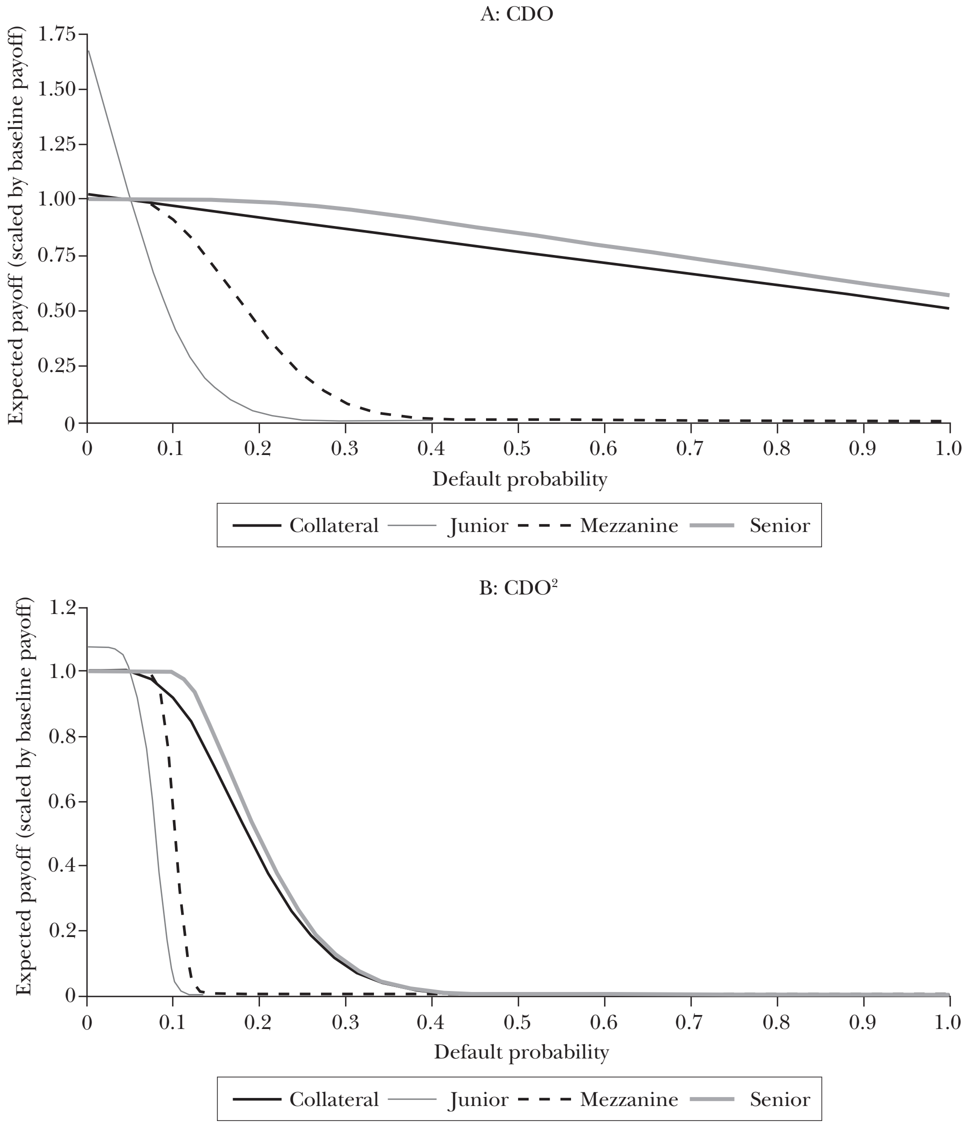
In Figure 2, we examine the effect of errors in estimates of the probability of default on the underlying securities on the expected tranche payoffs, while holding default correlation fixed at the baseline value of 0.20. As the default probability increases (declines) relative to the baseline estimate of 5 percent, the expected payoff on the underlying collateral decreases (increases) monotonically, and this effect is transferred to the tranches of the collateralized debt obligation. The sensitivity of the tranches to errors in the estimate of default probability is determined by their seniority. For example, an increase in the default probability from 5 to 10 percent results in a 55 percent decline in the expected payoff for the junior tranche, an 8 percent decline for the mezzanine tranche, and a 0.01 percent decline for the senior tranche.

