The Credit Crunch of 2007: What Went Wrong? Why? What Lessons Can Be Learned?

John C. Hull*
September 2008
Joseph L. Rotman School of Management
University of Toronto

Abstract

This paper explains the products that were used to securitize mortgages during the period leading up to the credit crunch of 2007 and explains why many of these products have performed so badly. It also examines some of the lessons that can be learned from the crisis.

*e-mail: hull@rotman.utoronto.ca. I am grateful to Richard Cantor and Roger Stein for useful comments on an earlier draft. All views expressed are my own.

The Credit Crunch of 2007: What Went Wrong? Why? What Lessons Can Be Learned?

The overexpansion of credit in the US housing market has led to huge losses by financial institutions and an almost unprecedented tightening of credit throughout the world. How long it will take world financial markets to recover and which financial institutions will fail is still unclear. In retrospect, the actions of almost all large financial institutions during the period leading up to 2007 were imprudent. It is clearly important for the regulators of financial institutions, and for financial institutions themselves, to analyze what went wrong and why. Hopefully, this analysis can result in those financial institutions that survive the crisis being stronger and more stable entities.

This paper has three objectives. The first is to explain the products that were used to securitize mortgages during the period leading up to the credit crunch of 2007; the second is to provide some insight as to why those products have performed so badly; the third is to suggest some lessons that can be learned from the crisis.

THE US HOUSING MARKET

A natural starting point for any discussion of the credit crunch of 2007 is the US housing market. Figure 1 shows the S&P /Case-Shiller composite-10 index for house prices between Jan 1987 and June 2008. In about the year 2000, house prices started to rise much faster than they had in the previous decade. The very low Fed Funds rate between 2002 and 2005 was an important contributory factor, but the bubble was largely fuelled by mortgage lending practices.

Mortgage lenders thought they were taking very little risk during the 2000 to 2007 period because the value of the collateral underlying their loans was rising very fast. Mian and Sufi (2008) produce results showing that there was a relaxation of the criteria used for mortgage lending. Their research defines "high denial zip codes" as zip codes where a high proportion of mortgage applicants had been turned down in 1996, and shows that mortgage origination grew particularly fast for these zip codes from 2000 to 2007. The new entrants to the real estate market created demand that was instrumental in pushing up prices.

Mortgages to less credit worthy borrowers are defined as “subprime”. A rule of thumb is that a subprime mortgage is a home loan to someone with a credit (FICO) score of less than 620, but some lenders classify a mortgage as subprime when the borrower has a credit score as high as 680 if the down payment is less than 5%. Standard & Poor’s has estimated that subprime mortgage origination in 2006 alone totalled $421 billion. AMP Capital Investors estimate that there was a total of $1.4 trillion of subprime mortgages outstanding in July 2007.

Mian and Sufi’s results suggest that lending criteria were relaxed progressively through time rather than all at once because originations in high denial zip codes are increasing function of time during the 2000 to 2007 period. Zimmerman (2007) provides some confirmation of this. He shows that subsequent default experience indicates that mortgages made in 2006 were of a lower quality than those made in 2005 and these were in turn of lower quality than the mortgages made in 2004. Some market participants understood what was going on. Terms such as “Liar Loans” (referring to the fact that people could safely lie on their mortgage application because their statements would not be checked) and NINJA (referring to applicants who had No Income, No Job, and no Assets) have been used to describe the market. But the full extent of the risks and their potential impact on markets was not appreciated until well into 2007. Evidence for this is that the ABX BBB index was above 70 in February 2007. (By September 2008, it had fallen to about 5.)

As pointed out by Zimmerman (2007), once the housing bubble had been started mortgage lenders wanted to keep it going by attracting new entrants to the market. Because house prices were going up they had to become creative in finding ways to make houses appear affordable. One approach was to offer an initial period of two or three years where rates were below market. In a 2/28 adjustable rate mortgage (ARM) the rate might be fixed at 8% (or lower) for two years and then set equal to six-month LIBOR plus 6% for the remaining 28 years. To quote from Krinsman (2007), “In 2005 and 2006 lenders made it easier for borrowers to obtain subprime loans. For example, the typical subprime borrower with a credit score between 450 and 680 could obtain a loan with little or no down payment, provide little or no documented proof of income or assets, obtain a loan with a low initial ‘teaser’ interest rate that reset to a new, higher rate after two or three years...”

