Innovations in Credit Risk Transfer: Implications for Financial Stability[1]

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Banks and other lenders often transfer credit risk in order to liberate capital for further loan intermediation. Beyond selling loans outright, lenders are increasingly active in the markets for syndicated loans, collateralized loan obligations (CLOs), credit default swaps, credit derivative product companies, "specialty finance companies," and other financial innovations designed for credit risk transfer. My purpose here is to explore the design, prevalence, and effectiveness of credit risk transfer. My focus will be the costs and benefits for the efficiency and stability of the financial system.

In addition to allowing lenders to conserve costly capital, credit risk transfer can improve financial stability by smoothing out the risks among many investors.

[1]I am grateful for motivation from Claudio Borio and for initial conversations with Richard Cantor, Mark Carey, Larry Forest, Michael Gordy, Serena Ng, David Rowe, and Kevin Thompson. I am especially grateful for research assistance by Cliff Gray and Andreas Eckner, and for technical assistance from Linda Bethel and Nicole Goh. I have benefited from comments, many of which remain to be reflected in a future draft, by Tobias Adrian, Scott Aguais, Adam Ashcraft, Jesper Berg, Claudio Borio, Eduardo Canabarro, Richard Cantor, Mark Carey, Moorad Choudhry, David Evans, Larry Forest, Michael Gordy, Jens Hilscher, Myron Kwast, Joseph Langsam, Sergei Linnik, Alexandre Lowenkron, Joseph Masri, Matthew Pritsker, Til Schuermann, Hisayoshi Shindo, David Shorthouse, Roger Stein, Kevin Thompson, and Anthony Vaz. I have also benefited exceptionally by discussions provided by Kenneth Froot and Mohammed El-Erian at the Sixth Annual Conference of the Bank of International Settlements at Brunnen in June, 2007, as well as from comments by others at this conference and at the Financial Advisory Roundtable of the New York Federal Reserve. Duffie is also with The National Bureau of Economic Research.

For example, a bank can substitute large potential exposures to direct borrowers with smaller and more diversified exposures.[2] Even if the total risk to be borne were to remain within the banking system, credit risk transfer allows banks to hold less risk, because of diversification. In practice, some risk is transferred out of the banking system, for example to institutional investors, hedge funds, and equity investors in specialty finance companies, all of whom are not as critical as banks for the provision of liquidity.

If credit risk transfer leads to more efficient use of lender capital, then the cost of credit is lowered, presumably leading to general macroeconomic benefits such as greater long-run economic growth. Cebenoyan and Strahan [2004] find that banks that manage their credit risk by both buying and selling loans on the secondary market have a ratio of capital to risky assets that is about 7% or 8% lower than that of banks that do not participate in this market. Further, they conclude, banks that "appear to rebalance their risk through both purchase and sale have capital ratios about 1.0% to 1.3% points lower than banks that just sell loans, and this difference is statistically significant." Goderis, Marsh, Castello, and Wagner [2006] estimate that banks issuing CLOs permanently increase their target loan levels by about 50%.

An argument against credit risk transfer by banks, particularly in the case of CLOs, is that it leads to greater retention by banks of "toxic waste," assets that are particularly illiquid and vulnerable to macroeconomic performance. Further, a bank that has transferred a significant fraction of its exposure to a

[2]Demsetz [1999] provides evidence favoring the hypothesis that banks that sell loans in order to diversify their loan portfolios.

borrower's default has lessened its incentive to monitor the borrower, to control the borrower's risk taking, or to exit the lending relationship in a timely manner. As a result, credit risk transfer could raise the total amount of credit risk in the financial system to inefficient levels, and could lead to inefficient economic activities by borrowers. It has also been suggested, for example by Acharya and Johnson [2007], that because a bank typically has inside information regarding a borrower's credit quality, the bank could use credit risk transfer to exploit sellers of credit protection. Credit risk transfer also generates complex structured credit products, including collateralized debt obligations (CDOs), whose risks and fair valuation are difficult for most investors and rating agencies to analyze.

I will pay particular attention to the market imperfections that underly the costs and benefits of credit risk transfer, and I will venture some opinions about how the tradeoffs between costs and benefits have gotten us to where we are. I will bring up the influences of our regulatory regime, especially with regard to bank capital regulation and accounting disclosure standards.

Credit risk transfer is intimately linked with innovations in security design, beginning with the emergence of collateralized mortgage obligations around 1980. As I will emphasize here, banks and other lenders design securitizations and loan covenant packages with the objective of reducing the costs of transferring credit risk to other investors.

With the goal of stimulating a productive debate, I offer the following summary of opinions, some of which are speculative and deserve to be the subject of more research.

1. Credit risk transfer (CRT) leads to improvements in the efficient distri-

bution of risk among investors. The retention by banks of "toxic waste" from securitization is likely to be accompanied by reductions in the effective leverage of bank balance sheets as well as improvements in diversification that increase the safety and soundness of the financial system.

2. Innovations in CRT security designs, especially default swaps, credit derivative product companies, collateralized loan obligations, and specialty finance companies, increase the liquidity of credit markets, lower credit risk premia, and offer investors an improved menu and supply of assets and hedging opportunities.

3. Even specialists in collateralized debt obligations (CDOs) are currently ill equipped to measure the risks and fair valuation of tranches that are sensitive to default correlation. This is currently the weakest link in CRT markets, which could suffer a dramatic loss of liquidity in the event of a sudden failure of a large specialty investor or a surprise cluster of corporate defaults.

4. Loans that are sold or syndicated tend to have better covenant packages. CRT is nevertheless likely to lead to a reduction in the efforts of banks and other loan servicers to mitigate default risk. Retention by lenders of portions of loans and of CLO toxic waste improve incentives in this regard.