The bottom panel of Figure 2 again illustrates the theme that changing the baseline parameters has a much starker effect on the CDO^2 comprised of the mezzanine tranches from the original collateralized debt obligations. In this case, as default probabilities rise, the values of the junior and mezzanine tranches quickly fall towards zero, and the value of the senior tranche falls substantially as well.

Table 3 provides a complementary illustration of how ratings are affected by changes in the underlying assets' default correlation and default probabilities. Although the expected payoff of the senior tranche of the collateralized debt obligation is relatively robust to changes in the model parameters, this is somewhat deceiving. Due to the fine partitioning of investment grade ratings, even modest changes in the model parameters can precipitate a meaningful rating downgrade for the senior tranche. For example, the rating of the senior tranche for the original collateralized debt obligation drops to A+ when the default probability reaches 10 percent and reaches the investment grade boundary of BBB− when the default probability reaches 20 percent. Again, the CDO^2 structure significantly amplifies the variation in the expected payoffs. When the default probability is increased to 10 percent, the mezzanine claim of the CDO^2, which was initially rated AAA, sees 50 percent of its expected payoff wiped out and its rating drop all the way below the rating scale. Even a slight increase in the probability of default on the underlying securities to 7.5 percent, which would only cause the underlying securities to be downgraded from BB+ to BB−, is sufficient to precipitate a downgrade of the AAA-rated mezzanine CDO^2 claim to BBB−. Given the plausible uncertainty in estimates of the underlying model parameters, the ".SF" rating modifiers recently proposed by regulators for structured finance instruments (U.S. Securities and Exchange Commission, 2008; Securities Industry and Financial Markets Association, 2008), are perhaps best regarded as warning labels.

Finally, the simulation illustrates that with plausible magnitudes of overcollateralization (the degree of protection offered by the junior claims—12 percent in our example), the expected payoff on a senior tranche of the original

Figure 2
Sensitivity of CDO and CDO² to Changes in Default Probability



Note: Figure 2 explores the sensitivity of the original collateralized debt obligation and the CDO² tranches to changes in the default probability for bonds in each collateralized debt obligation. The figure displays the expected payoff as a function of the default probability, normalized by the expected payoff under the baseline calibration.

collateralized debt obligation is well protected from large changes in default probabilities and correlations. While its rating might change, substantial impairments to the value of such claims seem implausible, short of an economic

Table 3
Effect of Changes in Underlying Parameters on CDO and CDO^2 Tranche Ratings

	Initial rating	Final rating					
		Default correlation (ρ)			*Default probability (pD)*		
	(ρ = 20%, pD = 5%)	*40%*	*60%*	*80%*	*7.50%*	*10%*	*12.50%*
CDO							
Junior	NR	D	C	CC	NR	NR	NR
Mezzanine	BBB−	BB−	B+	B+	B+	CCC	CC
Senior	AAA	A+	BBB−	BB	AAA	A+	BBB−
CDO^2 ([6, 12])							
Junior	C	D	NR	NR	NR	NR	NR
Mezzanine	AAA	B+	C	CC	BBB−	NR	NR
Senior	AAA	AAA	AAA	AA+	AAA	AAA	B−

catastrophe. On the other hand, all tranches of the second generation securitization, the CDO^2, are highly sensitive to changes in the baseline parameters. Even slight changes in default probabilities and correlations can have a substantial impact on the expected payoffs and ratings of the CDO^2 tranches, including the most senior claims.