As Figure 1 illustrates, the bubble burst in 2007. Many mortgage holders found they could no longer afford mortgages when teaser rates ended. Foreclosures increased. House prices declined. This resulted in other mortgage holders, who had borrowed 100%, or close to 100%, of the cost of a house having negative equity. Some exercised their implicit put options and "walked away" from their houses and their mortgage obligations. This reinforced the downward trend in house prices.

SECURITIZATION

Financial institutions frequently did not retain the mortgages they originated on their books. Subprime mortgages were securitized and sold to investors using asset-backed securities (ABSs).[1] Securitization has been an important and useful tool in financial markets for many years, but it played a part in the creation of the housing bubble. For example, as we will describe later, Keys et al (2008) show that there was a link between securitization and the lax screening of mortgages.

The basic structure of an ABS is shown in Figure 2. A portfolio of subprime mortgages (Asset 1 to Asset n) is created and the credit risks are "tranched out.'' The mechanism for doing this is known as a "waterfall.'' In the example shown, Tranche 3 is the senior tranche. Its principal is 75% of the total principal of the underlying mortgage portfolio. Tranche 2 is the mezzanine tranche. Its principal is 20% of the total. Tranche 1, with a principal of 5%, is the equity tranche.[2]

There are complicated rules defining what happens to the cash flows from the mortgages. Rules that are indicative of the design of an ABS are the following. Tranche 3 receives the cash flows until its promised return (6% in this example) is met. Any extra cash flows go to Tranche 2 until it has received its promised return. Only after Tranche 3 and Tranche 2 have received their promised returns does Tranche 1 receive anything. As an approximation, the structure can also be characterized in terms of who bears the losses on the underlying portfolio. Tranche 1 has 5% of the principal and bears the first 5% of the losses. As compensation for this, its return at any

[1] It has been estimated that 54% of subprime mortgages were securitized in 2001 and this rose to 75% in 2006.

[2] Figure 2 is a somewhat simplified. There are usually more than three tranches and subprime mortgages were sometimes mixed in with other financial instruments such as credit card receivables in the portfolio.

given time is 30% on the part of its principal that has not been eroded by losses. Tranche 1 is wiped out when losses exceed 5%. Tranche 2 bears losses between 5% and 25% on the portfolio. In return for doing this it earns 10% of its outstanding principal. Losses in excess of 25% are borne by the senior tranche, Tranche 3. (This characterization of the structure will be used for some "back-of-envelope" calculations later.)

The arranger of the ABS ensures that it is structured so that Tranche 3 is rated AAA. There is a huge unsatisfied demand for AAA-rated securities and so (at least until mid-2007) there was no difficulty in finding investors to buy Tranche 3. Tranche 1 was typically either retained by the originator or sold to a hedge fund. Finding a market for Tranche 2 proved to be more difficult. This is where financial engineers became creative (perhaps too creative). They designed a structure known as an ABS CDO or Mezz CDO. This tranches out the risks from a portfolio of mezzanine tranches in the same way that an ABS tranches out the risks from a portfolio of subprime mortgages when the original ABS is created. The structure is illustrated in Figure 3. The ABS CDO in Figure 3 is structured so that the senior tranche is rated AAA. This means that the total of the AAA-rated instruments created is 90% (75% plus 75% of 20%) of the principal of the underlying mortgage portfolio.[3]

In my example (admittedly simplified) the AAA-rated tranche of the ABS in Figure 2 would probably have been downgraded in the second half of 2007. However, it will receive the promised return if losses on the underlying mortgage portfolio are less than about 25%. The AAA-rated tranche of the ABS CDO in Figure 3 is not so lucky. It will get paid the promised return if losses on the underlying portfolios are less than about 10%. But, if they are 15%, 20%, and 25%, the losses on this tranche can be expected to be 33.3%, 66.7% and 100%, respectively.[4]

[3] It is tempting to increase the 90% further by forming a new ABS CDO from the mezzanine tranches of other ABS CDO. This did happen.