5. Risk-sensitive regulatory capital requirements improve the incentives for efficient CRT. Adjustments in regulatory capital standards for default correlation, or at least granularity, would offer further improvements.

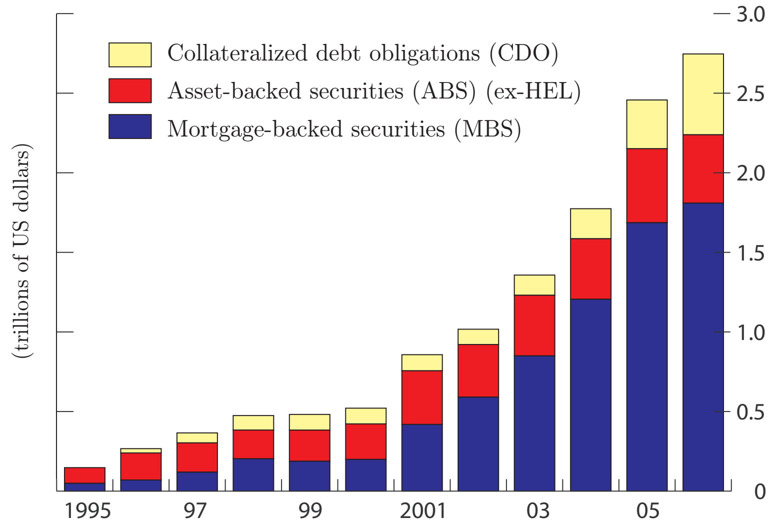

Figure 1: Securitization of bank credit risk. Source: IMF

6. Financial innovations designed for more efficient credit risk transfer appear to have facilitated a reduction in the degree to which credit is intermediated by banks, relative to hedge funds, credit derivative product companies, and specialty finance companies.

7. While the gross level of credit derivative and CLO activity by banks is large, the available data do not yet provide a clear picture of whether the banking system as a whole is using these forms of CRT to shed a major fraction of the total expected default losses of loans originated by banks. The recent dramatic growth of CRT markets is driven mainly by various other business activities by banks and non-bank financial entities.

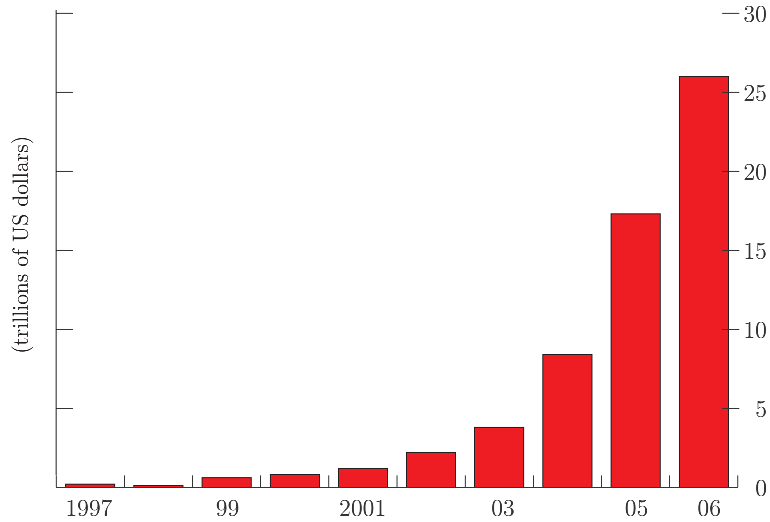

Figure 2: Outstanding notional amount of default swaps. Source: British Bankers Association.

1 Recent Credit Risk Transfer Activity

Figures 1 and 2 illustrate the significant growth in credit risk transfer through securitization and default swaps (CDS), respectively. Figures 3 and 4 provide Bank of America estimates of the fractions of total CDS protection selling and protection buying, respectively, that can be attributed to loan-portfolio risk management in 2006. These figures also show that the majority of CDS credit risk transfer performed by banks and securities dealers is due to trading on behalf of clients, rather than loan-portfolio hedging. The volume of net credit risk transfer away from banks' loan portfolios through CDS protection is nevertheless estimated by Bank of America to be significant. Figures 3 and 4 imply that net transfer of credit risk away from banks in 2006 through CDS was about 13% of the $25 trillion CDS market, or about $3.2 trillion.

In order to judge whether banks are indeed laying off a significant fraction of the risk in their own loan portfolios, I extended the study by Minton, Stulz, and Williamson [2006] of U.S. bank activity in default swaps during 2001-2003. Figure 5 shows that CDS positions by large U.S. banks during 2001-2006 grew at an average compounding annual rate of over 80%. CDS positions now dramatically exceed loan assets.[3] Of all 5700 banks reporting to the Fed, large or not, however, only about 40 showed CDS trading activity. Only three banks, J.P. Morgan, Citigroup, and Bank of America, have accounted for the majority of the CDS activity. For example, in 2006, according to new Chicago Fed data obtained by personal request, J.P. Morgan reported total CDS positions of approximately 4.7 times the size of its loan portfolio.

The buying and selling of CDS protection by large U.S. banks were relatively balanced in all years except 2005, when net CDS protection buying was about 17% of the total principal in these banks' loan portfolios. Table 1 provides a numerical breakdown of this CDS activity. Given only the available data, it is premature to conclude that banks are systematically using default swaps to significantly reduce the total expected default losses in their loan portfolios. They may be using default swaps to diversify their exposure to default risk. Much of the CDS activity by the three largest bank users of CDS is likely to be driven by CDS trading that is not related directly to loan hedging.

[3] Minton, Stulz, and Williamson [2006] selected banks with assets over $1 billion as of 2003. Of the 19 large banks in their study, there remain 13 due to consolidation. I follow the large banks tracked by Minton, Stulz, and Williamson [2006], or their successors. I am grateful to Cliff Grey for assistance in analyzing these data. Of the 345 banks with assets in excess of $1 billion, however, Minton, Stulz, and Williamson [2006] found that only 19 had used credit derivatives. Of these, 17 banks were net protection buyers.