As we show in the next section, a large fraction of collateralized debt obligations issued over the course of the last decade had subprime residential mortgage-backed securities as their underlying assets. Importantly, many of these residential mortgage-backed securities are themselves tranches from an original securitization of a large pool of mortgages, such that collateralized debt obligations of mortgage-backed securities are effectively CDO^{2}s. Moreover, since substantial lending to subprime borrowers is a recent phenomenon, historical data on defaults and delinquencies of this sector of the mortgage market is scarce. The possibility for errors in the assessment of the default correlations, the default probabilities, and the ensuing recovery rates for these securities was significant. Such errors, when magnified by the process of re-securitization, help explain the devastating losses some of these securities have experienced recently.

The Relation of Structured Finance to Subprime

To ensure a continuous supply of credit to home buyers, government-sponsored agencies such as Fannie Mae, Freddie Mac, and Ginnie Mae were chartered to purchase mortgages originated by local banks, provided they satisfy certain size and credit quality requirements. Mortgages conforming to these requirements are repackaged by these agencies into mortgage-backed securities, and resold in capital markets with the implicit guarantee of the U.S. government. In contrast, mortgages that do not conform to size restrictions or borrower credit quality standards are not eligible for purchase by the government-sponsored enterprises and are either held by their issuers or sold directly in secondary markets.[7] In recent years, issuance of so-called "non-conforming" mortgages has increased significantly. For example, origination of subprime mortgages—mortgages given to those below the credit standards for the government-sponsored enterprises—grew from $96.8 billion in 1996 to approximately $600 billion in 2006, accounting for 22 percent of all mortgages issued that year (U.S. Securities and Exchange Commission, 2008). During the same period, the average credit quality of subprime borrowers decreased along a number of measures, as evidenced by rising ratios of mortgage values relative to house prices, an increased incidence of second lien loans, and issuance of mortgages with low or no documentation (Ashcraft and Schuermann, 2008). When house prices declined, the stage was set for a significant increase in default rates as many of these borrowers found themselves holding mortgages in excess of the market value of their homes.

Because subprime mortgages were ineligible for securitization by government-sponsored agencies, they found their way into capital markets by way of "private-label" mortgage-backed securities, originated by Wall Street banks among others (Federal Deposit Insurance Corporation, 2006). These securities carried the dual risk of high rates of default due to the low credit quality of the borrowers; and high levels of default correlation as a result of pooling mortgages from similar geographic areas and vintages. In turn, many subprime mortgage-backed bonds were themselves re-securitized into what are called collateralized mortgage obligations, effectively creating a CDO^2. According to Moody's, the share of collateralized debt obligations that had other "structured" assets as their collateral expanded from 2.6 percent in 1998 to 55 percent in 2006 as a fraction of the total notional value of all securitizations. In 2006 alone, issuance of structured finance collateralized debt obligations reached $350 billion in notional value (Hu, 2007).

As it turned out, *all* of the factors determining expected losses on tranches of collateralized debt obligations backed by mortgage-backed securities had been biased against the investor. First, the overlap in geographic locations and vintages within mortgage pools raised the prospect of higher-than-expected default correlations. Second, the probability of default and the expected recovery values have both been worse than expected due to the deterioration in credit quality of subprime borrowers and because of assets being sold off under financial pressure in "fire sales," further driving down the prices of related assets. Finally, the preva-

[7] Jumbo mortgages have notional values exceeding the conventional loan limit, which was $417,000 for a single-family home in 2008. Subprime borrowers are defined as those with a FICO credit score below 620, limited credit history, or some other form of credit impairment. Alt-A borrowers have credit scores sufficient to qualify for a conforming mortgage, but do not have the necessary documentation to substantiate that their assets and income can support the requested loan amount.

lence of CDO^2 structures further magnified the deleterious effects of errors in estimates of expected losses on the underlying mortgages for investors.

