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Securitized Products, Financial Regulation, and Systemic Risk

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Abstract

It is widely believed that the practice of securitization is one of the causes that led to the 2007–08 financial crisis. In this paper, I show that securitized products such as collateralized debt obligations (CDO) are particularly vulnerable to systematic risk and tend to show higher tail risk. These characteristics, in turn, are closely associated with joint failures and systemic risk. In order to achieve greater stability of the financial system, it is important to prevent the recurrence of the collapse of specific markets as this may lead to the collapse of other components of the financial system. From this perspective, the financial regulations that should be applied to these problematic financial products and their relation to possible systemic risks are discussed.

JEL Classification: G01, G11, G28

Contents

1. INTRODUCTION

It is widely believed that the practice of securitization is one of the causes that led to the 2007–08 financial crisis.[1] Krugman (2007) summarizes the issue as follows: "in the later stages of the great 2000–2005 housing boom, banks were making a lot of dubious loans. For a while, the risks of subprime loans were masked by the housing bubble itself. Yet the banks making the loans weren't stupid: they passed the buck to other people. Subprime mortgages and other risky loans were securitized."[2] However, it turns out that the financial institutions that held a large amount of subprime-related securitized products recorded tremendous losses. As discussed in Diamond and Rajan (2009), it is surprising that these institutions held on to so many mortgage-backed securities (MBS) in their portfolios, given that the originators would have sensed the deterioration of the underlying quality of mortgages.

The financial statements of some banks revealed large holdings of these "toxic" securitized products. Citigroup disclosed that, at the end of September 2007, the total amount of their subprime-related direct exposures in securities and banking, which comprised net collateralized debt obligation (CDO) super-senior exposures and gross lending and structuring exposures amounted to US$54.6 billion. This amount decreased to US$19.6 billion one year later; at the end of March 2009, there was still US$10.2 billion in these investments. Although Citigroup claimed that much of its holdings were in "super-senior" tranches, its performance was far from expectations. UBS was another company that was heavily exposed to the risk of CDOs—which were mainly backed by subprime-related structured products—and recorded huge losses. According to the report of the Swiss Federal Banking Commission (2008), in 2007 and through the first half of 2008, UBS (including Dillon Read Capital Management) suffered high write-downs totaling approximately US$42.8 billion, out of which US$21.7 billion was a result of investments in super-senior CDOs. The bank's investment in these super-senior CDOs increased in the first half of 2007 and amounted to US$50 billion before the onset of the subprime crisis.

American International Group (AIG) was heavily exposed to underwriting credit default swaps (CDSs) on subprime-related CDOs. According to its published documents, at the end of March 2008, the AIG's exposure to the risk of super-senior CDS amounted to US$469.5 billion on a notional amount basis. The CDS contracts on multi-sector CDOs were transferred to a special purpose company called Maiden Lane III LLC, co-funded by the Federal Reserve Bank of New York, to restructure AIG's balance sheet.

Since the amounts of MBS held seemed to be too high to be purely inventory, Diamond and Rajan (2009) suspect that investment in MBS seemed to be part of a culture of excessive risk taking, possibly brought about by incentives for the top executives to compete with their rivals, flawed internal compensation and control systems, and/or short-term debt financing, or a combination of these. Under an incentive scheme based on short-term risk-adjusted performance, writing insurance on infrequent events (and thereby taking on what is termed "tail risk") and treating most of the insurance premium as income, instead of setting aside a significant fraction as a reserve for an eventual payout, is a very attractive option for asset managers. It is difficult to precisely estimate the tail risk, and therefore, it may not be possible to fully control the situation. Further, the so-called Greenspan Put may have encouraged banks to take on the risk of illiquidity.

In the context of the Asian economy, the subprime-related direct exposures of Asian financial institutions were substantially lower than those in the United States (US) or Europe. According to Kato (2008), Asia's exposure (excluding Japan) was estimated to be in the

[1] Nadauld and Sherlund (2009) provide some empirical evidence on this relationship.

[2] Krugman (2007).

range of US$20–30 billion as of spring 2008. He suggested that this limited exposure in Asia reflects “profitable domestic activities” that limit the “search for yield” elsewhere.

In this paper, I simulate the cash flow exercises of hypothetical MBS and CDOs and show that these securitized products are particularly vulnerable to systematic risk and tend to show higher tail risk. These characteristics, in turn, are closely associated with joint failures and systemic risk. In order to make the financial system more stable, it is important to prevent the recurrence of the collapse of specific markets, as this may result in the collapse of other components of the financial system. I discuss some of the financial regulations that should be applied to these problematic financial products and their relation to possible systemic risks.

The remainder of the paper is organized as follows. Section 2 provides a brief description on the development of the securitization and CDO markets. Section 3 uses simulation examples to illustrate the problematic aspects of the current securitization market, focusing on CDOs backed by asset-backed securities (ABS). Section 4 discusses the possibility of banning these problematic assets. Since the real issue lies in the systemic nature of the securitized products, Section 5 discusses the issue relating to macroprudential regulations. Section 6 presents the concluding remarks.

2. SECURITIZATION AND GROWTH OF CDO MARKETS

Securitization offers easier access to mortgage assets for institutional investors; direct holdings of home mortgage loans are difficult for them to procure because of uncertain credit quality of the loans and problems with servicing them. The pooling of assets achieves diversification as long as the assets are not perfectly correlated. By packaging together the mortgages from various areas, diversification would reduce the risks measured in terms of variance.

Furthermore, slicing the mortgage pool into different tranches according to credit quality makes them more acceptable to institutional investors: the riskiest claims against the mortgage pool could be sold to those who could tolerate high risk, while the safest AAA-rated portions could be held by more risk-averse investors. Because of the demand for AAA paper, the lower-quality securities that were issued against the initial package of mortgages were repackaged together with similar securities from other packages to create new AAA securities as portions of CDOs.

2.1 Securitization and CDO Structure

In the manner described above, structuring tranches with different levels of seniority reallocates risk across different securities. In the real world, as opposed to a Modigliani-Miller world characterized by perfect markets, there would be gains from tranching because of transaction costs, market incompleteness, and asymmetric information. As shown by DeMarzo (2005), a financial intermediary having superior information on his/her assets would like to sell the assets in a structured manner. When the number of assets is large and their returns are imperfectly correlated, the intermediary maximizes his/her revenue from the sale by pooling and tranching, as opposed to simply pooling or selling the assets individually. Tranching allows the intermediary to concentrate the default risk in one part of the capital structure, rendering a large share of the liabilities almost riskless; this, in turn, leads to a lower overall lemons discount that buyers demand.

Slicing through repeated securitizations of the original pools created very complicated structures of securities. The underlying difficulties in valuing these securities were not evident when the housing prices were rising and interest rates were low; these factors, in turn, kept the default rate unusually low. Once housing prices began to decline and the

default rates began to rise as a result, concerns over the pricing and true value and risk of these securities became apparent.

