

Risk Management Failures During the Financial Crisis

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1. Introduction

Many people saw this crisis coming and sound warning bells ahead of the subprime crisis, but they were ignored. Policymakers as early of 2006 have warned of the emerging weaknesses in financial markets and the global economy. But nobody listened. Too many people were busy making money originating mortgages, warehousing assets to be securitized, structuring CDOs and distributing these structured credit products to investors seeking desperately investments that offer yield enhancement in an environment of low interest rates and low volatility.

The current crisis was thus an accident waiting to happen. The trigger was a series of events that striked out of the blue and that were a shock for many market participants.

- In June 2007, was the attempt by Bear Sterns to bail out two hedge funds hurt by subprime mortgage losses. Then, the failed attempt by Merrill Lynch, the prime broker, to liquidate some of the collateral revealed how illiquid the market for such securities has become.
- In July, the first bailout by German regulators of IKB, a German regional bank specialized in lending to small companies and not involved in mortgage lending at all.
- In July also, the French bank BNP Paribas froze three investment funds with assets of 2 billion euros because the bank could not value the subprime assets in the funds.

It seems that all of a sudden the market realized that MBSs, CDOs of ABS and other structured products were mispriced.

As a consequence, during July and August 2007, lenders and investors began to worry not only about risk in mortgage-related securities but also about the extent of the

subprime exposure of banks and other financial institutions such as hedge funds, insurance companies and monoline financial guarantors.

This led to information problems and liquidity problems that helped cause markets for important securities to “freeze up” and models to fall apart.¹

Information problems

- Information was inadequate about the quality of the underlying mortgage loans and the borrowers, especially for subprime mortgages² and affordability products that required little or no down-payment, as well as no documentation of the borrower’s income. These loans were also known as “liar loans”.³ They

¹ In this chapter we emphasize weaknesses in risk models. Most pricing models were fine but useless. In the absence of liquidity, pricing models might give you the “right” hedge ratios, but it doesn’t help if you cannot execute the trades to rebalance your portfolio because trading liquidity has dried out.

² “Subprime” mortgages are mortgages to less credit worthy borrowers. A rule of thumb is that a subprime mortgage is a home loan to someone with a credit FICO score of less than 620. Subprime borrowers have limited credit history, or some other form of credit impairment. 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%. Alt-A borrowers fall between subprime and prime borrowers. They 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.

Prior to 2005, subprime mortgage loans accounted for approximately 10% of outstanding mortgage loans. By 2006, subprime mortgages represented 13% of all outstanding mortgage loans with origination of subprime mortgages totaling \$420 billion (according to Standard & Poor’s) representing 20% of new residential mortgages, compared to the historical average of 8%.

In July 2007 there was an estimated \$1.4 trillion of subprime mortgages outstanding.

³ “Liar loans” is referring to the fact that people could safely lie on their mortgage application because their statement would not be checked. These loans were also called NINJA referring to applicants who had No Income, No Job and no Assets.

This phenomenon was aggravated by the incentive compensation system for mortgage brokers based on volume of loans originated and not their performance, with few consequences for the brokers if the loan defaulted within a short period. Originating brokers had then little incentive to perform due diligence and monitor borrowers’ creditworthiness, as most of the subprime loans originated by brokers were subsequently securitized. In fact, fraud was also identified among brokers who were inflating the declarations of some applicants for them to obtain the loan.

To some extent this should have been mitigated by originators having to repurchase delinquent loans within a few months of origination (“early payment default” clause). However, as some of the brokers were experiencing financial difficulties and even in some cases filed for bankruptcy, this did not occur, leading to even greater losses on the underlying asset pools. For example, Merrill Lynch demanded in December 2006 that ResMae mortgage Corp. which sold it US\$3.5 billion in subprime mortgages, buy back US\$308 million of loans where the borrowers had defaulted. ResMae said, in its filing for bankruptcy protection in February 2007, that those demands “crippled” its operations. Accredited Home Lenders Holding reported a loss of US\$37.8 million due to repurchase of bad loans (February, 2007).

accounted for 40% of the subprime mortgage issuance in 2006, up from 25% in 2001.

- Market participants lost confidence in the accuracy of the credit ratings of CDO tranches given by the rating agencies as a huge fraction of tranches of CDOs of ABS saw their ratings downgraded sometime from AAA to non-investment grade, including default, in one shot.
- Market prices became unavailable or unrealistic for many securities, including those rated triple-A.
- There was a lack of knowledge about the positions and liabilities of the major banks and other players such as hedge funds and insurance companies.

Liquidity problems

- Home buyers could not refinance their loans as they had expected, and they could not make the required payments when their mortgages reset at much higher interest rates.⁴
- Hedge funds could not roll over the financing of their leveraged positions. As their losses increased, they had to sell off securities to meet demands for cash from lenders and investors who were trying to withdraw capital. Compounding the problem was the demand from primary dealers for more collateral. As a result hedge funds were forced to unwind positions in illiquid markets feeding a downward spiral in asset prices.
- SIVs (Special Investment Vehicules) could not roll over their asset-backed commercial paper (ABCP) as rating agencies started to downgrade these

⁴ In 2005 and 2006 the most common subprime loans were of the “short-reset” type. They were the “2/28” or “3/27” hybrid ARMs (adjustable rate mortgages) subprime. These loans had a relatively low fixed teaser rate for the first two or three years, and then reset semi-annually to a much higher rate, i.e., an index plus a margin for the remaining period with a typical margin in the order of 400 to 600 bps.

Short-term interest rates began to increase in the U.S. from mid-2004 onwards. However, resets did not begin to translate into higher mortgage rates until sometime later. Debt service burdens for loans eventually increased, which led to financial distress for some of this group of borrowers. In 2008, US\$500 billion in mortgages reset.

structures. Most sponsoring banks ended up bailing out their SIVs and took over their assets on their balance sheet.⁵

- Some investors, like money market funds, may only hold triple-A rated securities. As these securities, in particular, triple-A rated super senior tranches of CDOs, were downgraded, these investors were forced to sell these securities in illiquid markets putting more downward pressure on the price of structured credit products.

As more and more complex securities, such as MBSs, CDOs of ABS, etc., and later on monolines, were downgraded, banks experienced huge amount of losses and write-downs which reached US\$700 billion in November 2008. These losses are far in excess of what pricing models, rating models and risk models would have predicted. Risk measurement models totally underestimated the risks and many risk managers didn't see it coming.