Table 1: Aggregate Loans and CDS positions, in billions of U.S. dollars, for large U.S. banks (those with at least $1 billion in assets as of 2003). The first three columns are totals for the 19 banks within the sample of Minton et al (2006), or their successors. Bank-specific data for "Total Loans" (BHCK2122), "CDS Bought"(BHCKA535), and "CDS Sold" (BHCKA534) are from the Federal Reserve Bank of Chicago's bank holding company data, 2001-2006, using fourth-quarter holdings. The Federal Reserve data are from FR Y-9C reports filed by the banks (www.chicagofed.org).

Year	Total Loans	CDS Bought	CDS Sold	CDS Gross	CDS Net	CDS Bought % of loans	CDS Sold % of loans	CDS Net % of loans
2001	2125	217	220	437	−2	10.2%	10.3%	0.0%
2002	2238	342	288	630	54	15.3%	12.9%	2.4%
2003	2379	520	469	988	51	21.8%	19.7%	2.1%
2004	2671	1179	1092	2270	87	44.1%	40.9%	3.3%
2005	2891	3002	2518	5520	484	103.8%	87.1%	16.7%
2006	3298	4165	4094	8259	71	126.1%	124.1%	2.1%

2 Why does a bank transfer credit risk?

When transferring credit risk to another investor, a bank suffers two major costs:

1. The lemon's premium that the investor charges because of the bank's inside information regarding the credit risk. For example, as suggested by Akerlof [1970], if the bank offers to sell a loan at par, then the investor infers that the loan is worth at most par, so offers less, whether or not the loan is truly worth par. That banks indeed have private information about a borrower's default risk, and that banks are likely to suffer lemon's premia from loan sales, are consistent with research by Dahiya, Puri, and Saunders [2003] and Marsh [2006], who show that sale of a bank loan is associated with a significant drop in the price of the borrower's equity.

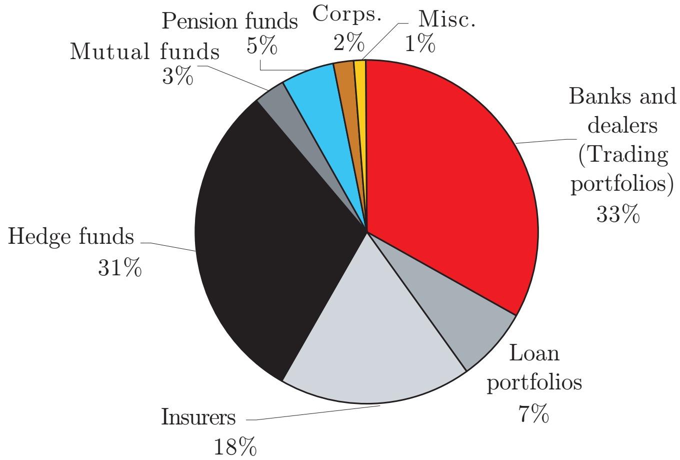

Figure 3: Estimated breakdown of CDS buyers of protection. Source: Bank of America, March 2007.

2. Moral hazard, resulting in inefficient control by the lender of borrowers' default risks. For example, a bank has less incentive to control the credit quality of a loan that it sells than of a loan that it retains. Thus, the price received from the sale of a loan is less than it would be if the bank controlled the borrower's default risk as the sole owner of the loan asset.

Legal, marketing, and other arrangement costs for credit risk transfer are relevant, but will not be within our primary focus.

The principle benefits of credit risk transfer are diversification and a reduction in the costs of raising external capital for loan intermediation. As suggested by Froot, Scharfstein, and Stein [1993] and Froot and Stein [1998], we expect an equilibrium in which a lender transfers credit risk until the costs of doing so exceed the benefits associated with lower capital requirements relative to the scale of the lending business.

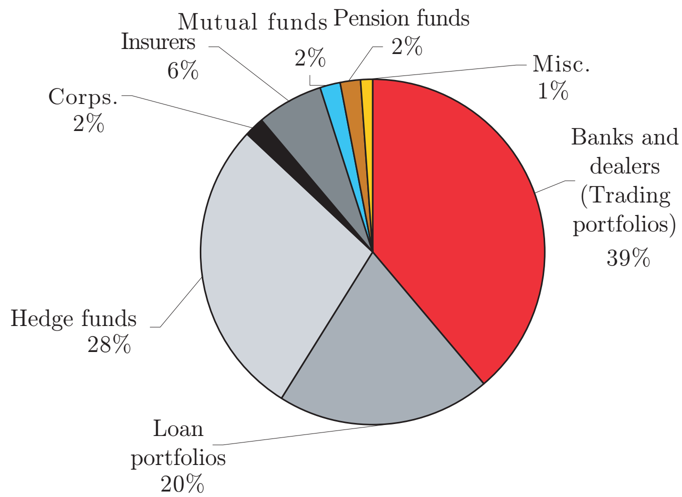

Figure 4: Estimated breakdown of CDS sellers of protection. Source: Bank of America, March 2007.

If financial markets are imperfect, credit risk transfer in the form of CDOs can also provide specialized investors with access to relatively low-risk investments that might otherwise be available only at a higher price. Extremely-low-risk securities such as government bonds are in demand by investors with a relatively high value for liquidity, because they are easily exchanged[4] and have high transparency. There is a relatively small supply of extremely highly rated (Aaa) corporate debt instruments, which often command a price premium associated with liquidity. A "super-safe" corporate bond, moreover, has adversely skewed risk, paying off in full with high probability, but losing roughly half of its principal value in default. CDO payoffs are not so adversely skewed because their exposure to any one default is normally a small fraction of the CDO principal. Investors with a low demand for liquidity but a high demand for safety benefit from access to senior CDOs, which offer a moderate reward to patient insti-

[4]In the United States, Treasuries and agency securities are among the few securities accepted by Fedwire, for same-day secure exchange in the interbank market.