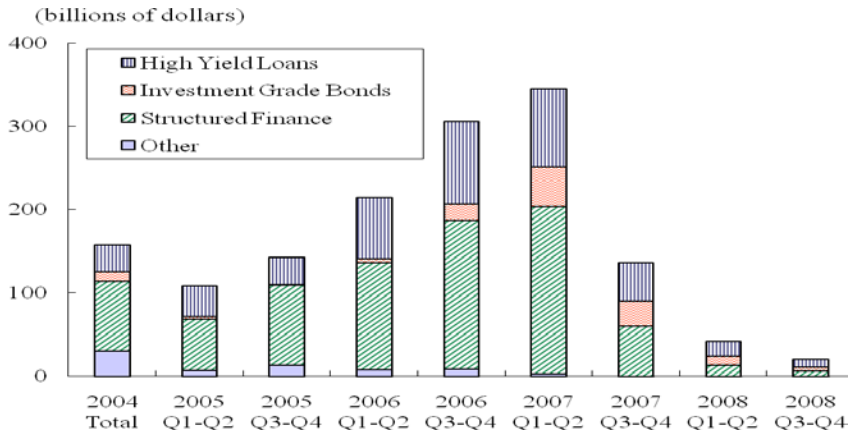
CDOs contain many underlying assets, and modeling the payoffs of these securities require sophisticated cash flow models. Investors rely heavily on credit ratings in their valuation. At the time, however, there was little public information on how these ratings were calculated and how ratings on CDO securities were related to the underlying collateral quality.[3]

2.2 Growth of CDO Markets and Ratings

CDOs are special-purpose vehicles that hold portfolios of assets and issue securities backed by the cash flows from those assets. The collateral assets bear credit risk and are legally sold to a special-purpose entity to ensure bankruptcy remoteness from the issuer. The first CDOs were created in the 1980s, but the growth of the CDO markets did not accelerate until the early 2000s and it peaked in the first half of 2007. CDOs were regarded as "one of the most important new financial innovations of the past decade" (Longstaff and Rajan 2008).

Figure 1 presents the summary data of the amount of CDO issuances by type of underlying assets. The total amount of issuances peaked in the first half of 2007; the heavily used underlying collateral comprised structured financial products that included assets such as residential mortgage-backed securities (RMBS), commercial mortgage-backed securities (CMBS), ABS, collateralized mortgage obligations (CMOs), CDOs, CDSs, and other securitized/structured products. Since mid-2008, issuances have almost ceased. Hereafter, the CDOs backed by ABS (such as subprime RMBS) are referred to as ABS CDOs; these are typically resecuritized products. Sometimes, CDO-squared were created by further securitization of CDOs.

Figure 1: Amount of Global Issuance of CDOs by Type of Underlying Assets



Note: Unfunded synthetic tranches are not included in the analysis.

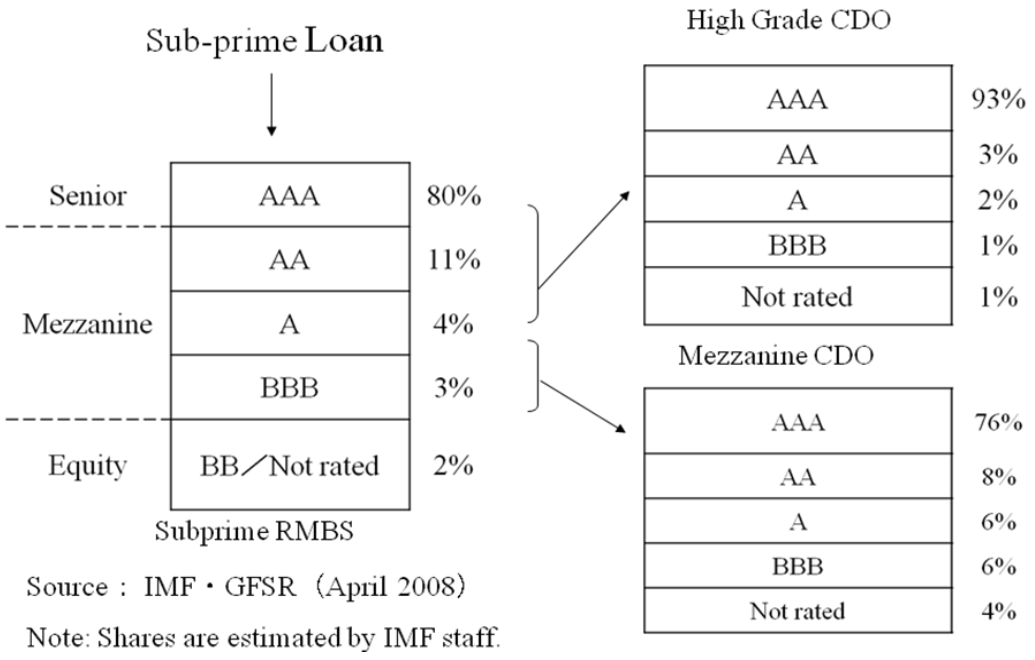
Source: Securities Industries and Financial Market Association.

The defining feature of CDOs is their multi-tiered liability structure. As shown in Figure 2, CDOs typically issue multiple classes of financial claims with differing levels of seniority, against a diversified pool of assets. As funds to make interest and principal payments are generated by the underlying collateral, proceeds are distributed to the CDO investors in a prespecified manner, in order of seniority. When assets in the collateral pool miss payments, or default, the subordinated tranches are the first ones to absorb the losses.

[3] See, for example, Securities and Exchange Commission (SEC 2008). BIS (2008a) also describes CDO markets from 2005 to 2007 in detail.

One important aspect of these structured financial product markets is the extent to which investor demand is driven by credit ratings.[4] A large fraction of the securities issued by CDOs were rated AAA: as shown in Figure 2, approximately 80% of the value of securities issued by CDOs was estimated to be rated AAA. In order to create a large share of safe securities from a pool of very risky assets, various tools of credit enhancements have been employed. These tools include overcollateralization and subordination, excess spread, and active management of the pool.

Figure 2: Securitization: An Illustration



Source: IMF (2008).

3. TOXIC ASSETS: WHAT WENT WRONG WITH ABS CDOS?

Although there is no exact data available about the ex-post loss rate by products at any moment in time, the International Monetary Fund (IMF) estimates suggest that, among the many structured and property-related assets, ABS CDOs exhibited the highest loss ratio, amounting to more than 70% of their par value (Table 1).[5] This was an average number for the outstanding total; the number for lower rated tranches (e.g., those rated below BBB) would probably be much higher. Usually, the lower rated tranches of these CDOs are regarded as "toxic"; however, since these products were so vulnerable to a change in the default rate in the underlying assets and other related conditions, even the most senior tranches were not really immune to systematic risks and should thus also be regarded as "toxic." Table 1 indicates that ABS CDOs are "toxic", even with higher ratings, under the stressed situations in housing markets.

[4] Benmelech and Dlugosz (2009) discussed the ratings of CDO and related issues, focusing on collateralized loan obligations (CLOs).

[5] IMF (2008).

Table 1: Estimates of Mark-to-Market Losses on Related Securities

(In billions of US dollars)

	Outstanding(A)	Estimated MTM loss(B)	(B) / (A)
ABS	1,100	210	19.1%
ABS CDOs	400	290	72.5%
Prime MBS	3,800	80	2.1%
CMBS	940	160	17.0%
Consumer ABS	650	0	0.0%
High-grade corporate debt	3,000	130	4.3%
High-yield corporate debt	600	80	13.3%
CLOs	350	30	8.6%
Total for securities	10,840	980	9.0%
Total for loans and securities	23,210	1,405	6.1%

Note: ABS = asset-backed security; CDO = collateralized debt obligation; CLO = collateralized loan obligation; CMBS = commercial mortgage-backed security; GSE = government-sponsored enterprise; MBS = mortgage-backed security; MTM= mark to market.

Source: IMF(2008).

The typical rating process for structured products involves two stages: In the first stage, an expected loss distribution for the underlying collateral pool is estimated; in the second stage, cash flow simulations are used to determine whether a tranche can withstand the necessary level of defaults to earn a given rating. In the calculation of cash flows of RMBS, many items indicating the quality of the underlying loans are incorporated. However, in estimating an expected loss distribution for ABS CDOs, the model basically depends on five key parameters: current ratings, maturity, location, industry, and type of the underlying structured products. Using this information, important data such as default rate, recovery, and asset correlation was worked out. Some simplified assumptions were also made about default correlation, and the Monte Carlo simulation was used to generate the distribution of portfolio cash flow losses.