In this chapter, first we analyze what went wrong in risk management and risk modeling, then, we draw some lessons from this fiasco.

2. What went wrong in risk management and risk modeling

Major weaknesses in risk assessment and risk modeling are at the origin of the credit losses in financial institutions, worldwide, which mostly originate from over-reliance on:

- misleading ratings from rating agencies;
- unrealistically simple risk models, i.e., models that were not designed to deal with the complexity of structured credit products;
- inaccurate data;
- short-term financing with too little consideration for liquidity risk.

⁵ Most sponsoring banks distributed their credit exposures through SIVs in which they retained contractual and reputational liquidity exposures. These vehicles, like banks themselves, were funding longer-term assets with short term liabilities, and like banks, were subject to a run when their lenders became concerned about the quality of the assets.

2.1 Over-reliance on misleading ratings from rating agencies.

Rating agencies are at the center of the current crisis as many investors relied on their ratings for many diverse products: mortgage bonds, asset-backed commercial paper (ABCP) issued by the structured investment vehicles (SIVs), Derivative Product Companies (DPCs) and monolines which insure municipal bonds and structured credit products such as tranches of CDOs.

Money market funds are restricted to investing only in triple-A assets, pension funds and municipalities are restricted to investing in investment grade assets and base their investment decision on the rating attributed by the rating agencies.⁶ Many of these investors invested in assets that were both complex and contained exposure to subprime assets mainly because these assets benefited of an investment grade rating and were promising a yield higher than traditional assets, such as corporate and Treasury bonds, with an equivalent rating.

Investors in complex credit products had considerably less information at their disposal to assess the underlying credit quality of the assets they held in their portfolios than the originators. As a result, these end-investors often came to rely heavily on the risk assessments of rating agencies. Implicitly in the investment decision is the assumption that ratings are timely and relatively stable. No one was expecting, until recently, a triple-A asset to be downgraded to junk status within a few weeks or even a few days. The argument could be made that as the yields on these instruments exceeded those on equivalently rated corporations, the market knew they were not of the same credit and/or liquidity risk. But investors still mis-judged the risk.

Large numbers of rating downgrades on structured credit products, in particular tranches of subprime CDOs, have thus revived the questions about the nature of structured finance ratings, their sensitivity to changes in credit fundamentals, the degree

⁶ Most of the US\$2.5 trillion sitting in money market funds is invested in such assets as U.S. Treasury bills, certificates of deposit and short-term commercial debt. In the recent low interest rate environment these funds have also invested in triple-A super-senior tranches of CDOs and triple-A rated ABCP, in order to increase the yield generated by these funds.

to which rating transitions should be expected to differ from those of corporate bonds, and the extent to which ratings can serve as universal measures of credit risk.⁷

In particular, the nature of the risks involved in holding a triple-A rated super-senior tranche of a subprime CDO was completely missed by all the players: rating agencies, regulators, financial institutions and investors. Subprime CDOs are in fact CDO-squareds, because the underlying pool of assets of the CDO is not constituted of individual mortgages, but instead is composed of subprime RMBS (Residential Mortgage-Backed Securities), or mortgage bonds, that are themselves tranches of individual subprime mortgages (Box 1).

2.1.1 “Cliff” effects or nonlinearities in the risk of subprime CDO tranches.

Perhaps, one of the biggest failing in the subprime crisis was the failure to understand the binary (zero-one) nature of the senior tranches of subprime CDOs. The problem is that the initial level of subordination for a triple-B mortgage bond is relatively small, between 3 and 5 percent and the width of the tranche is very thin 2.5 to 4 percent maximum.

As prepayments occur the level of subordination of the lower tranches increases, in relative terms, and can reach 10 percent over time. Assuming a recovery of 50 percent on the foreclosed homes, means that a default rate of 20 percent on subprime mortgages, which is realistic in the current environment, will most likely hit most of the triple-B tranches. Moreover, it is also most likely that in the current downturn in the housing market and recessionary economic environment, the loss correlations across all the triple-B tranches will be close to one. As a consequence, if one triple-B tranche is hit, it is most likely that most of the triple-B tranches will be hit as well during the same period. And, given the thin width of the tranches, it is most likely that if one MBS bond is wiped out, they all will be wiped out at the same time, wiping out the super-senior tranche of the subprime CDO. In other word, we are in a binary situation where either the cumulative default rate of the subprime mortgages remains below the threshold that keeps the

⁷ Moody’s first took rating action on 2006 vintage subprime loans in November 2006. In 2007, Moody’s downgraded 31% of all tranches for CDOs of ABS it had rated, and 14% of those initially rated AAA.

This raises questions about the rating methodologies employed by the different agencies. See Ashcraft and Schuermann (2007) for a detailed description of the rating of subprime MBS.

underlying RMBS bonds untouched and the super-senior tranches of subprime CDOs won't incur any loss, or the cumulative default rate breaches this threshold and the super-senior tranches of subprime CDOs could all be wiped out.

2.1.2 Wrong estimates of default rates and default correlations⁸

Rating agencies based their ratings on wrong estimates of the underlying securities' default risks, and how likely defaults were to be correlated in a stressed environment. Rating agencies based their estimates of default rates on a very short history going back to 2001 characterized by a fairly benign environment for the real estate market. They did not take into account two major changes into their rating model: the rupture in the delinquency statistics starting in 2005 and the inflexion in the real estate market and the economic environment which made defaults on mortgages no longer an isolated phenomenon, but rather a systemic event with borrowers defaulting in cluster in some geographic areas such as parts of California and Florida.

Delinquencies on subprime mortgages rose significantly after mid-2005 for at least four reasons:⁹

First, subprime borrowers are typically not very creditworthy, often highly levered with high debt-to-income ratios, and the mortgages extended to them have relatively large loan-to-value ratios. Until recently, most borrowers were expected to make at least 20% down payment on the purchase price of their home. During 2005 and 2006 subprime borrowers were offered "80/20" mortgage products to finance 100% of their homes. This option allowed borrowers to take out two mortgages on their homes. In addition to a first mortgage for 80% of the total purchase price, a simultaneous second mortgage, or "piggyback" loan for the remaining 20% would be made to the borrower.