[4] To illustrate the calculations, consider the case where losses on the underlying mortgage portfolios are 20%. A total of 5% of the losses are borne by the equity tranche of an ABS and 15% by the mezzanine tranche. The mezzanine tranche has 20% of the principal so that 15/20 or 75% of the principal of each ABS mezzanine tranche is lost. The ABS CDO therefore consists of a portfolio of instruments each bearing a 75% loss. Of the 75% loss on this portfolio, 5% is borne by the equity tranche of the ABS CDO, 20% by the mezzanine tranche of the ABS CDO, and 50% by the senior tranche. This means that the senior tranche loses 50/75 or 66.7% of its principal.

These results are shown in Table 1. The value of the tranches of an ABS is dependent of both the default rate and correlation. The ABS CDO incorporates a form of leverage and, as the example illustrates, the values of its tranches are very highly dependent on default rates and correlations.[5] The example helps explain why in July 2008 Merrill Lynch agreed to sell $30.6 billion of senior tranches of ABS CDOs that had previously been rated AAA to Lone Star Funds for as little as 22 cents on the dollar.[6]

LESSONS

While acknowledging that it is easy to be wise after the event, this section will review some lessons that can be learned from the crisis.

Agency Costs: Originators and Investors

A key issue is the extent to which the behavior of mortgage originators was influenced by their knowledge that the majority of the loans would be securitized. Casual empiricism suggests that the interests of mortgage originators were not aligned with the interests of investors. Mortgage originators did not ask the natural question: "Is this a good lending opportunity. Will the borrower make payments as promised?" Instead the question was "Can I make a profit by selling this mortgage to someone else?"

A key consideration in mortgage lending is the borrower's FICO score. For mortgages with little or no documentation a FICO score of 620 is a cut-off. Mortgages can be securitized relatively easily if the FICO score is above 620, but not if it is below 620. In their research Keys et al (2008) compared low-documentation mortgages with FICO scores just below 620 to those with FICO scores just above 620 and found that the former were less likely to default. This suggests that originators were more careful about the loans they made when they knew that they might not be securitized and took soft data (i.e., data other than the FICO score) into account.

[5] If the mezzanine tranches of ABS CDOs are themselves tranched out (see footnote 3), the dependence on default rates and correlations is even more extreme.

[6] Furthermore, Merrill Lynch agreed to finance 75% of the purchase price.

In an environment where securitization is common it is clearly important that the interests of a loan originator are aligned with those of an investor in the loan. In making the decision on whether to lend, the originator should be motivated to look at the loan in the same way as an investor. Very often, after securitization, the originator becomes the administrator of a mortgage, deciding what to do when the borrower is behind with payments, when to foreclose, etc. The originator should be motivated to take these decisions in the best interests of investors.

In some cases, the mortgage originator keeps the equity tranche. This provides some alignment of interests. But when the equity tranche is worth zero (as it now is for most ABSs and ABS CDOs), the originator no longer has any financial interest in the portfolio.

If the securitization market is to have a rebirth, some changes are likely to be necessary to give investors confidence. One idea is that the originator should keep a certain percentage (say, 20%) of all tranches. Regardless of what happens the interests of originators are then aligned with the interests of investors. Note that there is a big difference between a) an originating institution securitizing 80% of its portfolio and b) an originating institution securitizing 100% of its portfolio while keeping 20% of each tranche. In the first case there will always be a suspicion that the better loans have been retained by the originator and that screening was lax on the rest. Also, the originator has less incentive to be an effective administrator of the securitized portfolio in the first case. Rating agencies might reasonably assign a higher rating to tranches of a portfolio where a percentage of each tranche has been retained.