To illustrate the causes that led to the collapse of subprime-related RMBS CDOs, I conduct a simulation exercise of cash flows and show the sensitivity of these flows to the various parameter values.

3.1 Analytical Framework and Simplified Assumptions: A Simulation Exercise

I construct a simple model of RMBSs and CDOs, both comprising three tiers: senior, mezzanine, and equity tranches. For simplicity, it is assumed that all tranches have a maturity period of five years. In the first stage, I collect 1,000 loans to create an RMBS. Underlying mortgages are assumed to be homogeneous with a prespecified default rate and recovery (loss given default, or LGD) in the event of default. Specifically, it is assumed that the annual default rate is 3% and the LGD is 50%; both are set to be constant over the period. Default correlation is given as a parameter, and in our base case scenario, 0.1 is assumed as the model value of asset correlation. In the second stage, 10 mezzanine tranches of RMBSs are pooled to create a new ABS CDO, which is also sliced into three tiers.

To obtain the loss distribution of the cash flows of the loan pool and tranches, a standard one-factor Gaussian copula model is used. The details are explained in the Appendix. In this specification, the loss distribution depends on the following parameters: default probability of underlying mortgages, asset correlation, and LGD. It should be noted that this exercise only shows the loss in terms of cash flows; the interactions between loan defaults and interest rate movements are abstracted because of a simplifying assumption on cash flows.

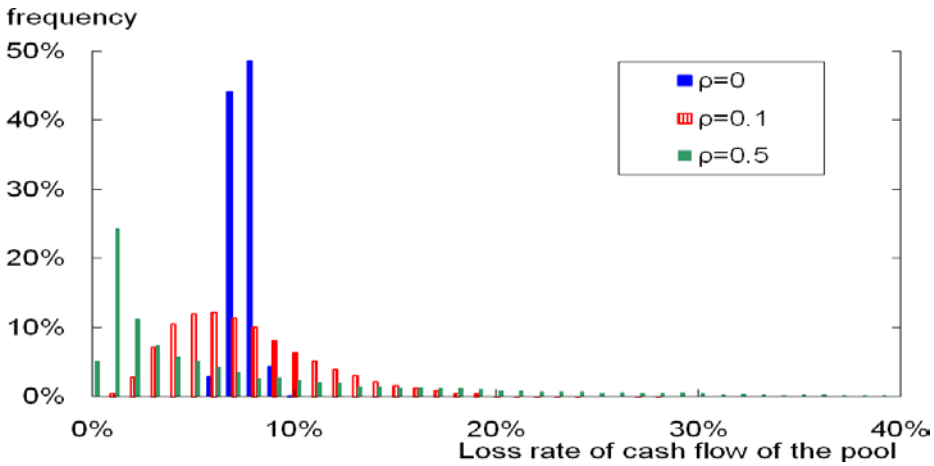
Tranching in RMBS is carried out so that the senior tranche has 1% of the expected chance of default and 10% of the principal is rated as equity. Thus, the remaining part is rated as the mezzanine tranche, which consists of approximately 10% of the total amount of the principal in the case of the first-stage RMBS, since approximately 80% of the principal is rated as a senior tranche according to the criteria described above. For our second-stage hypothetical CDO, 30% is rated as senior and 60% as mezzanine in our example.

3.2 Asset Correlation and Loss Distribution of the Pool

Given the above assumptions, Figure 3 illustrates the relationship between the loss distribution of our hypothetical loan pool and the correlation parameter of the underlying mortgages. If there is zero correlation, the expected rate of loss approaches the mean, which is 7% in the 5-year maturity in this model. However, if the pool assets have a higher positive correlation, the loss distributions tend to be skewed to the left with a heavier tail. It should be noted that in the CDO-like multi-tier structure, a rise in correlation implies more adverse effects on senior tranches rather than on subordinated tranches.

The overall risk of the financial system is based not only on the sum of the risks arising from within individual institutions but also on the degree of correlation among the institutions' balance sheets: the higher the correlation, the higher one would expect the systemic risk to be.

Figure 3: Default Correlation and the Accumulated Loss Distribution of the Pool (in%)



Note: Accumulated loss distributions are shown with different correlation parameter value (ρ) of 0, 0.1, 0.5, respectively.

Source: Author's calculations.

3.3 Larger Tail Risk and Higher Sensitivity to Macro Risk in ABS CDOs

In this model, cash flows are subject to two types of risk: idiosyncratic risk and economy-wide systematic risk.[6] When I simulate the cash flows of these hypothetical RMBS and

[6] In the one-factor Gaussian copula model, conditional independence is assumed.

resultant ABS CDOs, it is clearly shown that the tranches of the ABS CDOs are more vulnerable to systematic risk than those of RMBS. There are two reasons for this. First, the quality of the underlying assets is inferior in CDOs to those in first-stage RMBSs. Note that second-stage CDOs comprise mezzanine tranches of RMBS. Second, the size of each tranche decreases in comparison with the original size of the mortgage pool; securitization is repeated and this causes the losses in that tranche to be highly sensitive to a default of any one of the underlying mortgages. Numerical results show these characteristics more clearly.

Table 2 shows the simulation results represented by several risk measures of each tranche of our hypothetical RMBSs and ABS CDOs. In the case of a CDO comprising mezzanine tranches of RMBSs, even a senior tranche has a higher tail risk—the risk of the event is infrequent but very damaging—as shown in the large values of 99% value at risk (VaR) and 99% expected shortfall (ES).

Table 2: Simulation Results of Base Cases (in %)

	Chance of Default	Expected loss rate	Mode (loss rate)	99% VaR	99% ES
Loan Pool	100.0%	7.1%	6%	17.8%	19.5%
RMBS Senior	0.2%	0.0%	0%	0.0%	0.0%
RMBS Mezzanine	19.0%	5.4%	0%	77.5%	90.0%
RMBS Equity	100.0%	65.2%	100%	100.0%	100.0%
CDO Senior	1.3%	0.7%	0%	20.3%	63.3%
CDO Mezzanine	14.1%	5.8%	0%	100.0%	100.0%
CDO Equity	24.7%	17.4%	0%	100.0%	100.0%

Note: Numbers are based on 10,000 Monte Carlo simulations.

Source: Author's calculations.

3.4 Sensitivity Analysis for Changes of Parameter Values

In the simple model employed in this paper, the performance of our hypothetical RMBS and CDOs is highly dependent on the quality of the underlying housing loans, specifically, the probability of default and the correlation among them. The higher probability of default markedly amplifies the tail risk as shown in Table 3, in which the probability of default of the underlying loans is set to be 1.5 times higher than the base case, that is, 4.5% instead of 3%, annually. Similarly, Table 4 shows the simulation results of a higher correlation equal to 0.5, instead of 0.1 of the base case. I can confirm that the performance of senior tranches deteriorates greatly and there is a small positive impact on the equity tranche of RMBS if the assumed correlation increases.

Table 3: Sensitivity Analysis of Increased Probability of Underlying Mortgages Default

	Chance of default	Expected loss rate	Mode	99% VaR	99% ES
Loan Pool	0.0%	+3.3%	+2%	+5.6%	+6.2%
RMBS Senior	+3.1%	+0.1%	0%	+4.2%	+7.1%
RMBS Mezzanine	+28.1%	+13.7%	0%	+22.5%	+10.0%
RMBS Equity	0.0%	+18.1%	0%	±0.0%	+0.0%
CDO Senior	+7.7%	+5.1%	0%	+79.7%	+36.7%
CDO Mezzanine	+25.0%	+15.6%	0%	0.0%	0.0%
CDO Equity	+30.7%	+27.3%	0%	0.0%	0.0%

Note: Default probability of the underlying mortgages is assumed to be 4.5% annually, which is 1.5 times higher than that of the base case. Numbers show changes from the base case in percentage points, based on 10,000 Monte Carlo simulations.