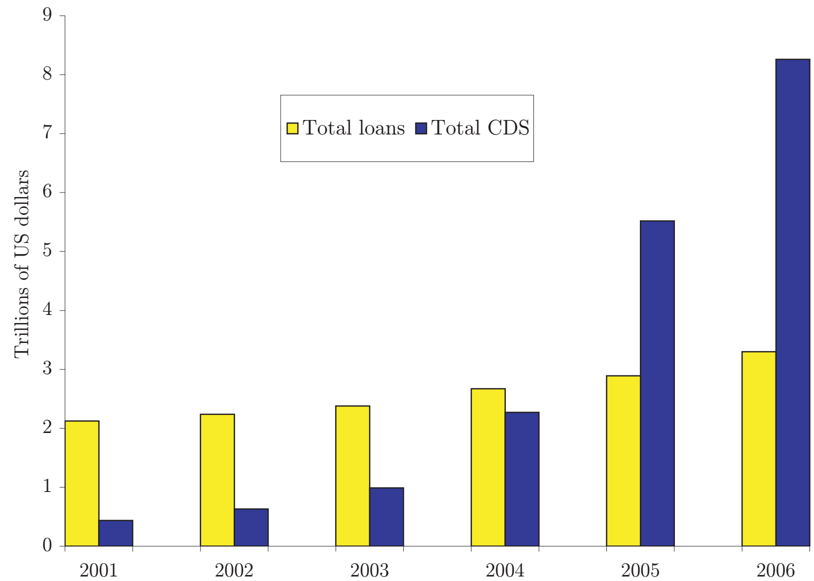

Figure 5: Aggregate U.S. Large-Bank Loans and CDS positions (Data: Federal Reserve Bank of Chicago (2006).

tutional investors, such as pension funds and insurance companies, for bearing a small amount of default risk, and for bearing some illiquidity.[5] Gale [1992] emphasizes the value of "standard securities," those for which investors have overcome much of the fixed costs of understanding the security design. One of the causes of growth in the CDS and CDO markets is the relative standardization of collateralized debt obligations and default swaps, creating a positive feedback effect on market acceptance.

Consider a bank whose assets consist of $100 billion of risky loans, and suppose that it is optimal or required by regulation to hold $9 billion in capital as a buffer against default risk on this portfolio. The capital buffer mitigates distress costs to the bank and systemic risk costs to the financial system. At first, we suppose that the only available form of credit risk transfer is the outright sale

[5] This motivation for innovation is related to, but somewhat different than, that of Allen and Gale [1988].

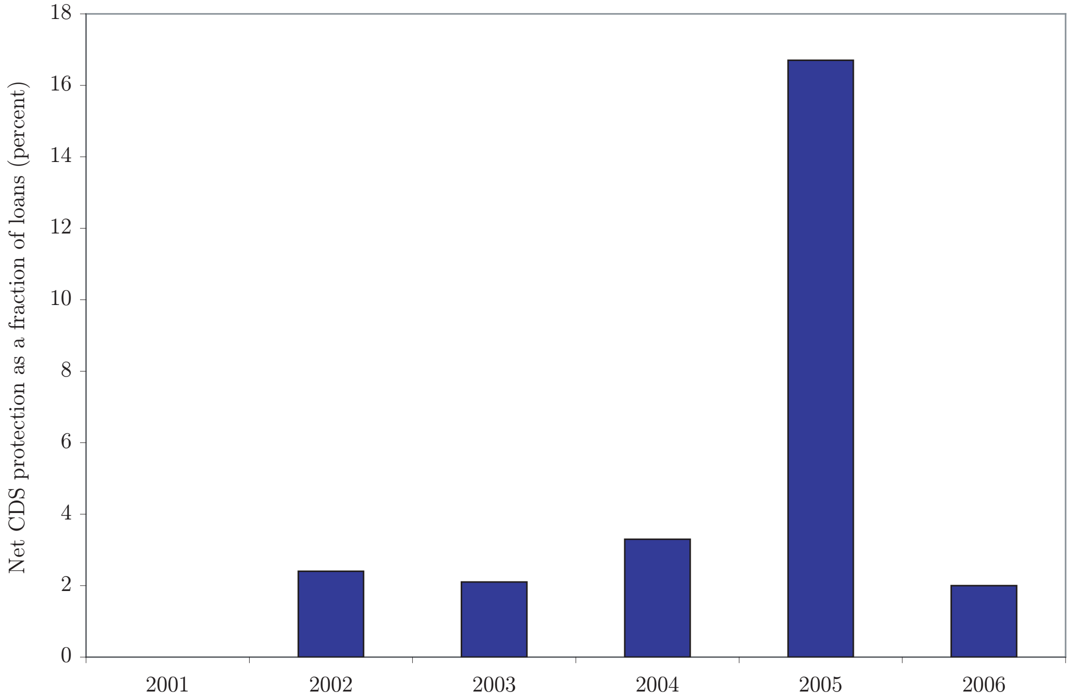

Figure 6: Net CDS protection bought as a fraction, in percent, of loan portfolio size.

of loans in the secondary market. If the frictional costs of raising capital are high enough relative to the above-named frictional costs associated with selling loans, and if loan origination is sufficiently profitable, then the bank increases the return on its capital by selling loans for cash (and for regulatory capital relief) in order to intermediate additional loans. Unless some loans are more costly to sell than others, the bank should sell loans as soon as possible after their origination, holding only the capital necessary to cover the loans while they are temporarily on the bank's balance sheet. As we shall discuss, CDS hedging and loan syndication can be near substitutes for loan sales.