The results of Keys et al suggest that this proposal might have reduced the market excesses during the period leading up to the credit crunch of 2007. However, it should be acknowledged that one of the ironies of the credit crunch is that securitization did not in many instances get the mortgages off the books of the originating banks. Often AAA-rated senior tranches were bought by other parts of the bank. Because banks were investors and originators, one might expect a reasonable alignment of the interests of investors and originators. But perhaps the part of the bank investing in the mortgages was far removed from the part of the bank originating the mortgages and there was little information flow from one to the other.

Agency Costs: Financial Institutions and Their Employees

It is clear from the current crisis that the interests of many employees of financial institutions are not aligned with the interests of the financial institutions and their shareholders. The huge bonuses paid by Wall Street are widely reported. For many employees short-term cash bonuses are a large proportion of remuneration, more important than either the base salary or longer-term incentives such as employee stock options. Short-term bonuses are paid at a year end, and relate to profits made during the year. If an employee generates huge profits one year and is responsible for severe losses the next year, the employee will receive a big bonus the first year and will not have to return it the following year. The employee might lose his or her job as a result of the second year losses, but even that is not a disaster. Financial institutions seem to be surprisingly willing to recruit individuals with losses on their resumes.

All this creates a situation where the employees of financial institutions have very short-term horizons. Many people saw the possibility, if not the inevitability, of a collapse in the US housing market long before it happened (although few expected the consequences to be as severe as they have been.) Why did traders continue to expose the banks they worked for to this risk? Unfortunately, when trading and other decisions were being taken in 2006, many bank employees did not care what would happen in 2007. Their attention was focused on how large their bonuses would be in 2006.

The issue here is not the size of bonuses, but how they are calculated. It would be an improvement if annual bonuses reflected performance over a longer period (say, five years) with "clawbacks". One idea is the following. At the end of each year a financial institution awards a "bonus accrual" (positive or negative) to each employee reflecting the employee's contribution to the business. The actual cash bonus received by an employee at the end of a year would be the average bonus accrual over the previous five years or zero, whichever is higher. For the purpose of this calculation, bonus accruals would be set equal to zero for years prior to the employee joining the financial institution and bonuses would not be paid after an employee leaves it. Although not perfect, this type of plan would motivate employees to use a multi-year time horizon when making decisions.

Transparency

An ABS or ABS CDO is typically defined by a legal document several hundred pages long. It is safe to assume that most investors did not read the document when they bought AAA-rated tranches of the structures. They relied on the "AAA" label. Once the tranches were perceived as risky it became almost impossible to trade them.[7] This was because potential investors did not understand enough about the underlying portfolio and the algorithm used to determine the cash flows received by the various tranches.

ABSs (and particularly ABS CDOs) are arguably the most complex credit derivatives that are traded. Lawyers should move with the times and define these instruments using software rather than words. In addition to providing a data file with the attributes of the mortgages or other instruments underlying the instruments, lawyers should provide software enabling the cash flows realized by different tranches in different circumstances to be calculated.[8] The user's inputs to the software would define a possible outcome concerning interest and principal payments on the underlying instruments each year. The outputs would be the cash flows realized by each tranche holder each year.[9] Structures like ABS CDOs where tranches are defined in terms of other tranches could be handled efficiently.

This would have a huge advantage. Investors and independent researchers would have no difficulties in running scenario analyses and forming their own opinions about the values of different tranches. The current illiquidity of the ABS and ABS CDO market might well have been avoided if ABSs and ABS CDOs had been defined in the way I have described. (Indeed with this type of software investors might have better understood the risks in the ABS CDO

[7] The rating measures credit quality not liquidity, but the two are sometimes confused.

[8] Given its widespread use by the financial community VBA is a natural choice for the computer language.