Source: Author's calculations.

Table 4: Sensitivity Analysis of Increased Default Correlation

	Chance of default	Expected Loss	99% ES
Loan Pool	-5.2%	+0.1%	+23.7%
RMBS Senior	**+10.4%**	**+1.2%**	+28.9%
RMBS Mezzanine	+5.9%	+11.5%	+10.0%
RMBS Equity	**-5.2%**	**-20.0%**	0.0%
CDO Senior	**+12.6%**	**+11.4%**	**+36.7%**
CDO Mezzanine	+8.6%	+12.2%	0.0%
CDO Equity	+2.4%	+6.8%	0.0%

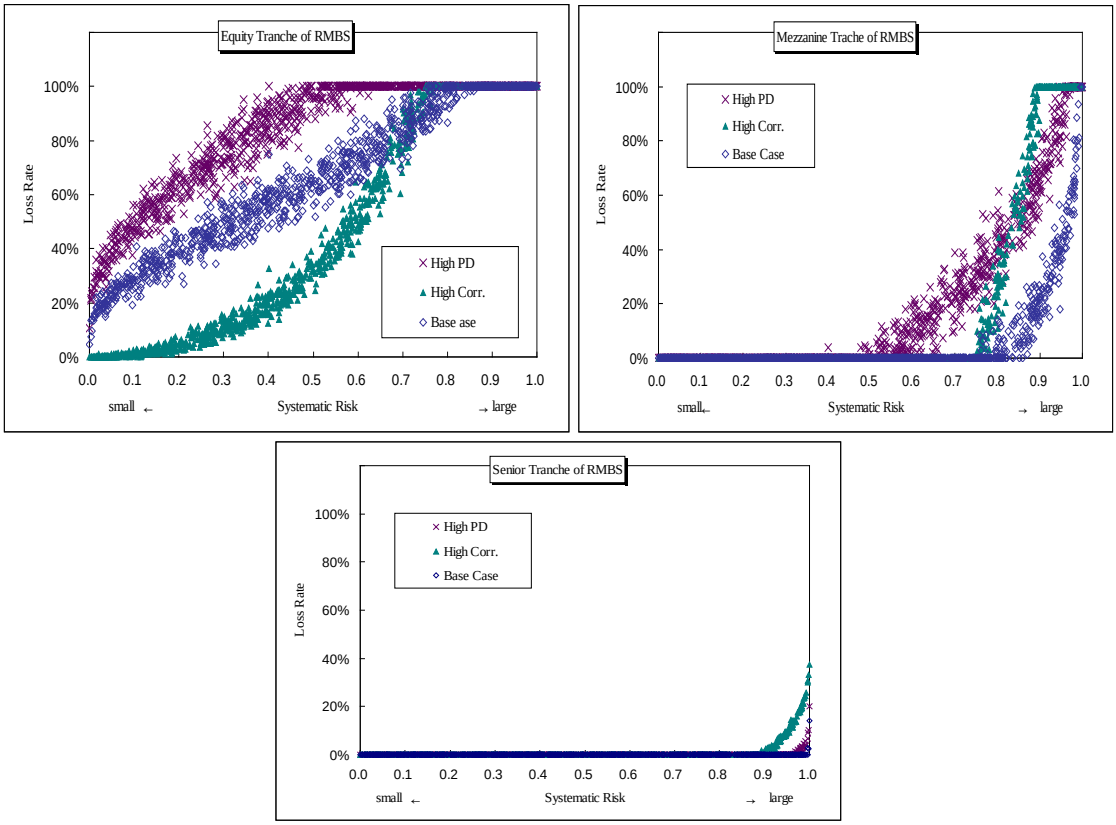
Note: Default correlation is assumed to be 0.5, which is higher than the base case value of 0.1. Numbers show changes from the base case in percentage points, based on 10,000 Monte Carlo simulations.

Source: Author's calculations.

It is also possible to have simulation results against various situations in economy-wide systematic risk which is modeled as a latent macrovariable. In the model, idiosyncratic risk is independent given a particular value of a systematic risk. By changing the size of the systematic risk, the sensitivity of the cash flows of securitized products to the latent macrovariable could be shown as a graph. The result suggests that each tranche of CDOs exhibits higher sensitivity to these changes than each tranche of RMBSs. Charts 4 and 5 illustrate a contrast of these differences in the properties of our hypothetical RMBS and ABS CDOs.

The charts clearly show that resecuritized products such as our hypothetical ABS CDO have higher sensitivity to macro common factors and this is also true for its senior tranches. A high probability of default significantly reduces the level of the risk of macrofactors at which the loss starts to increase sharply. Thus, once the subprime markets deteriorate and some other macroconditions affect them adversely, there should be a sharp rise in the losses in ABS CDOs. The simulation results suggest that this could lead to a collapse of the CDO market.

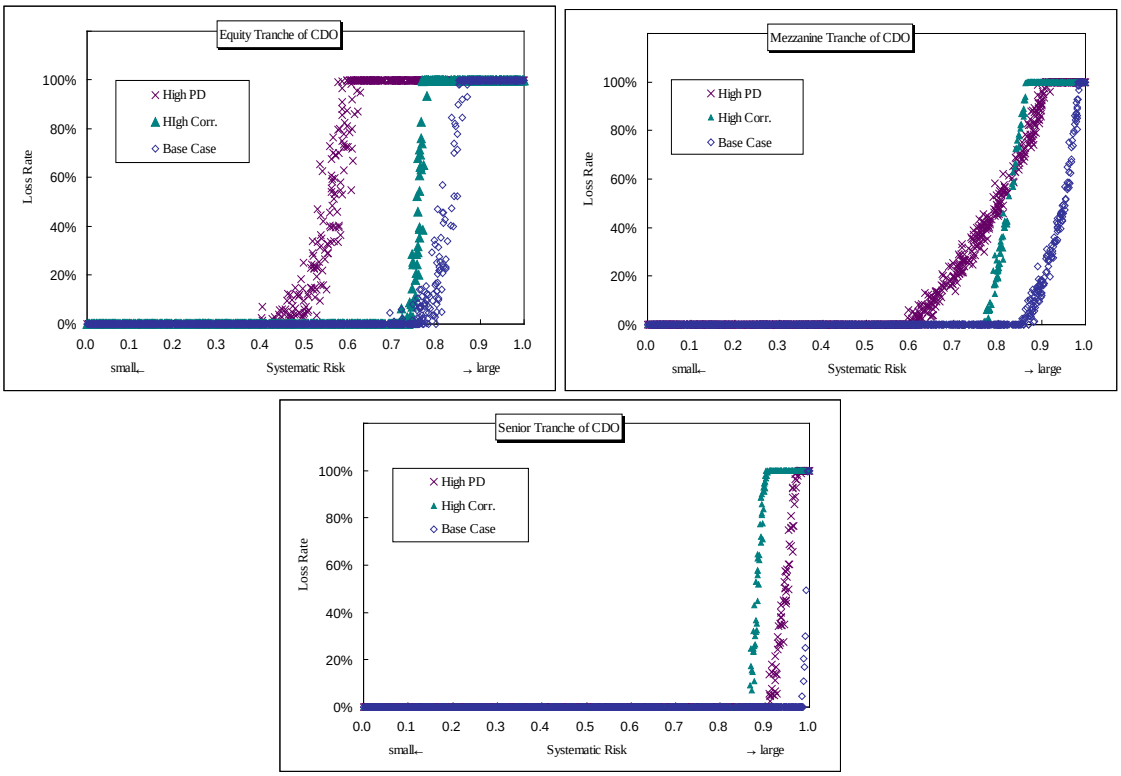
Figure 4: Changes in Systematic Risk: Case of RMBS



Note: Loss rates of RMBS are shown for the cases of higher default probability of underlying mortgages (high PD), and higher default correlation (high Corr.) with those of the base case. Numbers are based on 10,000 Monte Carlo simulations.