3 What credit risk to keep, and what to transfer?

Still supposing that credit risk transfer occurs only through the outright sale of loans, suppose that the costs of selling loans diverge widely across the pool of loans that a bank originates. Then we expect the bank to sell only those loans that provide the greatest benefit in capital reduction net of the costs of sale. The marginal loan sold is that for which the marginal benefit from the associated release of capital is equal to the marginal loan-sale costs. The moral-hazard and lemons-premium costs described above are typically related to the level of default risk. If the capital released from the sale of a loan does not depend on the quality of the loan, then only the lowest-quality loans would be retained. Given that a bank's chosen or mandated level of capital ought to be sensitive to the riskiness of the bank's loan portfolio, however, the amount of capital that is liberated by the sale of a high-risk loan is greater than that for a low-risk loan. Depending on the circumstances, selling risky loans could be preferred over selling safe loans. Assuming that regulatory capital is binding, the "Basel II" capital accord is an improvement in this respect. Notably, high-risk loans are increasingly not held by traditional banks, as indicated in Figure 7. Loan syndication, which from the viewpoint of the lead bank has some of the essence of a loan sale, is also increasingly oriented toward speculative-grade loans, as indicated in Figure 8.

Consistent with the above cost-benefit tradeoff, Drucker and Puri [2006] show that loans that are sold appear to be those with relatively low monitoring costs. For example, sold loans tend to have more restrictive covenant packages than

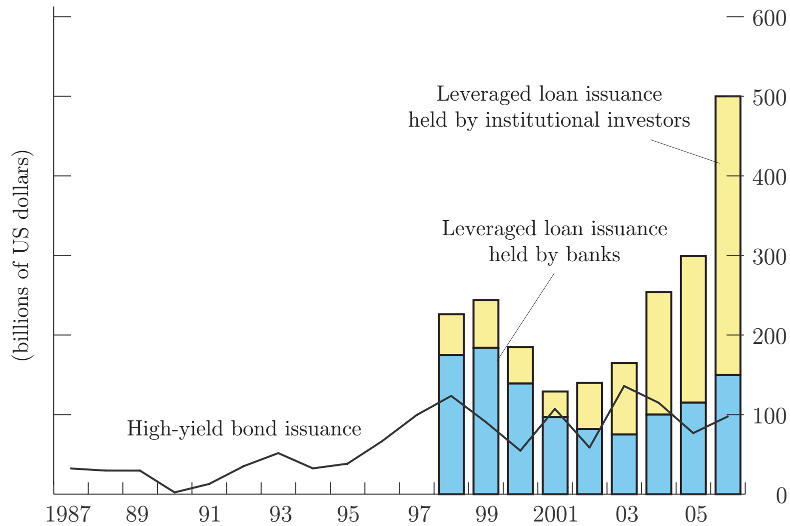

Figure 7: Bank and non-bank investment in leveraged loans. Source: IMF.

unsold loans. Drucker and Puri [2006] also find that the covenant packages tend to be more restrictive when rating agencies disagree on the borrower's rating, a signal of informational asymmetries. Drucker and Puri [2006] note that these covenant packages actually appear to be frequently designed to ease the loan sale, given that over 60% of loan sales occur within a month of origination. More than half of sold loans are eventually resold, further indicating the intention of creating a loan instrument that will be liquid in the secondary market. Of sold loans, nearly 90% have a credit rating. Of unsold loans, only about 40% have a credit rating. As for the incentive to sell loans that tie down a significant capital buffer, Drucker and Puri [2006] indeed find that, after controlling for other relevant predictors, having a junk credit rating increases the likelihood of sale significantly.

The picture emerges: Banks often sell loans that are designed specifically for an intermediation profit rather than for a long-run investment profit, using

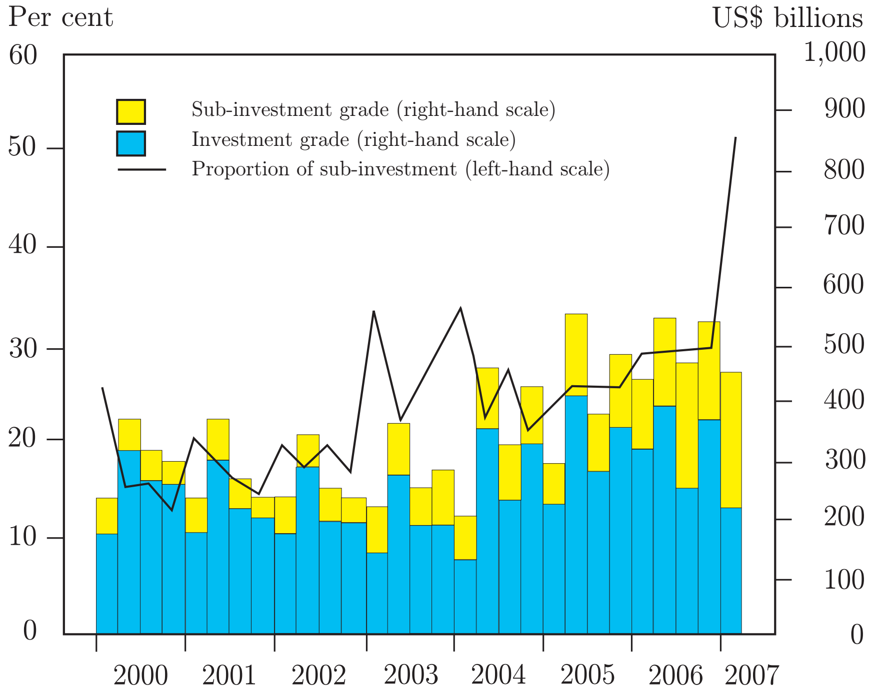

Figure 8: Decomposition of syndicated loan issuance by investment grade and sub-investment grade. Source: Bank of England, Financial Stability Report (2007).

more restrictive covenant packages that mitigate selling costs. The riskier loans are more the likely to be sold, controlling for other effects, perhaps because they tie down more bank capital.