[9] I understand that some investors did have access to waterfall software (from sources other than lawyers). My point here is that the more freely and easily available this software is to investors--and to independent researchers--the less the potential for transparency problems. Software is simply a more efficient and more transparent way of making the terms of a deal available to as wide a range of investors and researchers as possible. (This is particularly true when some components of a portfolio are tranches of other portfolios.)

market in the first place.) A good case can be made for handling many derivatives (particularly the more complex ones) in this way so that confirms are replaced by subroutines.[10]

The Need for Models

Normally financial institutions do not trade instruments unless they have satisfactory models for valuing them. Typically there is a group within a financial institution that has the responsibility of vetting the model used for valuing a product and the product cannot be traded in any volume until the model has been approved. What is surprising about the subprime crisis is that financial institutions were prepared to trade senior tranches of an ABS or an ABS CDO without a model. Possibly it was thought that a model is unnecessarily for valuing a AAA-rated instrument. But the lack of a model makes risk management almost impossible and causes problems when the instrument ceases to be rated.

The readiness of financial institutions to trade ABS CDOs is particularly surprising. An ABS CDO is a similar structure to what is called a CDO squared in the synthetic CDO market.[11] CDO squareds are recognized by traders in the synthetic CDO market as highly risky products that are difficult to price. The market for them disappeared largely for this reason a few years ago. A tranche of an ABS CDO is no less risky and no less difficult to price than a CDO squared, but was nevertheless considered by many financial institution to be a good investment. Because models were not developed, the key role of correlation in valuing ABSs and (particularly) ABS CDOs was not well understood.

How Models Should be Used

Having the models to value ABSs and ABS CDOs would have helped, but it would not by itself have been enough to mitigate the subprime crisis. To understand how models might have helped we have to consider how they should have been used.

[10] In my work with financial institutions I have come across mistakes in confirms that were several years sold indicating that the parties did not really rely on the confirms for their understanding of how a deal worked.

[11] See for example Hull and White (2006) for a discussion of CDO squareds.

The risk measures used by regulators, and by financial institutions themselves, are largely based on historical experience. For example, value-at-risk measures for market risk are typically based on the movements in market variables seen over the last two to three years. Credit risk measures are based default experience stretching back over 100 years. Stress testing often involves looking at the largest market moves experienced over the last 10, 20, or 30 years.

There can be no question that historical data provides a useful guide for risk managers. But historical data cannot be used in conjunction with models in a mechanistic way to determine if risks are acceptable.[12] In the risk management arena it is important that models be supplemented with human judgement. A risk management committee should meet regularly to consider the key risks facing a financial institution. Stress tests should be based on the scenarios generated by these managers in addition to those generated from historical data. The risk committee should be particularly sensitive to situations where the market appears to be showing bouts of "irrational exuberance."

One of the lessons from past financial crises is that correlations increase in stressed market conditions. Using standard value at risk techniques to estimate correlations from past data and assuming that those correlations will apply in stressed markets is not appropriate. One of the roles of the risk management committee should have been to recognize the bubble in house prices and insist that stress tests where default rates simultaneously rise in all parts of the country be carried. Of course it is also important that the senior management of bank actually listen to their risk managers and other advisers during periods of irrational exuberance. There is some evidence that they did not,[13] but reducing the short-term nature of incentive plans as discussed earlier has the potential to help as far as this is concerned.

[12] There was in any case very little relevant historical data relating to subprime mortgages. This is because the subprime mortgages during the 2000 to 2007 period were different from subprime mortgages in previous years. The latter were primarily second mortgages.

[13] Some bank employees such as Keishi Hotsuki, co-head of risk management at Merrill Lynch, and David Rosenberg, chief North American economist at Merrill Lynch, did sound warning bells ahead of the credit crunch, but were ignored. Ed Clark, CEO at TD Bank, who had the foresight to close down the bank's structured products business ahead of the crisis, has indicated that this decision met with huge opposition within the bank.

CONCLUSIONS

The underlying cause of the credit crunch was the high level of correlation between the default rates in different parts of the US. Investors in ABSs and ABS CDOs thought they were protected because the underlying mortgage portfolios were geographically diverse, but were proved to be wrong. Mezzanine tranches of virtually all ABSs suffered losses and as a result all the tranches of ABS CDOs suffered losses. The rough calculations given earlier for the simplified structures in Figures 2 and 3 illustrate how this happened.