Second, in 2005 and 2006 the most common subprime loans were of the "short-reset" type. They were the "2/28" or "3/27" hybrid ARMs subprime. These loans had a relatively low fixed teaser rate for the first two or three years, and then reset semi-

⁸ A third factor, i.e., the amount recovered in the event of default also named recovery rate, affect the expected loss. Very few data is available to calibrate this parameter for subprime loans and it was estimated across the board at 40%.

⁹ See Crouhy et al. (2008)

annually to a much higher rate, i.e., an index plus a margin for the remaining period with a typical margin in the order of 400 to 600 bps. Short-term interest rates began to increase in the U.S. from mid-2004 onwards. However, resets did not begin to translate into higher mortgage rates until sometime later. Debt service burdens for loans eventually increased, which led to financial distress for some of this group of borrowers.

Third, many subprime borrowers had counted on being able to refinance or repay mortgages early through home sales and at the same time produce some equity cushion in a market where home prices kept rising. As the rate of U.S. house price appreciation began to decline after April 2005, it became more difficult for subprime borrowers to refinance and many ended up incurring higher mortgage costs than they expected to bear at the time of taking their mortgage.¹⁰

Fourth, a decline in credit standards by mortgage originators in underwriting over the last three years, was a major factor behind the sharp increase in delinquency rates for mortgages originated during 2005 and 2006. The pressure to increase the supply of subprime mortgages arose because of the demand by investors for higher yielding assets. A major contributor to the crisis was the huge demand by CDOs for BBB mortgage-backed bonds that stimulated a substantial growth in home equity loans. This CDO demand for BBB ABS bonds was due to the fact that the bonds had high yields, and the CDO trust could finance their purchase by issuing AAA rated CDO bonds paying lower yields. This was because the rating agencies assigned AAA ratings to the CDO's senior bond tranches that did not reflect the CDO bond's true credit risk.¹¹ Because these tranches were mis-priced, the CDO equity holders generated a positive net present value investment from just repackaging cash flows. This process boosted the demand by CDOs

¹⁰ The economy started to change during 2004. First, mortgage rates started to increase, as the Federal Reserve increased the Fed Funds rate and second, house price appreciation decelerated. There are many factors that cause delinquency in the mortgage markets, major candidates being: job loss, unanticipated medical expenses, divorce and rising mortgage expenses. House prices can also affect the default decision. If house prices are falling, this can affect this decision in two ways. First, it limits the ability to re-finance and second, it can cause the home owner's equity to become negative if the initial equity stake was small, as is often the case for subprime mortgages. Since the middle of 2005, the rate of house price appreciation has been continuously decreasing.

¹¹ We will subsequently discuss why the CDO tranches were mis-rated. Briefly, the rating methodology did not reflect current market conditions and the sensitivity of losses incurred by senior tranches to errors in delinquency rates and default correlations, without mentioning the incentive problem in the way rating companies were compensated for rating assignments.

for residential mortgage-backed securities (RMBS). Furthermore, this repackaging was so lucrative, that it was repeated a second time for CDO-squared trusts. A CDO-squared trust purchased high yield (low rated) bonds and equity issued by other CDOs. To finance the purchase of this collateral, they issued AAA rated CDO-squared bonds with lower yields. This, in turn, created demand for CDOs containing mortgage-backed securities (MBS) and CDO tranches.

This environment encouraged questionable practices by some lenders. Some mortgage borrowers have ended up with subprime mortgages, even though their credit worthiness qualifies them for lower risk types of mortgages, others with mortgages that they were not qualified to have.¹² Some borrowers and mortgage brokers took advantage of the situation and fraud massively increased but it seems that it was ignored by the rating agencies.

According to rating agencies, ratings assumed a default correlation of 20%, which is probably a high estimate in a benign economic environment where defaults are essentially due to idiosyncratic factors: job loss, unanticipated medical expenses, divorce, etc. which are specific to an individual or family and won't affect the other borrowers in the same geography. When a recession hits the economy as it started in 2007, it is a different story. Whole industries are affected, companies are going bankrupt and have to layoff thousands of people which makes the impact of the recession even more severe in the geographic areas affected by these corporate bankruptcies. Delinquencies occur in waves and defaults are becoming a systemic phenomenon with defaults becoming highly correlated at least in some locations.

Rating agencies, as well as structures and investors totally occulted the fact that the securitization process substitute idiosyncratic risks that are largely diversifiable in a benign economic environment, for systemic risk which is not diversifiable during a severe economic downturn.

¹² Lenders were far too willing to lend as evidenced by the creation of new types of mortgages, known as “affordability products” that required little or no down payment, and little or no documentation of a borrower’s income, the last ones being known as “liar loans”. Liar loans accounted for 40 percent of the subprime mortgage issuance in 2006, up from 25 percent in 2001.

2.1.3 Sensitivities of the rating of senior subprime CDO tranches to estimation errors of delinquency rates, recovery rates and default correlations.

Ratings of tranches of CDOs and other credit instruments such as corporate debt, are indicators of default risk based on expected loss (Moody's) or probabilities of default (Standard & Poor's and Fitch Ratings).¹³ Rating agencies rely on Monte-Carlo simulation to simulate cash flows and correlated defaults of the assets in the pool, and allocate the cash flows to the various tranches according to the waterfall. This simulation produces a loss distribution for the pool and an expected loss for each tranche of the capital structure of the securitization transaction. These expected losses are then mapped into the letter based rating scale. The tranching is structured so that the senior tranches obtain a triple-A rating.

Simple simulations show that small errors in the evaluation of the delinquency rate of the underlying mortgages, recovery rates and default correlations can result in major changes in the expected loss of the senior tranches of a CDO, and consequently their rating.¹⁴ Rating transitions for structured credit products such as tranches of subprime CDOs differ substantially from those of corporate bonds. Therefore, it is misleading to use the same rating scale for bonds and structured credit products. They may have the same expected loss at the time the rating is produced, but their future dynamics may differ substantially.

Rating agencies missed the impact of the leverage imbedded in structured credit products which makes the senior tranches quite sensitive to errors in the evaluation of default rates of the underlying loans and to default correlations.

Small errors in the evaluation of these parameters would not have major consequences for the rating of a corporate bond. On the contrary, tranches of CDOs with their imbedded leverage are much more sensitive to these factors. In addition, the expected loss of senior tranches of CDOs is highly sensitive to the default correlations.