Source: Author's calculations.

Figure 5: Changes in Systematic Risk: Case of ABS CDO



Note: Loss rates of ABS CDO are shown for the cases of higher default probability of underlying mortgages (high PD), and higher default correlation (high Corr.) with those of the base case. Numbers are based on 10,000 Monte Carlo simulations.

Source: Author's calculations.

3.5 Collapse of CDO Markets

In the previous simulation examples, a latent variable representing systematic risk may correspond to the condition of the real estate markets or the level of interest rates that affect all mortgages simultaneously. In addition to this variable, a higher value of the default correlation among loans implies greater vulnerability of senior tranches, especially in ABS CDOs; there is a high probability of this characteristic of resecuritized products contributing to the collapse of the CDO market.

During the boom, several factors contributed to obfuscate the true risk of subprime-related CDOs. First, the housing boom and the Federal Reserve's interest rate policy lowered the default probability by providing opportunities to refinance with better terms, which also lowered the correlation among defaults. Second, the ratings of CDO tranches had been inflated on the basis of these data.

4. CDOS AND FINANCIAL REGULATIONS

The collapse of the CDO market was basically caused by the liability structure of resecuritization. In light of this, in February 2009, the Basel Committee on Banking Supervision at the Bank for International Settlements (BIS) decided to place a higher risk weight on these resecuritized products.[7]

[7] CDO structures, particularly their AAA tranches, are partly driven by investor demand, which is closely related to rating-dependent regulation. The relatively common view held is that an extensive use of credit ratings in the regulation of financial institutions created a natural clientele for CDO securities, especially for highly rated

However, resecuritization is only one of the reasons that triggered the 2007–08 financial crisis. The mechanism in which the collapse of one market spread rapidly to other markets and brought about a large-scale dislocation of financial markets, eventually leading to a systemic risk, should be discussed. Once the sources of systemic risk are identified, I have to create institutional mechanisms that enhance safety.

The US Treasury Department released its report on "Financial Regulatory Reform–A New Foundation: Rebuilding Financial Supervision and Regulation" in June 2009.[8] In its report, among others, they proposed strengthening the supervision and regulation of securitization markets through the following measures: (1) Federal banking agencies should promulgate regulations that require originators or sponsors to retain an economic interest in a material portion of the credit risk of securitized credit exposures. (2) Regulators should promulgate additional regulations to align the compensation of market participants with longer term performance of the underlying loans. (3) The Securities and Exchange Commission (SEC) should continue its efforts to increase the transparency and standardization of securitization markets and be given clear authority to require robust reporting by issuers of ABS. (4) The SEC should continue its efforts to strengthen the regulation of credit rating agencies, including through measures to promote robust policies and procedures that manage and disclose conflicts of interest, differentiate between structured and other products, and otherwise strengthen the integrity of the ratings process. (5) Regulators should reduce their use of credit ratings in regulations and supervisory practices, wherever possible. Although the details of the above proposals are not available, item (3) appears to be most relevant to our discussion.

4.1 Possibility of Product Regulation

Since the 1980s, financial innovations have been rapidly adopted and financial deregulation in the Organisation for Economic Co-operation and Development member countries, led by the US, has been advanced. In most cases, the implicit presumption was that these innovations improve welfare, with negligible downside risk exposure. The prolonged period of what was dubbed the "Great Moderation" further alleviated concerns about the downside risk associated with financial intermediation. This trend was particularly evident in the last several years until 2007, as is reflected in the remarkable decline in the market price of risk.

The moderation also reduced the demand for regulation.[9] Concerns about the inherent principal-agent/moral hazard associated with financial intermediation were arguably eliminated, and thereby, the potential role of the regulator seemed to have been minimized in order to enhance the efficiency gains in major financial centers.

Under these circumstances, financial product regulations have been lifted in most advanced economies, especially for financial products that are specifically designed for institutional investors. It is rather common for the products sold to so-called qualified investors to be exempted from general product regulations. It seems that, in the past two years, even institutional investors were involved in serious problems related to complex financial products; therefore, some people argue that new regulations may be needed for such complex products. If this is the case, the purpose of the regulation must be different from the traditional rationale: in fact, product regulations are originally stipulated for the purpose of protecting individual investors.

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securities. The reliance on the ratings in evaluating financial risks should be reviewed by both individual institutions and regulatory authorities.

[8] Furthermore, the following are proposed: All advisers to hedge funds whose assets under management exceed some modest threshold should be required to register with the SEC under the Investment Advisers Act of 1940. The advisers should be required to report specific information on the funds they manage; this information should be sufficient to assess whether any fund poses a threat to financial stability.

9 Aizenman (2009) provides theoretical analysis of the paradox of under- and over regulation.

In hindsight, regulating specific risky products by either placing a higher risk weight or placing them under a more direct regulation seems to be possible; however, in reality, it is not clear whether it is possible to regulate these products in advance because of their innovative nature.

Although the 2009 BIS annual report suggests the possibility of a registration and certification system of (newly introduced) financial products, the feasibility of such product regulation is highly doubtful. Past experiences of product regulation show that such regulation proved to be not only ineffective because of the circumventing activities of financial institutions, but also inefficient in that a significant amount of resources were used in checking and monitoring a variety of products.[10] Simply reversing the policy stances of the past 20 years could backfire as I may overshoot the needed adjustment, creating other distortions.

The problem herewith is not confined to one particular type of financial product; it also concerns the problems arising from common exposure to a particular risk and high sensitivity to some changes in macrovariables such as interest rates and housing prices. Thus, in the next subsection, I will discuss the issue from the perspective of macroprudential regulations.

4.2 Securitized Products and Systemic Risk: Extensive Reporting Requirements

To address the nature of systemic risk, the aggregation of risk information is critical. CDOs are largely sold in private markets, and thus, detailed data is not publicly available. The undisclosed positions of the so-called toxic assets negatively affect the counterparty risk of financial institutions. In stressed situations, ambiguity with regard to the trading volume and relevant market information deteriorates liquidity. This fear was especially prevalent in over-the-counter (OTC) trades.

Against the background described above, an approach that financial regulators can adopt is to collect information about financial products, especially new and rapidly growing products, and release aggregate figures. Extensive required reporting of the marketable outstanding, size of issuance, and positions should be considered. It could contribute to being cautious about the potential economy-wide risk that concerns regulators. As has already been proposed by some authorities, reporting requirements of the positions of large institutions is also useful. The challenge lies in specifying the relevant measures of appropriate reporting items.

Aggregate data provides the basis of judgment on the soundness of a particular market. The Japanese Financial Service Agency (FSA) has been releasing data on the total number of holdings of subprime-related assets by Japanese banks since November 2007.[11] This must contribute to the elimination of an unfounded fear concerning Japanese banks associated with subprime-related losses. Although some of major US banks began disclosing the positions of toxic assets, it was still unclear as to what extent US banks altogether were exposed to these assets and whether the scale of capital were sufficient for these exposures.

In addition to the common exposure to particular risks and vulnerability to macroeconomic risks, the existence of complex and opaque instruments—for example, the various structured products, including securitized subprime mortgages that were difficult to value and sell—could create systemic risks, as has already been discussed.

[10] For example, in Japan, there were extensive and tight regulations of financial products and other detailed decisions by commercial banks until the late 1990s; however, these regulations could not prevent the creation of a bubble.