Could the problems reasonably have been anticipated and the crisis made less severe? As already acknowledged, it is easy to be wise after the event. But it is difficult to avoid the conclusion that the period leading up to 2007 was one of irrational exuberance where banks chose to ignore the housing bubble and its potential impact on some very complicated products they were trading. Agency problems in the banks' originate-to-distribute model and short-term employee incentives were contributory factors.

REFERENCES

Hull, J and A. White, "Valuing Credit Derivatives Using an Implied Copula Approach," *Journal of Derivatives*, 14, 2 (Winter 2006), 8-28.

Keys, B. J., T. Mukherjee , A. Seru, A., and V. Vig, "Did Securitization Lead to Lax Screening? Evidence from Subprime Loans," Working paper, University of Michigan, 2008.

Krinsman, A.N., "Subprime Mortgage Meltdown: How Did it Happen and How Will It End," *The Journal of Structured Finance*, Summer 2007, 13-19.

Mian, A. And A. Sufi, "The Consequences of Mortgage Credit Expansion: Evidence from the 2007 Mortgage Default Crisis," Working Paper, Graduate School of Business, University of Chicago, 2008.

Zimmerman, T., "The Great Subprime Meltdown," *The Journal of Structured Finance*, Fall 2007, 7-20.

Figure 1: U.S. Real Estate Prices, 1987 to June 2008
S&P/Case-Shiller Composite-10 Index

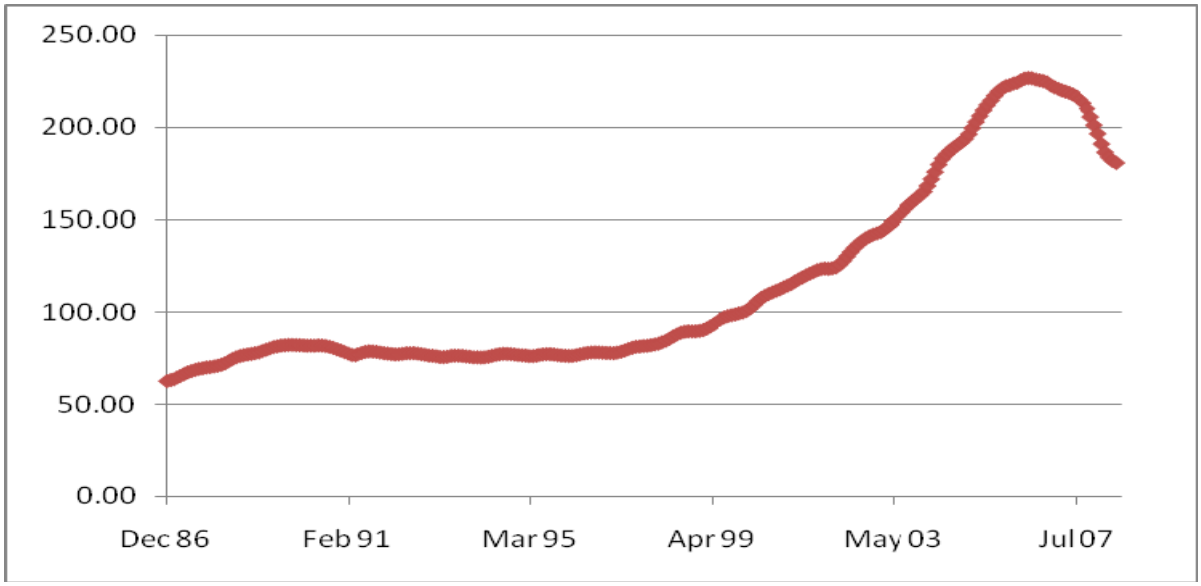

Figure 2: An Asset Backed Security (Simplified)