3.1 Fractional retention as a signal or commitment

If a fraction of a loan can be sold, that fraction optimally trades off capital relief against selling costs. For example, in the case of selling costs arising from information about borrower quality that is held privately by banks, Leland and Pyle [1977] use a signalling equilibrium to model the partial sale of an asset by an informed owner. The loan seller signals a higher-quality loan by the costly retention of a larger fraction of the loan. Whether a bank can credibly commit

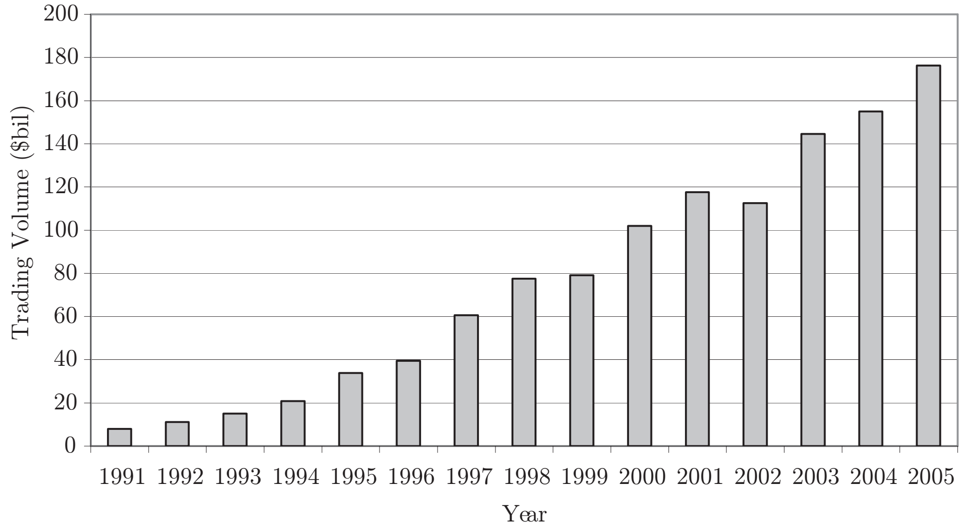

Figure 9: Secondary-market loan sales. Source: Drucker and Puri (2006).

not to later sell the portion of the loan that was originally retained may depend on the development of a reputation for retention that is worth keeping. There is clearly scope for further theory in this direction.

Alternatively, one can consider the case of selling costs that are associated with moral hazard with regard to costly efforts by a bank to control the default risk of the borrower, in the spirit of Gorton and Pennachi [1995].

We can consider a simple illustrative theoretical framework that will be extended when we consider the design of collateralized loan obligations. Suppose that a bank is indifferent between having one dollar of additional assets, against which capital must be retained, and having b dollars of additional capital. For example, if $b = 0.99$, then there is a shadow price of 1% for holding assets on the balance sheet. Unless the cash to be liberated by the loan sale is large relative to the bank's capital, the marginal value of each dollar of capital liberated by the loan sale would not depend on the fraction of the loan sold. Consider the sale by the bank of some fraction f of a loan whose market value would be par if market participants assume a minimally acceptable effort by the bank to control default losses. The bank's total value for what is sold and what is retained is thus

$$U(f, x) = f(1 + x) + b(1 - f)(1 + x) - C(x), \tag{1}$$

where x is a candidate for the improved value of the loan that could be achieved through efforts by the bank to lower the borrower's default risk, and where $C(x)$ is the bank's cost of achieving this additional loan value x.

The buyer of the loan understands that the bank, when choosing an effort level, focuses only on the value of the retained fraction of the loan net of monitoring costs, therefore solving

$$\max_x \; (1 - f)b(1 + x) - C(x). \tag{2}$$

Letting $X(f)$ be the optimal effort for a sold fraction f, the bank thus faces the loan-sale decision

$$\max_f \; U(f, X(f)). \tag{3}$$

For example, suppose that the effort necessary for a fractional increase in loan value of x has a proportionate cost to the bank of $C(x) = kx^2$, for some coefficient k. Then, from the first-order condition[6] for (2), we have $X(f) = (1 - f)b/(2k)$. Substituting $X(f)$ into (3), the optimal fraction of the loan to sell[7] is

$$f^* = \frac{k}{b} \frac{\left(1 + \frac{b}{2k}\right)(1 - b)}{1 - \frac{b}{2}}. \tag{4}$$

[6]The first-order condition for optimal effort x^* by the bank implies that $C'(x^*) = (1 - f)b$.

[7]This is the first-order condition. The second-order condition for a maximum is always satisfied. One should restrict attention to cases with $f^* < 1$.

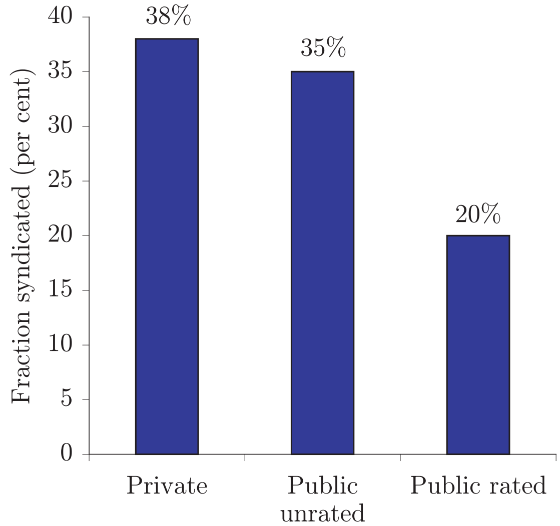

Figure 10: Estimates by Sufi (2007) of syndicated loan retention by lead arranger.