¹³ Contrary to a corporate bond, an MBS or a tranche of a CDO does not default in the sense of a corporate default event. Instead, depending on the rate of delinquencies on the underlying pool of assets, these securities will experience cash flow shortfalls and principal write-downs over the life of the transaction.

¹⁴ See Coval et al. (2008) and Fender et al. (2008).

As default correlations increase part of the risk is shifted from the equity to the senior tranches. The expected loss of the equity tranche decreases while the expected loss of the senior tranches increases. This effect is amplified for CDO-squareds, i.e., CDOs of tranches of CDOs, as the leverage effect is more important than for CDOs. During economic crises when the systemic factors become dominant compared to idiosyncratic risks, the senior tranches become much more risky.

From the mid 2007 going forward it has become clear that investors in senior tranches initially rated triple-A have been holding securities much more risky than initially estimated when the impact of systemic risk was totally occulted in the rating and pricing of these tranches. These features, the large sensitivity of expected loss to parameter estimation errors and the exposure to systemic risk of senior tranches, should have demanded much higher risk premia from investors for holding highly rated tranches of CDOs than corporate bonds of the same rating.

This is consistent with the downgrade actions reported by the rating agencies. In February 2007, S&P took the unprecedented step of placing on “credit watch” transactions that had been closed as recently as the previous year. From the first quarter of 2005 to the third quarter of 2007, Standard and Poor’s (2008) reports for CDOs of asset backed securities, 66% were downgraded and 44% were downgraded from investment grade to speculative grade, including default.¹⁵ End of 2008 more than 50% of the CDO tranches that received initially an A rating or above have been downgraded, compared to 10% only for corporate bonds. Most of the corporate bonds that have been downgraded lost one full notch, say from A to BBB, while 80% of the CDO tranches lost 3 full notches in one shot.

It is therefore important for rating agencies, investors and regulators to understand the fundamental difference between the rating of a corporate bond and the rating of tranches of CDOs when it comes to exposure to systemic risk. They cannot be rated on the same scale. It has misled investors seeking safe investments who did not appreciate the risks of highly rated structured products compared to Treasuries or corporate bonds of

¹⁵ For residential subprime mortgage backed securities, 17% were downgraded, and 9.8% were downgraded from investment grade to speculative grade, including default.

the same rating. Corporate bonds are mainly exposed to idiosyncratic risks, i.e., risks specific to the firm, the quality of its management, the positioning of the company within its industry. The risk of a company will be affected by the economic environment but systemic risk is not the dominant factor in assessing the risk of an individual company. On the contrary, a senior tranche of a CDO has the features of a catastrophe bond which is strongly affected in extreme scenarios.¹⁶ Investors in those securities wrote insurance against a major recession but were not properly compensated for the associated risk. In the case of subprime CDOs the collapse of the real estate market in the context of an economic recession is the extreme scenario characterized by very high default correlations and a transfer of risk from the junior tranches to the senior ones.

2.2 Over-reliance on unrealistically simple risk models

Value-at-Risk (VaR) has become the universal risk measure for financial institutions in understanding their sensitivity to changes in market risk drivers such as interest rate, asset prices, correlations and volatilities. Banks implemented their VaR models in the mid-nineties as a response to the 1996 Amendment to the Basel Accord (implemented in 1998 under the auspice of the Bank for International Settlements and therefore referred to widely as “BIS 98”) which extended the initial Accord to include risk-based capital requirements for the market risks that banks incur in their trading book. The authorities recognized the complexity of correctly assessing market-risk exposures, especially for derivatives products. The Basel Committee therefore allowed institutions that met certain risk management standards to use their own internal VaR model.

Given the amount of calculations involved in running a VaR model, the pricing of securities within a VaR model requires some shortcuts. Either, one can rely on closed-form formula for relatively simple products and one should price complex securities based on their first and second order sensitivities (the “Greeks” in the jargon of quants and traders).

¹⁶ See Coval et al. (2007). According to these authors: “...a triple-A rated tranche of a CDO bears risks that are highly similar to those of a 50% out-of-the-money five-year put spread on the S&P 500 index. However, on average, the put spread offers nearly three times more compensation for bearing these risks.”

At the time VaR models for market risk, then for credit risk, were designed, structured credit products that are sensitive to changes in credit spreads, default rates, recovery rates and default correlations, did not exist. So far, we are not aware of any full-fledged extension of these models that accounts for the complexity of structured credit products such as tranches of subprime CDOs.

Since structured credit products are rated using the same rating scale as for corporate bonds, banks have naturally taken as proxy for these securities in their VaR models corporate bonds with similar ratings. We have demonstrated in the previous section that this approach is fundamentally flawed and may lead to major underestimation of the risks involved with holding these complex securities.

UBS provides an example of the abyssal losses that can result from not modeling the full complexity of the structured credit products when assessing the risk profile of the bank's portfolio. UBS was the second largest bank in the world by total assets at the end of 2006 and was the winner of Euromoney magazine's "Global Best Risk Management House" award for excellence in 2005. As of August 2008, UBS had written-down its assets by \$45 billion and had capital infusion of \$28 billion.

A post mortem shareholder report (UBS, 2008) on UBS's write-downs indicates that "short cuts" were taken to speed up the production of risk reports. But these short cuts were systematically gamed so that risks were structured in such a way they did not show up at all in the risk calculations.¹⁷ Stress tests were carried out but worst case scenarios did not envisage a severe enough real estate crisis. It is reported in the post mortem report that market fluctuations larger than envisaged in the stress tests were not hedged. In other words, the profits being booked were the reward for the assumption of catastrophe risk outside the risk envisaged in the stress tests.

2.3 Over-reliance on inaccurate data.

For reasons indicated earlier in section 2.1.2 the delinquency rate for subprime mortgages increased significantly after 2004. Statistics in tables 1 and 2 show that the market experienced a major change of regime in 2004 which was totally occulted in the risk

¹⁷ See Honohan (2008) for a detailed discussion.

measures, not only by the rating agencies, but also by the banks and other investors holding subprime structured credit products.