A succinct view of the severity of the deterioration in private-label residential mortgage-backed securities is provided by the ABX.HE indices. These indices are compiled by Markit in cooperation with major Wall Street banks and track the performance of subprime residential mortgage-backed securities along various points in the rating spectrum.[8] For example, the ABX.HE.BBB 07-01 captures the average value of 20 BBB-rated mortgage-backed securities obtained by pooling and tranching subprime mortgages issued in the first half of 2007. Intuitively, each of the underlying mortgage-backed securities can be thought as loosely corresponding to a mezzanine tranche of a collateralized debt obligation in our simulation. Although the ABX.HE.BBB 07-01 index traded as high as 98.35, by August 2008, it had an average rating of CCC and a market price of roughly 5 cents on the dollar. With such abysmal performance in the residential mortgage-backed market, collateralized debt obligations backed by this type of structured collateral are virtually guaranteed to fail. As illustrated by our simulation, a collateralized debt obligation made up of investment grade mezzanine tranches—that is, a CDO^2—can sustain very large losses even with small changes in the realized default probabilities and correlations.

The Pricing of Systematic Risk in Structured Products

When credit rating agencies started rating both structured finance and single-name securities on the same scale, it may well have lured investors seeking safe investments into the structured finance market, even though they did not fully appreciate the nature of the underlying economic risks. In the logic of the capital asset pricing model, securities that are correlated with the market as a whole should offer higher expected returns to investors, and hence have higher yields, than securities with the same expected payoffs (or credit ratings) whose fortunes are less correlated with the market as a whole. However, credit ratings, by design, only provide an assessment of the risks of the security's expected payoff, with no information regarding whether the security is particularly likely to default at the same time that there is a large decline in the stock market or that the economy is in a recession.

Because credit ratings only reflect expected payoffs, securities with a given credit rating can, in theory, command a wide range of yield spreads—that is, yield in excess of the yield on a U.S. Treasury security of the same duration—depending on their exposure to systematic risks. For example, consider a security whose default likelihood is constant and independent of the economic state, such that its

[8] Additional information on the Markit ABX indices, including pricing, can be found at ⟨http://www.markit.com/information/products/category/indices/abx.html⟩.

payoff is unrelated to whether the economy is in a recession or boom, whether interest rates are rising or falling, or the behavior of any other set of economic indicators. An example of this type of a security is a traditional catastrophe bond. Catastrophe bonds are typically issued by insurers and deliver their promised payoff unless there is a natural disaster, such as a hurricane or earthquake, in which case the bond defaults. Under the working assumption that a single natural disaster cannot have a material impact on the world economy, a traditional catastrophe bond will earn a yield spread consistent with compensation for expected losses. Investors are willing to pay a relatively high price for catastrophe bonds because their risks are uncorrelated with other economic indicators and therefore can be eliminated through diversification.

At the other end of the range, the maximum yield spread for a security of a given rating is attained by a security whose defaults are confined to the worst possible economic states. If we assume that the stock market provides an ordering of economic states—that is, if the Standard and Poor's 500 index is at 800, the economy is in worse condition than if that same index is at 900—then the security with maximal exposure to systematic risk is a digital call option on the stock market. A digital call option pays $1 if the market is above a pre-determined level (called a "strike price") at maturity and $0 otherwise. Because this security "defaults" and fails to pay only when the market is below the strike price, it represents the security with the greatest possible exposure to systematic risk. By selecting the appropriate strike price, the probability that the call fails to make its promised payment can be tuned to match any desired credit rating. However, because a digital call option concentrates default in the worst economic states, investors will insist on receiving a high return as compensation for bearing the systematic risk and require the option to deliver the largest yield spread of all securities with that credit rating.

The process of pooling and tranching effectively creates securities whose payoff profiles resemble those of a digital call option on the market index. Intuitively, pooling allows for broad diversification of idiosyncratic default risks, such that—in the limit of a large diversified underlying portfolio—losses are driven entirely by the systematic risk exposure. As a result, tranches written against highly diversified collateral pools have payoffs essentially identical to a derivative security written against a broad economic index.