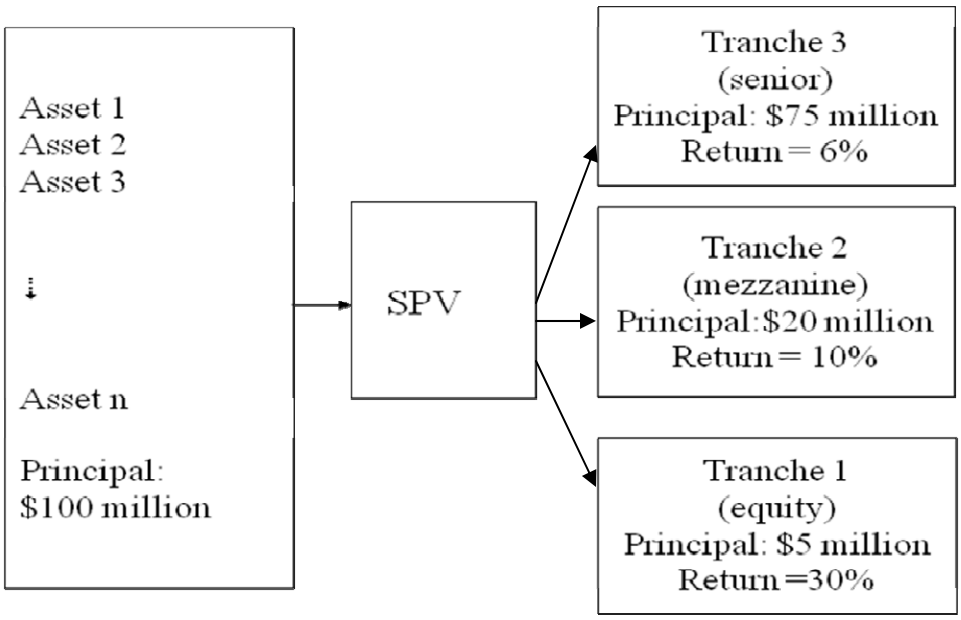

Figure 3: An ABS CDO (Simplified)

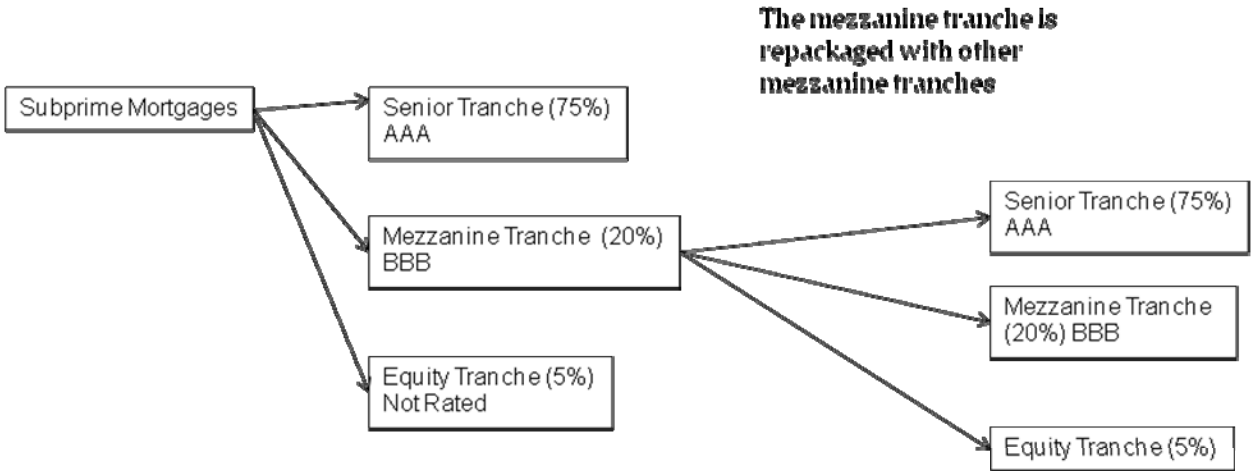

Table 1

Losses to AAA Tranches of ABS CDO in Example

Losses to Subprime portfolios	Losses to Mezzanine Tranche of ABS	Losses to Equity Tranche of ABS CDO	Losses to Mezzanine Tranche of ABS CDO	Losses to Senior Tranche of ABS CDO
10%	25%	100%	100%	0%
15%	50%	100%	100%	33.3%
20%	75%	100%	100%	66.7%
25%	100%	100%	100%	100%