Vintage	Subprime	Alt-A	Seconds	Prime	Total
2003	2.7%	0.3%	4.4%	0.1%	1.6%
2004	3.0%	0.5%	6.3%	0.1%	1.7%
2005	7.5%	1.3%	17.2%	0.2%	4.5%
2006	19.3%	4.5%	43.9%	0.3%	12.7%
2007	<u>22.9%</u>	<u>5.4%</u>	<u>62.2%</u>	<u>0.8%</u>	<u>17.4%</u>
Total	10.3%	2.4%	28.5%	0.2%	6.9%

Table 1: Predicting losses of mortgage products by vintage and rating
(Source: UBS, November 2007)

Vintage	Aaa	Aa1	Aa2	Aa3	A1	A2	A3	Baa1	Baa2	Baa3	BIG	NA	Total
2003	6%		16%	81%	12%	17%	20%	12%	14%	18%	71%	14%	16%
2004	12%	6%	8%	6%	16%	9%	7%	8%	12%	18%	30%	29%	12%
2005	10%	4%	8%	5%	8%	12%	18%	28%	38%	49%	68%	44%	23%
2006	22%	30%	46%	59%	66%	69%	80%	82%	88%	91%	97%	85%	69%
2007	<u>25%</u>	<u>53%</u>	<u>55%</u>	<u>73%</u>	<u>77%</u>	<u>72%</u>	<u>82%</u>	<u>83%</u>	<u>84%</u>	<u>76%</u>	<u>88%</u>	<u>70%</u>	<u>70%</u>
Total	15%	17%	26%	34%	41%	35%	46%	45%	47%	55%	76%	50%	40%

Table 2: Predicting losses of subprime mortgage bonds by vintage and rating
(Source: UBS, November 2007)

These statistics demonstrate clearly that as early as 2004 a change of regime had occurred. Risks should have been assessed for the purpose of both structuring, and rating structured credit products based on subprime mortgages, on new estimates of default rates and default correlations more in line with the new economic environment.

2.4 Over-reliance on short-term financing with too little consideration for liquidity risk.

Since the beginning of the 1990s banks have gradually shifted away from the traditional business model “originate and hold” toward the new “originate-to-distribute” business model. Under this new business model, the bank services the loans but the funding of the loans is sourced out to investors, and the risk of default is also transferred out to these investors, without recourse.¹⁸ This new business model was supposed to disperse credit risk throughout the financial system and make financial institutions safer and less sensitive to credit crises, as well as provide banks with additional sources of funding for their lending activities.

This is the theory. In practice the implementation of this business model was flawed and this crisis demonstrated that the redistribution of credit risk among final investors that it was supposed to achieve was only an illusion.

Banks moved away from their balance sheets the assets to be securitized to locate them into structured investment vehicles (SIVs) that are limited purpose, bankruptcy-remote companies. Their purpose is to fund the purchase of the assets, which are primarily long-term assets, with short-term asset-backed commercial paper (ABCP) and some medium-term notes and capital.

Liquidity risk arises because of the need to refinance due to the maturity mismatch between assets and liabilities. The SIV must demonstrate that apart from the vehicle’s cash flows that provide liquidity, it has backstop lines of credit from different institutions, and highly liquid assets that can be sold, so that it is able to deal with market disruptions.

The SIVs relied on being able to continuously roll over their short-term funding and, even though they were “bankruptcy remote” from their sponsors, those that were unable to achieve this were able to turn to their sponsoring banks that had undertaken to provide them with backstop liquidity via credit lines in such situations. In fact, these SIVs, akin to “unregulated banks” funding long-term assets with short-term funding resources, have been a contributor to the current credit crisis. As the credit crisis

¹⁸ See Crouhy et al. (2006, chapter 12).

intensified and the mortgage-backed securities held by the SIVs suddenly started to decline in value, some of the ABCP were downgraded, sometimes all the way to default within a few days. An increasing number of SIVs became unable to roll their ABCP, due to concerns about the value of collateral, and turned to their sponsor banks for rescue.

When banks were unable to roll the ABCP funding these SIVs, and market liquidity had totally evaporated for subprime related assets, banks to preserve their reputation had no other alternative, but to take back the assets on their balance sheet and face funding liquidity issues that led to the bankruptcy of Lehman and the rescue of Bear Sterns, Merrill Lynch and AIG in the U.S or Northern Rock in the U.K..

One of the most striking case of over-reliance on contingent funding liquidity is provided by the German state bank Sachsen, specialized in lending to local small and medium size companies. This bank opened an affiliate in Dublin only specialized in establishing off-balance sheet vehicles to hold mainly highly rated U.S. mortgage-backed securities in a volume equivalent to one-third of the parent's bank balance sheet. This operation was highly profitable until 2007. It contributed 90% of the group's total profit in 2006. The SIVs benefited from a back-up loan facility from the parent bank Sachsen itself for a staggering amount approaching 25% of the total balance sheet of the parent bank.¹⁹ It is clear that both the size of the operation and of the commitment was too big relative to the size of the balance sheet and the capital of the parent bank. Subprime related write-downs and losses in 2007 wiped out the capital of the parent bank. At the end, Sachsen was sold to another German state bank.

The risk management system of Sachsen did not consider this funding liquidity commitment as liquidity risk but simply as operational risk, on the argument that only some operational failure could trigger the back-up liquidity facility to be drawn down. As such it was assigned a very low risk and attracted very little capital.

To revive the “originate-to-distribute” business model we need to find mechanisms that transfer the risk of default, with no recourse, to final investors. Banks need to ensure that when they distribute risks into the market through securitization, the

¹⁹ See Honohan (2008) for a detailed discussion of this case and others.

risks really are distributed and will not come back onto their balance sheet later. This suppose that investors don't rely only on risk ratings but also carry out the necessary due diligence to verify the accuracy of the information given by the trust on the quality of the assets being securitized, and that investors carry out their own risk analysis.²⁰

3. Lessons from this fiasco

A number of important lessons can be drawn from this post mortem analysis of the failures of risk management during the crisis.²¹

3.1 Differentiate the ratings of corporate bonds and structured credit products

To have confidence in a model, it is necessary to have a clear definition of what a rating means for a particular type of instrument, the factors that an agency considers when assigning a rating and how well a rating model performs in different economic environments. There is a lack of clarity about what does a rating actually measure. Is it a measure of the probability of default or the expected loss over some specified horizon?²² What is the length of the horizon? Does a rating, say BBB, have the same meaning for asset backed securities as for corporate bonds?