In effect, structured finance has enabled investors to write insurance against large declines in the aggregate economy. Investors in senior tranches of collateralized debt obligations bear enormous systematic risk, as they are increasingly likely to experience significant losses as the overall economy or market goes down. Such a risk profile should be expected to earn a higher rate of return than those available from single-name bonds, whose defaults are affected by firm-specific bad luck. If investors in senior claims of collateralized debt obligations do not fully appreciate the nature of the insurance they are writing, they are likely to be earning a yield that appears attractive relative to that of securities with similar credit ratings (that is, securities with a similar likelihood of default), but well below the return they could have earned from simply writing such insurance directly—say, by making the appropriate investment in options on the broader stock market index. In Coval, Jurek, and Stafford (forthcoming), we provide evidence for this conjecture, showing that senior tranches in collateralized debt obligations do not offer their investors nearly large enough of a yield spread to compensate them for the actual systematic risks that they bear.

The fact that corporate bonds and structured finance securities carry risks that can, both in principle and in fact, be so different from a pricing standpoint casts significant doubt on whether corporate bonds and structured finance securities can really be considered comparable, regardless of what the credit rating agencies may choose to do.

The Rise and Fall of the Structured Finance Market

The dramatic rise and fall of structured finance products has been remarkable. In under a decade, issuance of these products within the U.S. economy grew more than ten-fold. In the first three quarters of 2005, $25–$40 billion of structured finance products were issued in each quarter, according to data from the Securities Industry and Financial Markets Association. In the last quarter of 2006 and the first two quarters of 2007, issuance of structured finance products peaked at about $100 billion in each quarter. But by the first two quarters of 2008, these quantities had dropped to less than $5 billion per quarter.

It is easy to see how the events of 2007 and 2008 compelled investors to reassess the risks they were bearing in structured products. Less obvious is how structured finance achieved such amazing growth in such a short period of time. Why were investors eager to purchase structured products and issuers eager to supply them? As we have argued, the key to understanding the market's dramatic rise and fall is to recognize the tendency of pooling and tranching to amplify mistakes in the assessment of underlying asset default risks and correlations as well as their ability to concentrate systematic risks in the most senior tranches.

The rapid growth of the market for structured products coincided with fairly strong economic growth and few defaults, which gave market participants little reason to question the robustness of these products. In fact, all parties believed they were getting a good deal. Many of the structured finance securities with AAA-ratings offered yields that were attractive relative to other, rating-matched alternatives, such as corporate bonds. The "rated" nature of these securities, along with their yield advantage, engendered significant interest from investors. However, these seemingly attractive yields were in fact too low given the true underlying risks. First, the securities' credit ratings provided a downward-biased view of their actual default risks, since they were based on the credit rating agencies' naïve extrapolation of the favorable economic conditions. Second, the yields failed to account for the extreme exposure of structured products to declines in aggregate economic conditions (in other words, systematic risk). The spuriously low yields on senior claims, in turn, allowed the holders of remaining claims to be overcompensated, incentivizing market participants to hold the "toxic" junior tranches. As a result of this mispricing, demand for structured claims of all seniorities grew explosively. The banks were eager to play along, collecting handsome fees for origination and structuring. Ultimately, the growing demand for the underlying collateral assets lead to an unprecedented reduction in the borrowing costs for homeowners and corporations alike, fueling the real estate bubble that is now unwinding.

It seems that few investors were worried that the underlying assets were overvalued, and those who were had incentives to disregard this possibility. This changed rapidly when subprime mortgage defaults started increasing. As we demonstrated earlier, errors in default probabilities adversely affect all of the tranches, with the junior tranches taking the first losses. Moreover, the CDO^2 structure, which was especially common in this market, magnifies these errors, such that even their senior-most tranches can be significantly impaired.