For the anticipated case of b near 1, we have $f^* \simeq 2k(1-b)$. For example, at $k = 25$ and $b = 0.99$, the optimal fraction to sell is about $f^* = 50\%$. Relative to the value of the loan if it were sold in its entirety, the bank chooses to protect its investment in the retained portion of the loan by efforts that lower the market value of total loan default losses by about $X(f^*) = 1\%$, at a monitoring cost $C(0.01)$ of about 25 basis points of the loan value. Net of the cost of tying down capital in the retained portion, $1 - b = 1\%$ of the 50% retained, the bank achieves a net improvement in value for the loan of about 25 basis points.

Consistent with the role of monitoring in explaining the incentive to sell a particular loan, Sufi [2007] finds that the fraction of a syndicated loan retained by the lead arranger is about 38% for a private-firm borrower, about 35% for a public but unrated borrower, and about 20% for a public and rated borrower, as illustrated in Figure 10. The fraction retained is lower for more reputable lead arranging banks. By studying the relationship over time between the borrower and the lead arranger, Sufi finds more support for the moral-hazard motive for loan retention than for the lemon's-premium motive. A longer borrower-lender relationship implies a greater lemon's premium, but presumably lowers monitoring costs. Sufi's data do not support greater loan retention with a prior lender-borrower relationship.

Rather than the sale of a loan, buying default-swap protection can be used to transfer credit risk. If the maturity of a loan is identical to that of the default swap, then buying CDS protection is essentially equivalent to loan sales, ignoring the risk of default swap counterparty performance. Loan sales are currently somewhat superior to CDS protection from the viewpoint of regulatory capital and accounting disclosure. A cross-jurisdictional review of regulatory capital and disclosure treatment of CDS protection of bank loans is provided in the Joint Forum Report on Credit Risk Transfer, BIS [2005]. Typically, a CDS-protected loan is treated for regulatory-capital purposes as though it is a loan that is guaranteed by a counterparty of the quality of the CDS protection seller, subject to maturity matching and other provisions.[8] The Basel II accords will provide a more uniform regulatory capital framework.

Duffee and Zhou [2001] provide a theory by which CDS protection of loans with default swaps of shorter maturities than those of the loans can be effective if the default risk is concentrated near or at the maturity of the loan. Arping [2004] further shows that CDS protection buying by lenders can be more effective without a maturity match, when balancing the costs of moral hazard by

[8] An important distinction across jurisdictions is whether the default swap must cover restructuring in order to quality for regulatory capital reduction, as in Europe.

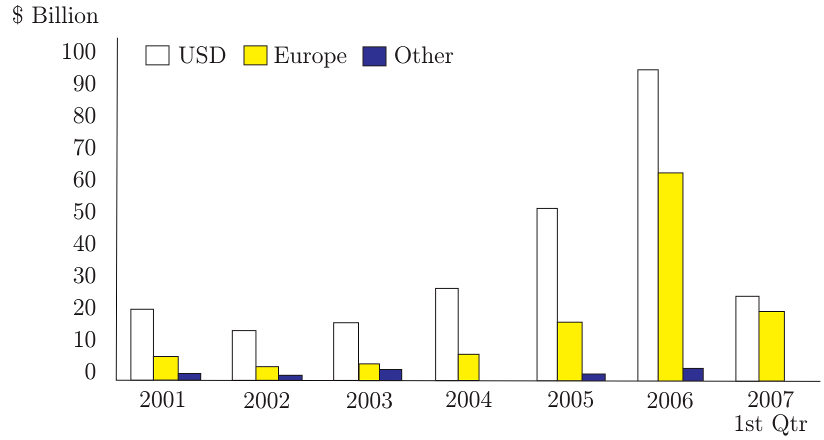

Figure 11: Issuance of CLOs by year and region. Source: Morgan Stanley. Data from Thompson Financial show total 2006 issuance of CDOs backed by high-yield bonds of $164 billion, roughly consistent with the Morgan Stanley data. Fitch data indicate European CLOs in 2006 of approximately 30 trillion Euros. SIFMA reports balance-sheet CDO issuance in 2006 of about $70 billion, based on Thompson Financial data.

the lender against the benefits of the borrower's "free riding" on the lender's incentive to bail out the borrower.

4 Collateralized Debt Obligations

A collateralized debt obligation (CDO) is a debt security whose underlying collateral is typically a portfolio of bonds (corporate or sovereign) or bank loans. The collateral is held by a special purpose vehicle (SPV), a corporation or trust whose only purpose is to collect collateral cash flows and pass them to CDO investors. CDOs backed by consumer loans, such as mortgages or credit card debt, are often called "asset-backed securities" (ABS). Those backed by corporate loans are usually called collateralized loan obligations. CDOs allocate interest income and principal repayments from the asset collateral pool to pri-