[11] In November 2007, the data of the holdings of subprime-related assets by Japanese banks as of the end of September 2007 was released. Since then, this data has been released semiannually.

First, the structured products present the obvious problem that evaluations of their riskiness are unlikely to be reliable. When the valuation is imprecise, it complicates not only risk management within individual institutions, but also the already difficult task of evaluating common exposures. A concentrated position or a series of counterparty relationships poses the systemic risk of joint failures if market participants and regulators fail to understand and accurately value these financial instruments.

The second systemic risk posed by such instruments is their capacity to exacerbate procyclicality. Typically, booms are characterized by financial innovations. When things are going well, firms and individuals feel confident to experiment. They create new, untested instruments that are difficult to understand and value. Investors tend to be highly optimistic about future economic conditions during the boom without seriously considering the possible risks when markets deteriorate; further, sellers have little incentive to convince them otherwise. The result is that during a boom, flourishing financial innovation tends to create hidden, underpriced risks. However, as strains develop and the boom begins to wane, the previously unseen risks materialize, deepening the retrenchment that is already underway. Although financial innovation is a source of progress, it could become a source of procyclicality and systemic risk as well.

While the second issue was difficult to address by financial regulations, the first issue arising from the opaqueness of valuation may be improved by regulations on rating agencies and voluntary actions on the part of industry. For example, the data on CDS transactions became more extensively available after November 2008 through the Depository Trust & Clearing Corporation (DTCC) system, which could reduce counterparty risk involved in these transactions.

4.3 Policy Implications for Asia

From the perspective of the benefits originally associated with securitization, it is important to develop the markets for securitization in emerging markets. With respect to securitization, I need to learn the following lessons from the 2007–08 financial crisis. First, underlying assets should have appropriate credit quality with sufficient historical records of defaults, their relationship to macroeconomic variables, and other relevant information. Second, complicated structures should be avoided since they lead to more opaqueness, vulnerability to macro shocks, and therefore, ambiguity in pricing. The original idea of securitization is simple: risk reduction through diversification. To the extent that large enough amounts of underlying assets are pooled, additional gain obtained from resecuritization must be limited.[12] Slicing into too many tranches is also problematic; it makes the exact pricing of each tranche more difficult and more vulnerable to a deterioration in the credit quality of the underlying assets.

To reap the benefits of securitization while minimizing risks, the Shadow Financial Regulatory Committee of Asia, Australia-New Zealand, Europe, Japan, Latin America, and the US proposed that the system implemented in Denmark, which is a “partially asset backed” model, be followed. In the securitization system implemented in Denmark, leverage is effectively limited by capital requirements since loans must remain on the banks’ balance sheets. Covered bonds are similar types of securitization and are popular in Europe.[13] These bonds are characterized by essential features that are achieved under special-law based frameworks or general-law based frameworks with regard to the issuers’ status and obligations.

In order to promote the standardization and ensure the transparency in securitization in emerging markets, it may be necessary to discuss the issue at a practical level. In Europe,

[12] See Fujii and Takemoto (2009).

[13] Covered bonds are debt instruments secured by a cover pool of mortgage loans to which investors have a preferential claim in the event of default. Legal requirements specify the safe nature of covered bonds.

the Directive on Undertakings for Collective Investments in Transferable Securities (UCITS) plays an essential role. In Asia, in order to introduce a standardized securitization framework, I must have a mechanism to deepen the understanding of each market and discuss the future course of common factors in the basic legal framework for securitization.

With regard to the financial product regulations for retail investors, I can safeguard these investors from the risk posed by a complex structure of securitization by applying more general principles of financial regulations, such as suitability and disclosure. According to the BIS report (2008b), the suitability principle is well recognized in regulatory requirements; however, there are differences in its application by sector, and probably greater differences by country, which partly stem from the fact that not all supervisors have consumer protection mandates. If the authority wishes to avoid the problems arising from overly complex products, the basic principles such as disclosure and suitability must at least aim for protecting retail investors.

As discussed in the previous section, the financial debacles of 2007–08 were more closely associated with "sophisticated investors" and systemic risk. In this regard, the same prescriptions are applicable: timely disclosure of aggregated risk information should be prioritized.

5. NEED FOR MACROPRUDENTIAL REGULATIONS ON FINANCIAL INSTITUTIONS

The global nature of the 2007–08 financial crisis highlighted the need for macroprudential regulations. Traditional prudential regulation concerns the factors that affect the stability of individual institutions, while the newly emphasized aspect of prudential regulation—macroprudential regulation—concerns the factors that affect the stability of the entire financial system.

One need for implementing macroprudential regulations is that the presumption that regulators can safeguard the entire system by securing individual institutions is not necessarily true, as indicated by the 2007–08 crisis. Another observation is that excessive risk taking was suspected from rising leverage levels despite the fact that the risk-weighted capital ratios were maintained at the required regulatory level.

Financial problems that primarily stem from the temporary liquidity issue could lead to solvency issues. The general understanding regarding "insolvent" financial institutions is that the going concern value of such institutions does not exceed the expected value of their liabilities. Under a stressed market condition, liquidity issues affect valuation and, sometimes, liquidity is highly related to the solvency of particular institutions. This is especially true if the concerned institution is highly leveraged.

I am also reminded of the lessons learnt from the 1998 experience of Long-Term Capital Management. When one institution holds a sufficiently large position, it can create common exposures that put the system at risk, and when transactions occur bilaterally, as they do in OTC markets, the failure of one individual or institution can, through linkages across firms and markets, generate joint failures.[14]

Proposals to mitigate the risks arising from common exposures focus on the implementation of a systemic capital charge (SCC). Implementing such a scheme requires a measure of systemic risk and an understanding of the marginal contribution of each institution to the overall system. As discussed by Brunnermeier et al. (2009), the nature of the regulation applied to an individual financial institution crucially depends on how "systemic" its activities

[14] Procyclicality—which implies that over time, the dynamics of the financial system and of the real economy reinforce each other, thus increasing the amplitude of booms and busts and undermining stability in both the financial sector and the real economy—is another key issue of the macroprudential policy.

are, with regard to its size and degree of leverage, and the interconnectedness to the rest of the system. One way to mitigate the possibility of systemic risk is for bigger or more interconnected players hold more capital and have lower leverage; this is in effect, taxing size to create a level playing field from a system-wide perspective. Again, the challenge lies in choosing the appropriate measures of effective size or interconnectedness.

All these concerns justify introducing some form of regulation for financial leverage, one measure of which would be the non-risk-based measures suggested in the G-20 statements issued in April 2009. In this regard, it should be emphasized that a change in leverage appears to be a more relevant indicator than the level of the leverage itself, since the latter differs significantly according to the business models of the different types of financial activities (Table 5). A well-designed approach should be adopted toward the dynamic change in leverage. Failed, merged, or supported institutions, such as Bear Sterns, Lehman Brothers, Merrill Lynch, Citigroup, and UBS, have shown significant increases in their gross leverage ratio. Although this measure by itself is obviously not enough to monitor the soundness of financial activities of each institution, it apparently provides some additional information about the risk profile of the financial institutions.

In a complicated financial system, it is unrealistic to expect that only one specific measure such as risk-weighted capital ratio could detect any risk of financial fragility. I definitely need a mix of several measures focusing on the soundness of the system to cover all types of financial institutions. Table 5 suggests the possibility of an additional complementary measure to gauge the riskiness of the institutions although further research is required to estimate the appropriateness and feasibility of its implementation.