It is tempting to lay the bulk of the blame for the rise and fall of structured finance on the credit rating agencies, since it was the agencies that evaluated and deemed assets created by collateralized debt obligations as "safe." There is certainly evidence that the rating agencies made some significant mistakes. For example, in May 2008, Moody's acknowledged that it had inadvertently given AAA-ratings to billions of dollars of structured finance products due to a bug in one of its ratings models (Jones, Tett, and Davies, 2008). In March 2007, First Pacific Advisors discovered that Fitch used a model that assumed constantly appreciating home prices, ignoring the possibility that they could fall. Robert Rodriguez (2007), the chief executive officer of First Pacific Advisors, describes the discovery:

> We were on the March 22 call with Fitch regarding the sub-prime securitization market's difficulties. In their talk, they were highly confident regarding their models and their ratings. My associate asked several questions. "What are the key drivers of your rating model?" They responded, FICO scores and home price appreciation (HPA) of low single digit (LSD) or mid single digit (MSD), as HPA has been for the past 50 years. My associate then asked, "What if HPA was flat for an extended period of time?" They responded that their model would start to break down. He then asked, "What if HPA were to decline 1% to 2% for an extended period of time?" They responded that their models would break down completely. He then asked, "With 2% depreciation, how far up the rating's scale would it harm?" They responded that it might go as high as the AA or AAA tranches.

It certainly appears that rating agencies did not fully appreciate the fragility of their estimates nor the possible effects of modest errors in assumptions about default correlations and probabilities in their credit ratings. But this lack of understanding was apparently shared by the regulators who tied bank capital requirements to ratings, as well as by the investors who outsourced their due diligence to rating agencies without sufficient consideration of whether credit ratings meant the same thing for structured finance as they had for single-name securities. In particular, none of the key parties seemed to recognize that small errors in rating individual securities, errors that would have no material effect in the single-name market, are significantly magnified in the tranches of a collateralized debt obligation structure, and can be further magnified when CDO^2 are created from the original collateralized debt obligations, as was common in the mortgage-backed securitizations.

There is also some evidence that perverse incentives induced questionable behavior on the part of market participants. One concern is over the possibility of conflicts of interest that may arise because the issuer, rather than the investor, pays for the rating. Mason and Rosner (2007) argue that the process and complexity of creating structured finance products requires rating agencies essentially to "become part of the underwriting team" rather than act as agents for outside investors. On the other side, the Committee on the Global Financial System from the Bank of International Settlements (2005, p. 26) investigated this concern and concluded that it was no more severe for structured finance products than for single-name credit products, arguing that reputation was a strong force against bad behavior in both markets: "In fact, there appear to be no fundamental differences in the rating processes for structured finance products and traditional bonds. The potential conflicts of interest arising in structured finance are thus unlikely to be materially different from those in the traditional segments of the agencies' business." Looking at the Bank of International Settlements (2005) report several years later, it offers an example of how a variety of important market participants viewed structured finance products and traditional bonds to be highly similar. It also articulates a widely-held view that market forces would solve potential problems. This confusion over the nature of structured products combined with a belief and reliance on market efficiency proved a potent combination.

The U.S. Securities and Exchange Commission (2008) recently summarized its findings from an investigation of several credit rating agencies. It found much that could be improved in the rating process and that analysts and managers generally understood how their actions affected profits and could be in conflict with the goal of accurate credit risk assessment (p. 12):

> For example, in one exchange of internal communications between two analysts at one rating agency, the analysts were concerned about whether they should be rating a particular deal. One analyst expressed concern that her firm's model did not capture "half" of the deal's risk and that "it could be structured by cows and we would rate it" (Email no. 1: Analytical Staff to Analytical Staff, Apr. 5, 2007, 1:13 PM).

> In another email, an analytical manager in the same rating agency's CDO group wrote to a senior analytical manager that the rating agencies continue to create an "even bigger monster—the CDO market. Let's hope we are all wealthy and retired by the time this house of cards falters. ;o)" (Email no. 2: Analytical Manager to Senior Analytical Manager, Dec. 15, 2006, 8:31 PM).