Subprime ABS ratings differ from corporate debt rating in a number of different dimensions. Corporate bond ratings are largely based on firm-specific risk, while CDO tranches represent claims on cash flows from a portfolio of correlated assets. Thus, the rating of CDO tranches relies heavily on quantitative models while corporate debt ratings rely essentially on the analyst judgment. While the rating of a CDO tranche should have the same expected loss as a corporate bond for a given rating, the volatility of loss, that is,

²⁰ The design of the SIVs can be altered to make them less sensitive to market disruptions. There are a number of ways to achieve this. Currently, some of the extant short-term commercial paper gives the vehicle the option to extend the maturity of the debt. Usage of this option could be expanded. Another type of option would be to allow the vehicle to convert the paper into one or two year floating rate debt. The option could be contingent on the event of a market disruption. The cost of the option would be relatively small, given that the probability of a market disruption is small. The cost of these modifications would be to decrease expected profits (See Crouhy et al., 2008).

²¹ See also Crouhy et al. (2008) for a more exhaustive and detailed analysis of the steps to prevent a repeat of such a crisis.

²² Moody's ratings are based on expected loss whereas those of Standard & Poor's and Fitch ratings are based on probability of default.

the unexpected loss, is quite different and strongly depends on the correlation structure of the underlying assets in the pool of the CDO.²³ This in itself warrants the use of different rating scales for corporate bonds and structured credit products.

For structured products, such as ABS collateralized debt obligations, it is necessary to model the cash flows and the loss distribution generated by the asset portfolio over the life of the CDO, implying that it is necessary to model *prepayments*²⁴ and *default dependence* (correlation) among the assets in the CDO and to estimate the parameters describing the dependence.²⁵ Over the life of a CDO, individual defaults may occur at any time, implying that it is necessary to model the loss distribution over time. This necessitates modeling the evolution of the different factors that affect the default process and how these factors evolve together.

It is critical to assess the sensitivity of tranche ratings to a significant deterioration in credit conditions affecting credit worthiness and default clustering. As discussed earlier, the impact of shocks affecting credit worthiness on CDO tranche ratings is very different than for a corporate bond. It depends critically on the magnitude and the clustering of the shocks and it tends to be non-linear.²⁶

If default occurs, it is necessary to estimate the resulting loss. Recovery rates depend on the state of the economy, the condition of the obligor and the value of its assets. Loss rates and the frequency of defaults are dependent (correlated): if the economy goes into recession, the frequency of defaults and loss rates increase. It is necessary to model the factors that affect the loss and the joint dependence between the frequency of default and loss. The level of dependence will vary, in general, with the state of the economy.

²³ See the discussion in Ashcraft and Schuermann (2007)

²⁴ Prepayments of principal include both voluntary and involuntary (default) prepayments. Voluntary prepayments depend strongly on the path followed by interest rates. Interest rate risk is a key source of uncertainty in the analysis of cash flows.

²⁵ There are many different types of factors that influence default dependence. For example, if the local economy deteriorates, then defaults might increase or if a particular sector of the economy deteriorates, then this will adversely affect obligors within the sector.

²⁶ See Fender et al. (2008) and Coval et a. (2008).

To test model predictions against actual outcomes requires data. Unfortunately, for many types of collateralized products, data availability is limited across instruments and does not extend over long periods. Consequently, there is little information about the accuracy and robustness of models over different parts of the credit cycle. To assess the credit risk of structures such as SIVs, it is necessary to consider other risk dimensions, such as market liquidity and valuation of collateral. These factors have been overlooked, though they affect the credit worthiness.

For the last few years, the characteristics of subprime mortgage borrowers were undergoing major changes due to declining underwriting standards and fraud. The failure to explicitly recognize the changing nature of the underlying data used in model estimation implied that the probabilities of default, recovery rates, default dependence and the dependence between default and recovery rates were poorly estimated. Models need to capture default contagion that exists in local housing markets.

For collateralized structures, there is the need for more transparency about (a) the types of models used by the agencies; (b) the assumptions about the data used to rate a particular structure; and (c) the accuracy and robustness of the rating methodologies to the underlying assumptions. Current methodologies failed due to the use of inappropriate assumptions derived from historic data for corporate CDOs with tranches much wider than for ABS CDOs. They also failed to appropriately model both default and recovery dependences.

To rate the commercial paper of a SIV, there are additional factors to consider. First is an assessment of the backstop lines of support and other contingent funding in the case of market disruptions. The rating agencies rate the contingent sources of funding available to a vehicle. Second, for an investor to buy asset backed commercial paper (ABCP), they need to know the *nature* of the assets supporting the paper and the *value* of the collateral. The agencies are clear that they make no statement about valuation. Yet if the value of the collateral deteriorates, this adversely affects the credit worthiness of the commercial paper. Thus logically, one must address the issue of the valuation of the collateral, if one is to assess the credit worthiness of the vehicle.

3.2 Check the quality of the data about the underlying assets and make sure it is complete and timely

It is essential to perform due diligence on the raw data – neither the rating agencies nor the banks which structured the CDOs have done it.

The rating agencies clearly state that they do not perform due diligence on the raw data. The current situation is analogous to accountants accepting at face value the figures given to them by firms. There is no auditing function. The current situation is problematic. In moving forward, if data auditing are required, then the issue of compensation both for rating and for auditing needs to be addressed. It is not clear that regulating the originators will solve the problem of faulty data unless there is adequate enforcement.

Clarity is required about the data sources used to reach a rating. Is the agency accepting data from a third party and has the agency done anything to check if there have been structural changes in the data sources? Has it checked the data to justify the validity of its distributional assumptions?

For asset backed securities, the government should sponsor an agency that collects information on a timely basis about the collateral pools and make it available to market participants. This will facilitate an independent party's ability to reproduce the credit ratings.

3.3 Complement the traditional VaR risk measure with worst-case scenario analysis and stress testing.

Value-at-Risk (VaR) is a useful measure of risk in normal market conditions and over a very short-term horizon, say 1 to 10 days. But it is well documented that VaR does not perform well in exceptional market conditions characterized by unprecedented price moves and significant tail risk. VaR must be complemented by other risk metrics such as “worst-case scenario analysis” and “stress testing” in order to assess the extent of losses consecutive to extreme market conditions that have a very low probability of occurrence but that are still realistic.