Table 5: Non-risk Based (Gross) Leverage Ratio

(at the end of)	2005	2006	2007	Change from 2005 to 07 (percentage points)
Bear Sterns	26.6	27.1	33.5	6.9
Goldman Sachs	25.2	23.4	26.2	1.0
JP Morgan Chase	11.2	11.7	12.7	1.5
Lehman Brothers	24.4	26.2	30.7	6.3
Merrill Lynch	19.1	21.6	31.9	12.8
Morgan Stanley	30.8	31.7	33.4	2.6
Bank of America	12.7	11.2	11.7	-1.0
Citigroup	13.3	15.7	19.3	6.0
Wachovia	10.9	10.1	10.2	-0.7
Wells Fargo	11.8	10.5	12.1	0.3
UBS	46.8	47.2	63.9	17.1

Note: Leverage ratio equals total assets divided by total shareholders' equity.

Source: Financial statements and annual reports of each institution. Assets and equity data are at the end of annual period which is either end-December or end-November of each year, and ratios are the author's calculations.

A macroprudential policy generally refers to the policy tools that are confined to financial regulations and that do not include monetary policy. Specifically, tools control the capital adequacy ratio, growth of loan extensions, and restrictions on an institution's portfolio. For a national economy, credit growth may be constrained against the historical averages, and/or relative to the gross domestic product (GDP). In this regard, the figures to measure the aggregate leverage of the total domestic banks should be carefully monitored for detecting the signs of a systemic crisis.

An example is shown in Table 6 that is compiled from the Irish macroeconomic data. In Ireland, as Table 6 shows, the leverage ratios of the aggregated major banking sector increased from 11.9 in 2000 to 21.6 in 2008 as the boom accelerated. The ratio of the major banks' total assets to nominal GDP also rose from 1.8 times to 5.35 times between 2000 and 2008. Since the current Irish financial crisis was basically brought about by the classical bust of the property bubble and not by a new innovative product such as CDOs, this type of

leverage figures may be useful to check the typical bubble-bust type of crisis. It is not clear whether this could be applied to the US case where the types of financial institutions are more diverse.

Table 6: Irish Major Banks: Assets and Liabilities

(in billions of Euro)

	December 2008	(as % of the total)	December 2000	(as % of the total)
Capital and reserves	46		16	
deposits from credit institutions and other MFIs(excluding Central Bank)	456	45.8%	63	33.5%
deposits from other residents	221	22.2%	86	45.5%
debt securities issued	109	11.0%	5	2.8%
total liabilities(including other items)	996	100.0%	189	100.0%
loans to credit institutions and other MFIs	288	28.9%	52	27.7%
loans to other residents	504	50.6%	105	55.4%
term/revolving loans	186	18.7%	39	20.9%
residential mortgages	115	11.6%	30	15.7%
holdings of securities	132	13.2%	14	7.3%
total assets(including other items)	996	100.0%	189	100.0%
Leverage*	21.6		11.9	
nominal GDP	186		105	
Total Assets to nominal GDP ratio*	5.35		1.80	

Note: MFIs are monetary financial institutions whose business is to receive deposits and/or close substitutes for deposits from entities other than MFIs, and, for their own account, to grant credits and/or make investments in securities.

*Ratios are author's calculations.

Source: Central Bank & Financial Services Authority of Ireland. (2009).

It is important to note that one of the most pressing tasks is the proper consolidation of the balance sheets of financial institutions. The 2007–08 financial crisis clearly exposed the risks created by the shadow banking system that was spun off by regulated institutions. Therefore, the first order of business in improving capital management is to bring all of these entities, including structural investment vehicles and the like, within the regulatory framework to ensure that appropriate capital is held against all obligations of the financial institutions. This will provide a more accurate picture of an institution's exposures.

6. CONCLUDING REMARKS

A healthy financial system is a precondition for sustained recovery. Ensuring financial stability requires the redesigning of financial sector policies. For regulatory and supervisory policies, it is necessary to adopt a macroprudential perspective to mitigate systemic risks.

The systemic risks are inherent to the financial systems, specifically, financial products, financial institutions, and markets. Regulators must pay attention to various aspects of the financial system, and act to identify, measure, and mitigate problems to guard against future crises. In this regard, reporting requirements should cover not only financial products but

also institutions, funds, and others. Addressing risk in only one area will not ensure the safety of the others. Therefore, direct regulations such as product regulation may not be sufficient and effective. Extensive reporting requirements, especially from those systematically important institutions, should be urgently introduced with close consultation between the regulatory authorities and these financial institutions.

It is worth considering the introduction of complementary measures in addition to the BIS risk-based capital adequacy ratio. Leverage ratios of individual institutions and similar measures at a national level may serve to detect a sign of boom and thus that of the accompanying systemic risk.

For Asian financial authorities, it is important to learn from the risk-management and regulatory failures in the US and Europe. The introduction of Basel II in several Asian countries will enhance the financial resilience to some extent, and furthermore, tools corresponding to macroprudential concerns could be used to reinforce financial stability.

REFERENCES

Aizenman, J. 2009. Financial Crisis and the Paradox of Under-and Over-Regulation. *NBER Working Paper 15018*. Cambridge, MA: National Bureau of Economic Research (NBER).

BIS, Basel Committee on Banking Supervision, the Joint Forum. 2008a. *Credit Risk Transfer: Developments from 2005 to 2007.*Basel, Switzerland: BIS.

———. 2008b. Customer suitability in the retail sale of financial products and services. Basel, Switzerland: BIS.

Benmelech, E., and J. Dlugosz. 2009. The Alchemy of CDO Credit Ratings. NBER Working Paper 14878. Cambridge, MA: NBER.

Brunnermeier, M., A. Crockett, C. Goodhart, A. D. Persaud, and H. Shin. 2009. *The Fundamental Principles of Financial Regulation, Preliminary Conference Draft, Geneva Reports on the World Economy 11*. Geneva, Switzerland: International Center for Monetary and Banking Studies and Centre for Economic Policy Research.

Central Bank & Financial Services Authority of Ireland. 2009. *Quarterly Bulletin* 02 (April).

DeMarzo, P. 2005. The pooling and tranching of securities: A model of informed intermediation. *Review of Financial Studies* 18(1): 1–35.

Diamond, D., and R. Rajan. 2009. The Credit Crisis: Conjectures about Causes and Remedies. NBER Working Papers 14739*.* Cambridge, MA: NBER.

Fujii, M., and R. Takemoto. 2009. Securitization and Financial Crisis: Risk Characteristics and Assessment of ABS CDO (in Japanese, Shokenka to Kinnyukiki: ABS CDO no risuku tokusei to sono hyouka). *FSA Research Review* 5: 215–245.

Group of Twenty (G-20). 2009. Declaration on Delivering Resources Through the International Financial Institutions. London, 2 April. Available:http://www.g20.org/Documents/Fin_Deps_IFI_Annex_Draft_02_04_09_-_1615_Clean.pdf

IMF. 2008*. Global Financial Stability Report*, *October*. Washington, DC:, IMF.

Kato, T. 2008. The Financial Crisis and Economic Outlook – Lessons for Securing the Benefits of Financial Deepening, Keynote address at the 43rd SEACEN Governors' Conference, Jakarta, 21 March.

Krugman, P. 2007. Just Say AAA. *New York Times*.2 July.

Li, D. X. 2000. On Default Correlation: A Copula Function Approach. *The Journal of Fixed Income* 9: 43–54.

Longstaff, F., and A. Rajan. 2008. An empirical Analysis of the pricing of Collateralized Debt Obligations. *Journal of Finance* LXIII (2): 529–563.

Nadauld, T., and S. Sherlund. 2009. The Role of Securitization Process in the Expansion of Subprime Credit. Fisher College of Business Working Paper Series, 2009-9. Columbus, OH: The Ohio State University.