The investment banks played a dual role of investors and dealers in the structured finance market. The business offered enormous short-run payoffs, which seemed too compelling to ignore even if value-destroying in the long-run. The banks were generally eager to keep the structured finance business going even as underwriting standards fell. The combination of low capital requirements imposed on AAA-rated assets and a commonly held perception that they were "safe," allowed banks to hold on to any senior tranches that were not sold to investors. But when the structured finance market collapsed in late 2007, the investment banks found themselves holding hundreds of billions of dollars of low-quality asset pools, many of which consisted of leveraged buy-out loans, subprime mortgages, and bonds from collateralized debt obligations in process—that is, where the tranches had not yet been sold to other investors.[9]

There is some evidence that Wall Street executives realized it would end one day, but in the meantime, they had little incentive to move to the sidelines. In July 2007, the then-CEO of Citigroup, Chuck Prince, acknowledged that the cheap credit-fueled buy-out boom would eventually end, but that in the meantime, his firm would continue to participate in structured finance activities (as reported in Nakamoto and Wighton, 2007): "When the music stops, in terms of liquidity, things will get complicated. As long as the music is playing, you've got to get up and dance. We're still dancing."

Finally, the minimum capital requirements for banks set forth in Basel I and II may have played an important role in the evolution of the structured finance market. Under these guidelines, banks holding AAA-rated securities were required to hold only half as much capital as was required to support other investment-grade securities. As a result of this built-in demand by banks for AAA-rated securities, a small yield advantage in AAA-rated structured finance securities may have led to a large increase in the demanded quantity. As discussed in the previous section, the structured finance machinery enabled the creation of AAA-rated securities that had a yield advantage over single-name AAA-rated securities, but only by filling these securities with systematic risks or by rating them incorrectly.

[9] For a detailed study of the market for collateralized loan obligations, see Benmelech and Dlugosz (2008).

Implications and Conclusions

During the credit crunch from late 2007 and into 2008, the buyers of highly rated structured finance products largely stopped buying. The initial cause for this change was that subprime-related securities were experiencing large losses, which created concerns about structured finance products more generally. Some practitioners believe that the credit crunch of 2007 and 2008 will work itself out, as such episodes tend to do, and the market for structured credit will return as before. We hold the more skeptical view that the market for structured credit appears to have serious structural problems that may be difficult to overcome.

As we have explained, these claims are highly sensitive to the assumptions of 1) default probability and recovery value, 2) correlation of defaults, and 3) the relation between payoffs and the economic states that investors care about most. Beginning in late 2007 and continuing well into 2008, it became increasingly clear to investors in highly-rated structured products that each of these three key assumptions were systematically biased against them. These investors are now reluctant to invest in securities that they do not fully understand.

The ability to create large quantities of AAA-rated securities from a given pool of underlying assets is likely to be forever diminished, as the rating process evolves to better account for parameter and model uncertainty. The key is recognizing that small errors that would not be costly in the single-name market, are significantly magnified by the collateralized debt obligation structure, and can be further magnified when collateralized debt obligations are created from the tranches of other collateralized debt obligations, as was common in mortgage-backed securitizations. The good news is that this mistake can be fixed. For example, a Bayesian approach that explicitly acknowledges that parameters are uncertain would go a long way towards solving this problem. Of course, adopting a Bayesian perspective on parameter uncertainty will necessarily mean far less AAA-rated securities can be issued and therefore fewer opportunities to offer investors attractive yields.

Additionally, investors need to recognize the fundamental difference between single-name and structured securities when it comes to exposure to systematic risk. Unlike traditional corporate bonds, whose fortunes are primarily driven by firm-specific considerations, the performance of securities created by tranching large asset pools is strongly affected by the performance of the economy as a whole. In particular, senior structured finance claims have the features of economic catastrophe bonds, in that they are designed to default only in the event of extreme economic duress. Because credit ratings are silent regarding the state of the world in which default is likely to happen, they do not capture this exposure to systematic risks. The lack of consideration for these types of exposures reduces the usefulness of ratings, no matter how precise they are made to be.

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