When VaR is calculated at a 99% confidence level, it is expected one exception, on average, every 100 days. A concentration of exceptions, i.e., daily trading losses greater than the daily VaR, over a short period of time is the signal that the VaR model is failing and does not produce an accurate aggregate risk measure for the trading book of the bank. That is precisely what happened at several banks during the third quarter of 2007, after the start of the subprime crisis. According to a Risk Magazine survey published in January 2008, Credit Suisse declared 11 exceptions during the 3rd quarter of 2007, Bear Sterns 10, UBS 16, while Lehman Brothers declared only 3 exceptions, Goldman Sachs 5 and Morgan Stanley 6, with the VaR of the 3 last banks being calculated at the 95% confidence level.

The subprime crisis introduced new risk features which are not captured in VaR models:

- Liquidity risk, i.e., the fact that trading liquidity dries out suddenly so that traders cannot adjust their hedging portfolios. The disappearance of liquidity is a common feature of financial crises. VaR models are, however, static models which cannot capture the impact of liquidity on asset prices, volatility and correlations.
- Strong non-linearities in risk for complex structured products such as subprime CDO tranches. We discussed earlier what we called the “cliff” effect for senior tranches of subprime CDOs. This risk is not captured by VaR models. Contagion risk also cannot be accounted for in a VaR model. Short cuts proposed to deal with these complexities within the framework of VaR have lead to major underestimations of risk. For example, some banks have taken as a proxy for a rated CDO tranche a corporate bond with the same rating. This is flawed for the reasons that we discussed earlier.

If it was not obvious before, this crisis has revealed the necessity to design stress tests and worst case scenarios that include business cycle stresses as well as event specific “tail risks”. The methodology must identify and take into account concentration risk, correlation risk, and liquidity risk and covers on-balance sheet as well as off-balance sheet assets. Scenario analysis must be implemented in a dynamic framework with

scenarios unfolding over a period of time, say a quarter, during which liquidity is limited and does not allow to hedge trading positions in a timely manner.

Risk Management should also run worst-case scenarios to measure the risk of future collateral calls and write-downs which can have a devastating effect on the finances of the firm. For example, AIG was forced to post about \$50 billion in collateral to its trading partners to offset drops in the value of more than \$400 billion of securities it insured with credit default swaps, and wrote-down several billion dollars. It was reported that no scenario was run at AIG that considered a sharp drop in housing prices and its impact on collateral calls and write-downs.²⁷

²⁷ See Wall Street Journal Europe, November 3, 2008.

Box 1: Basics of Securitization and the Manufacturing of Triple-A Securities

Securitisation is a financing technique whereby a company, the *originator*, arranges for the issuance of securities whose cash flows are based on the revenues of a segregated pool of assets (e.g. corporate investment grade loans, leveraged loans, mortgages and other asset-backed securities (ABS) such as auto loans, credit card receivables, etc.).²⁸

Assets are originated by the originator(s), and funded on the originator's balance sheet. Once a suitably large portfolio of assets has been originated, the assets are analyzed as a portfolio, and then sold or assigned to a bankruptcy-remote company, i.e., a **Special Purpose Vehicle** company (or " **SPV**"), formed for the specific purpose of funding the assets.²⁹ The pool of loans is therefore taken *off* the originator's *balance sheet*. Alternatively, loans can be bought from other financial institutions.

The **SPV** issues tradable "securities" to fund the purchase of the assets. These securities are claims against the underlying pool of assets. The performance of these securities is directly linked to the performance of the assets – and, in principle, there is no recourse back to the originator.³⁰

Tranching is the process of creating notes of various seniorities and risk profiles, including senior and mezzanine tranches and an equity (first loss piece). As a result of the prioritization scheme used in the distribution of cash flows to the tranche holders, the most senior tranches are far safer than the average asset in the underlying pool. Senior tranches are insulated from default risk up to the point where credit losses deplete the more junior ones. Losses on the mortgage loan pool are first applied to the most junior tranche until the principal balance of that tranche is completely exhausted. Then, losses are allocated to most junior tranche remaining, and so on.

This ability of repackaging risks and creating “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

²⁸ The borrower may be unaware of this, as the lender normally continues to be the loan servicer.

²⁹ The SPVs are also known as SIVs (Special Investment Vehicules).

³⁰ In practice, it didn't work that way for subprime SIVs after the crisis developed. To preserve their reputation most banks sponsoring subprime SIVs took back the assets on their balance sheet.

(See also section 2.1.2). Figure 1 gives a graphical representation of the securitization process.