SEC. 2008. Summary Report of Issues Identified in the Commission Staff's Examinations of Select Credit Rating Agencies. July. Available: http://www.sec.gov/news/studies/2008/craexamination070808.pdf

Swiss Federal Banking Commission. 2008. Subprime Crisis: SFBC Investigation Into the Causes of the Write-downs of UBS AG, September. Available: http://www.finma.ch/archiv/ebk/e/publik/medienmit/20081016/ubs-subprime-bericht-ebk-e.pdf

APPENDIX: THE MODEL FOR SIMULATIONS[15]

A1: Structure of CDOs: Seniority and Resecuritization

CDOs are special purpose vehicles that hold portfolios of assets and issues securities backed by the cash flows from these assets. Since the early 2000s, CDO markets have been growing rapidly. As subprime loans were securitized actively, the number of CDOs that had a portfolio of these subprime RMBSs significantly increased.

Both ABSs and CDOs have multi-tiered liability structures. I created a hypothetical RMBS by collecting 1,000 mortgages and sliced them into three tranches: senior, mezzanine, and equity. A new CDO was created by constructing a portfolio of 10 RMBS mezzanine tranches. This CDO cash flow should be distributed according to the prespecified seniority of senior, mezzanine, and equity tranches.

A2: Outline of the Model

Let $L_i(t)$ be the amount of loss incurred by loan i at time t; A_i, the amount of the principal of loan i; LGD_i, the loss given the default of loan i; and τ_i, the timing of default of loan i. Then, $L_i(t)$ is written as follows:

$$L_i(t) = A_i \times LGD_i \times \iota_{\{\tau_i \le t\}} \qquad (1)$$

where ι is an index function that takes the value of 1 if t is later than the time of default τ, and 0 otherwise. For simplicity, no prepayments are considered. The total loss L of the loan pool that consists of N loans is

$$L(t) = \sum_{i=1}^{N} L_i(t) = \sum_{i=1}^{N} A_i \times LGD_i \times \iota_{\{\tau_i \le t\}}. \qquad (2)$$

In order to obtain a loss distribution from equation (2), given the information of A_i, it is necessary to make specific assumptions on LGD_i and τ_i. In general, loan defaults are dependent not only on the idiosyncratic risks of each debtor but also on the macroeconomy. Thus, loan defaults are mutually dependent and it is necessary to know the joint distribution of the timing of the defaults of all loans, $G(\tau_1, \cdots, \tau_N)$.

Let $G_i(\tau_i)$ be a marginal distribution of τ_i, and I assume the one-factor Gaussian copula model. That is, if a common factor V is given, then the default timing of each individual loan $\tau_1, \cdots, \tau_N$, where $i (i = 1, \cdots, N)$ is assumed to be independent. Under this assumption, the marginal distribution, $G_i(\tau_i | V)$, is written as follows;

$$G(\tau_1, \cdots, \tau_N | V) = \prod_{i=1}^{N} G_i(\tau_i | V) \qquad (3)$$

With this assumption, once I know $G_i(\tau_i | V)$, then I can obtain the joint distribution of losses of the entire pool. It is noted that the joint distribution of the default timing, $G(\tau_1, \cdots, \tau_N | V)$ can be obtained as an integral of a common factor V with their distribution function G_V. That is,

[15]The simulation shown in this appendix is based on Fujii and Takemoto (2009) in which more details are explained.

$$G(\tau_1,\cdots,\tau_N)=\int_{-\infty}^{\infty} G(\tau_1,\cdots,\tau_N\,|V=v)dG_V(v)$$

$$=\int_{-\infty}^{\infty}\prod_{i=1}^{N} G_i(\tau_i\,|V=v)dG_V(v). \qquad (4)$$

To specify the marginal distribution of each loan, I introduce the latent variable X_i, which follows standard normal distribution, and assume the following for τ_i:

$$\tau_i = G_i^{-1}(\Phi(X_i))$$

where Φ represents a distribution function of standard normal distribution. Given a common factor V, if $X_1,\cdots,X_N$ are conditionally independent, then $\tau_1,\cdots,\tau_N$ are also conditionally independent. I model X_i as shown in equation (5):

$$X_i=\sqrt{\rho_i}V+\sqrt{1-\rho_i}\varepsilon_i \quad (i=1,\cdots,N) \qquad (5)$$

where a common factor V is assumed to follow the standard normal distribution and an idiosyncratic risk factor ε_i, which is independent of V, is assumed to follow the standard normal distribution[16].

Parameter $\rho_i\in[0,1]$ represents a correlation among the latent variables X_is[17]. Since the variable X_i determines the default timing, it could be interpreted as implying the debtor i's asset value and ρ_i is often referred to asset correlation. It should be noted that the correlation between the latent variables （$Corr(X_i,X_j)$）has a one-to-one correspondence with the correlation of the default timing ($Corr(\tau_i,\tau_j)$）; however, the values are not the same.

For $G_i(\tau_i\,|V)$, I put [18]

$$G_i(\tau_i\,|V=v)=Prob\{X_i\le\Phi^{-1}(G_i(\tau_i))\,|V=v\}$$

$$=Prob\left\{\varepsilon_i\le\frac{\Phi^{-1}(G_i(\tau_i))-\sqrt{\rho_i}v}{\sqrt{1-\rho_i}}\right\}$$

$$=\Phi\left(\frac{\Phi^{-1}(G_i(\tau_i))-\sqrt{\rho_i}v}{\sqrt{1-\rho_i}}\right). \qquad (6)$$

In the model described above, the following three assumptions determine the loss distribution of the pool: i) loss given the default of each loan i : $LGD_i(i=1,\cdots,N)$, ii) marginal distribution of the default timing of each loan: $G_i(\cdot)(i=1,\cdots,N)$, iii) correlation parameter among the default timing of each loan : $\rho_i(i=1,\cdots,N)$. Hereafter ρ_i is referred to

[16] $G_i(\tau_i)$ follows uniform distribution of $[0,1]$; therefore, $X_i=\Phi^{-1}(G_i(\tau_i))$ follows standard normal distribution.

[17] $Corr(X_i,X_j)=\sqrt{\rho_i\rho_j}$; thus, once I assume a specific value of ρ , I have $Corr(X_i,X_j)=\rho$. Sometimes, by writing $\rho_i=a_i^2$, $X_i=a_iV+\sqrt{1-a_i^2}\varepsilon_i$ is modeled. If this is the case, for example, if ρ_i is equal to 0.1, then a_i is equal to approximately 0.3.

[18] Plugging equation (6) into equation (4); as a result, the distribution of the default timing becomes Gaussian copula（Li. 2000）.

"default correlation" and, for simplicity, it is assumed to be the same for all loans regardless of i.

A3: Loss Calculations of RMBSs and CDOs

Cash flows arising from the underlying assets are distributed according to the prespecified seniority. In our simulation example, $N = 1{,}000$ is assumed and these loans are assumed to be homogeneous. For simplicity of calculation, a coupon is set to be 0. In tranching, the senior tranche is defined as a tranche that has 1% chance of default. 10% of the principal is set aside as equity tranche, and thus, the remaining part is rated as mezzanine. The Monte Carlo simulation is conducted 10,000 times, and the multiply-with-carry algorithm is used for quasi-random sampling.

The loss distribution is plotted at the timing of maturity, which is 5 years. In the case of the first-stage RMBS, the 99% point of cumulative density coincides with the loss rate of 20%; therefore, approximately 80% of the principal could be rated as AAA through this seniority structure. In the second-stage securitization for creating a CDO, 10 mezzanine tranches of RMBSs are pooled. This time, the 99% point of cumulative density coincides with the loss rate of 70%; therefore, approximately 30% of the principal could be rated as AAA through this seniority structure. As a result, 60% of the CDO principal is rated as mezzanine under the assumption that 10% of the principal is set aside as equity portion.