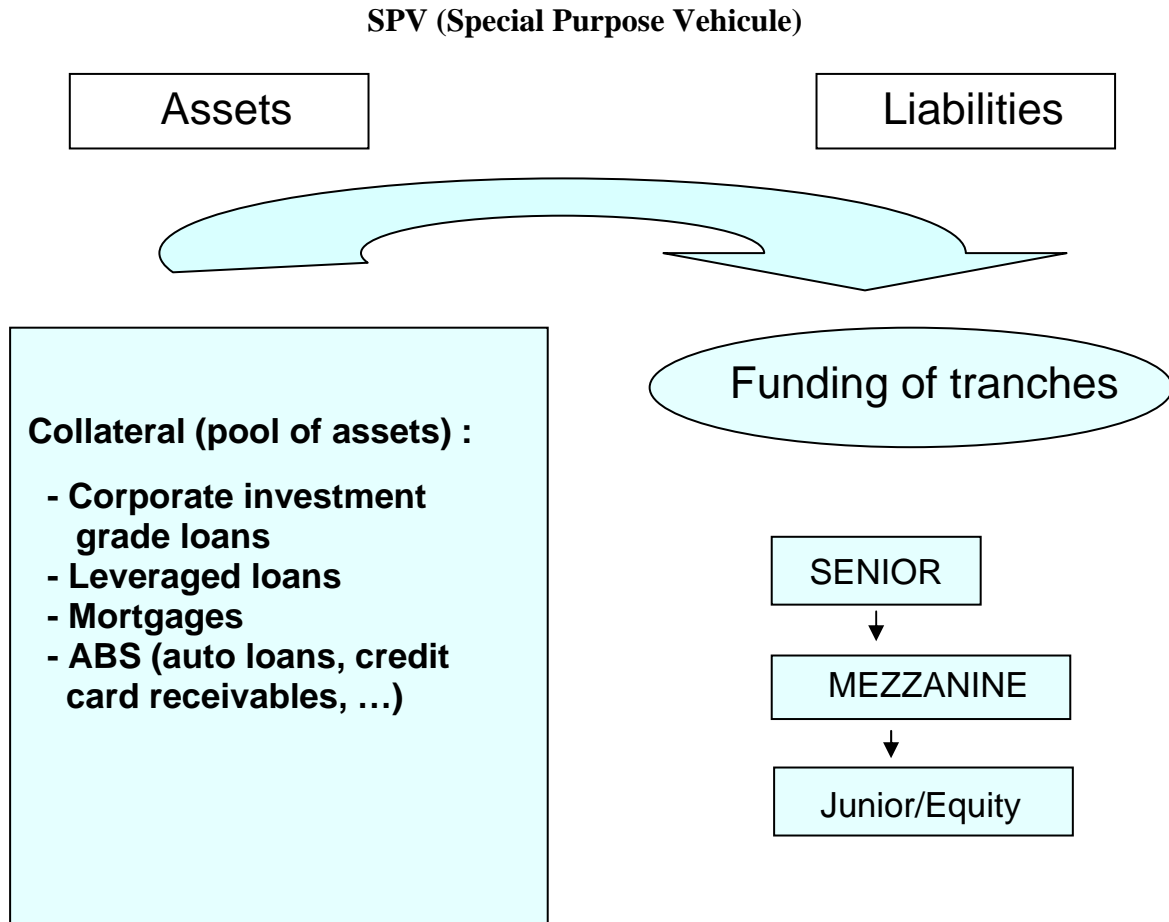


Figure 1: Securitization of financial assets

While CDO collateral pools can consist of various forms of debt, such as bonds, loans or synthetic exposures through CDS (credit default swaps), recent structures, such as subprime CDOs, have increasingly been based on other structured credit products such as tranches of mortgage-backed securities (MBS) or of other CDOs. Issuance of these so-called structured credit products increased dramatically since 2004. It represented 49% of the \$560 billion worth of issuance of CDOs during 2006 up from 40% in 2004.³¹

³¹ See Fender et al. (2008).

A typical subprime trust is composed of several thousand individual mortgages, typically around 3 to 5,000 mortgages for a total amount of approximately a billion dollars. The distribution of losses of the mortgage pool is tranching into different classes of residential mortgage-backed securities (RMBS) from the equity tranche, typically created through over-collateralization, to the most senior tranche, rated triple-A. A subprime CDO is a CDO-squared with a pool of assets composed of RMBS rated double-B to double-A, with an average rating of triple-B (Figure 2).³²

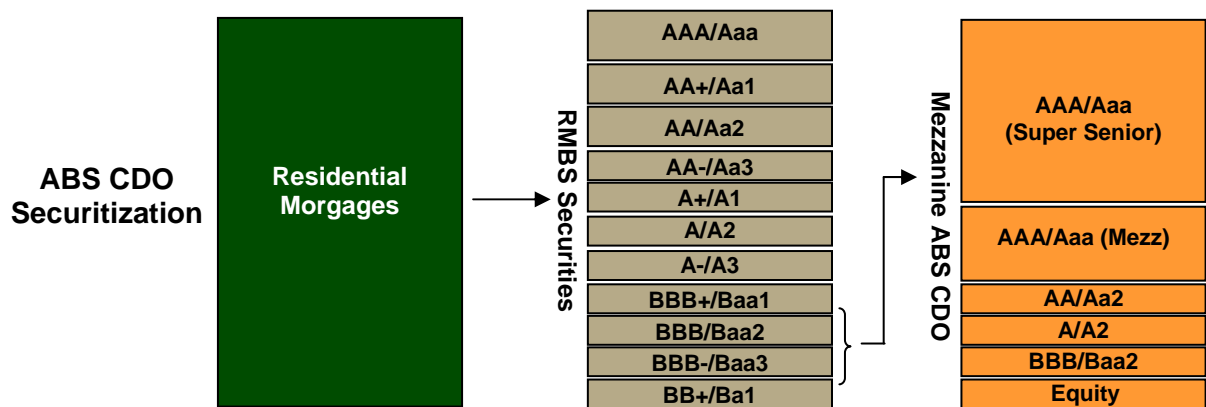


Figure 2: Securitization of asset-backed securities such as mortgages

In a typical subprime CDO approximately 75% of the tranches benefit from a triple-A rating. On average, the mezzanine part of the capital structure accounts for 20% of the securities issued by the SPV and is rated investment grade, the remaining 5% is the equity tranche (first loss) and stays unrated.

End of Box 1

³² As discussed earlier, there was a huge demand by institutional investors for triple-A rated senior and super-senior tranches of CDOs offering a higher yield than traditional securities, such as corporate and Treasury bonds, of equivalent ratings. Hedge funds were the main buyers of the equity tranches which were attractive to them even if there is a high probability for these tranches to be wiped out. The high interest rate paid on these tranches would still make up for the principal over time and pay a good return if defaults of the underlying assets in the pool occur late during the life of the CDO. Mezzanine tranches, with an average rating of triple-B, were harder to distribute so that banks securitized these tranches in new CDOs which are referred to as CDO-squareds.

References

- Ashcraft, A. B. and T. Schuermann, “Understanding the Securitization of Subprime Mortgage Credit”, Federal Reserve bank of New York, Working Paper, December 2007.
- Coval, J. D., J. Jurek and E. Stafford, “Economic Catastrophe Bonds”, Harvard Business School, Working Paper 07-102, 2007.
- Coval, J. D., J. Jurek and E. Stafford, “The Economics of Structured Finance”, Harvard Business School, Working Paper 09-060, 2008.
- Crouhy, M. G., D. Galai and R. Mark, The Essentials of Risk Management, McGraw-Hill, 2006.
- Crouhy, M. G., R. A. Jarrow and S. M. Turnbull, “The Subprime Crisis of 2007”, Journal of Derivatives 16(1), Fall 2008, pp. 81-110.
- Fender, I., N. Tarashev and H. Zhu, “Credit Fundamentals, Ratings and Value-at-Risk: CDOs versus Corporate Exposures”, BIS Quarterly Review, March 2008, pp. 87-101.
- Honohan, P., “Bank Failures: The Limitations of Risk Modelling”, Working Paper, 2008.
- Risk Magazine (288), “VaR Counts”, January 2008, pp. 68-71.
- Standard and Poor’s, “Structured Finance rating Transitions and Default Updates as of June 20 2008”, June 26, 2008.
- UBS, “Shareholder Report on UBS’ Write-Downs”, 2008