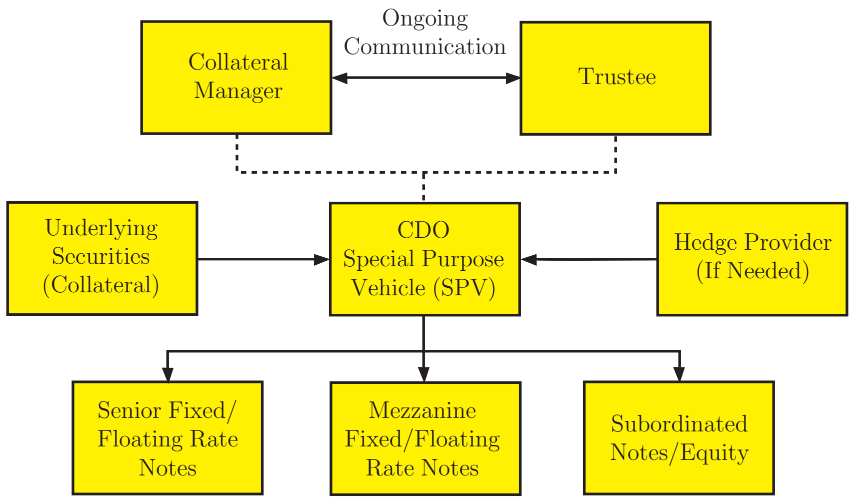

Figure 12: Typical CDO contractual relationships. Source: Morgan Stanley

oritized CDO securities, often called *tranches*. While there are many variations, a standard prioritization scheme is simple subordination: Senior CDO notes are paid before mezzanine and lower-subordinated notes are paid, with any residual cash flow paid to an equity piece.

A typical contractual framework for CDOs is pictured in Figure 12. Issuance of CLOs is growing rapidly, especially in Europe, as indicated in Figure 11.

The first generation of CDOs, appearing around 1980, were collateralized mortgage obligations (CMOs). Prioritizing the cash flows of a mortgage portfolio into relatively low risk and high risk tranches led to improved liquidity for mortgages and lower borrowing costs for homeowners. Notably, the CMO market collapsed in 1994 with dramatic changes in the term structure of interest rates and the failure of The Granite Fund, which had depended on unreliable valuation and risk management methodology. After a year-on-year decline in CMO issuance of 95%, the market subsequently recovered.

In 1997, Nations Bank issued one of the earliest major examples of a collateralized loan obligation (CLO), illustrated in Figure 13. A senior tranche of $2 billion in face value had priority over successively lower-subordination tranches. The ratings assigned by Fitch are also illustrated. The underlying pool of collateralizing assets consists of roughly 900 loans that had been previously made by NationsBank to various firms, most rated BBB or BB. Most of these loans had floating interest rates. Any fixed-rate loans in the collateral pool were significantly hedged against interest rate risk by having the SPV enter payer (fixed-to-floating) interest-rate swaps. The majority of the (unrated) lowest tranche was retained by NationsBank, presumably based on the adverse-selection and moral-hazard costs of selling that we have explained in the context of outright loan sales.[9]

4.1 Theories of CDO Design

We have discussed the role of moral hazard and adverse selection as motives for retention by the lender in the case of an outright loan sale. Given a CDO design, essentially the same story applies to retention of CDOs by the issuer. A CDO also presents moral hazard and adverse selection through the lender's opportunity to select the loans for the pool of CDO collateral. The CDO design problem is to develop an algorithm for assigning cash flows from the collateral pool to each CDO tranche so as to maximize the sum of the market value for

[9]A *cash-flow* CDO is one for which the collateral portfolio is not actively traded by the CDO manager, implying that the uncertainty regarding interest and principal payments to the CDO tranches is determined mainly by the number and timing of defaults of the collateral securities. The NationsBank CLO illustrated in Figure 13 is an example of a cash-flow CDO. A *market-value* CDO is one for which the CDO tranches receive payments based essentially on the mark-to-market returns of the collateral pool, which depends on the trading performance of the CDO asset manager.

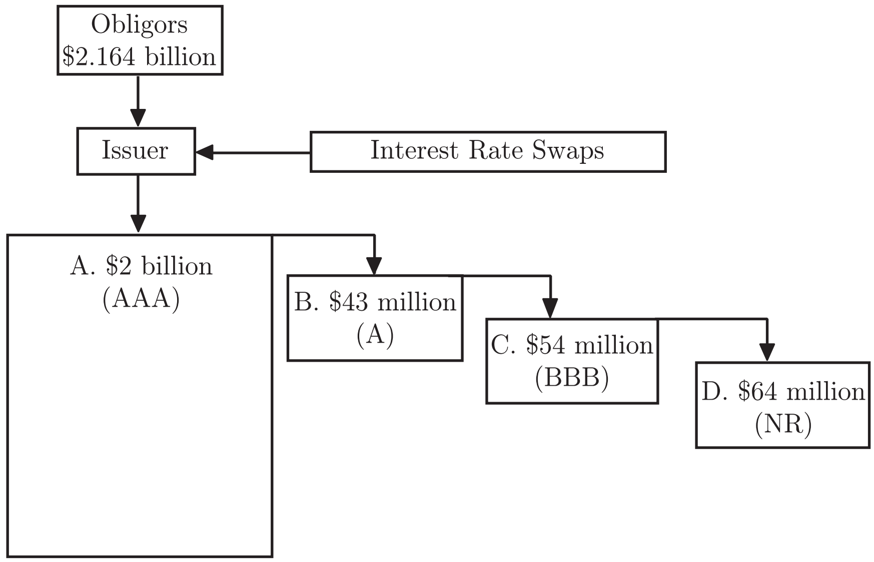

Figure 13: NationsBank 1997-1 CLO tranches (Source: Fitch)

what is sold and the effective value to the issuer for what is retained.

An additional incentive for the creation of CDOs is the demand by certain investors for debt instruments of a given credit quality. Those developing structured credit products have pointed to such clientele effects, with limited if any support from academic research. In perfect capital markets, the pricing of risk is identical across all assets. Issuing high quality debt and retaining the residual has no benefit over the converse issuance strategy, along the lines Modigliani and Miller [1958]. If, however, there is a pool of investor capital that is dedicated to relatively high-quality debt instruments, the supply of such instruments to the market can lag the demand, and in the meantime an issuer of asset-backed securities can earn attractive rents. As illustrated in Figure 14, the structured finance industry has indeed created a very large supply of high quality fixed-income assets out of a pool of lower quality assets, by concentrating the credit risk into a small amount of highly risky assets.

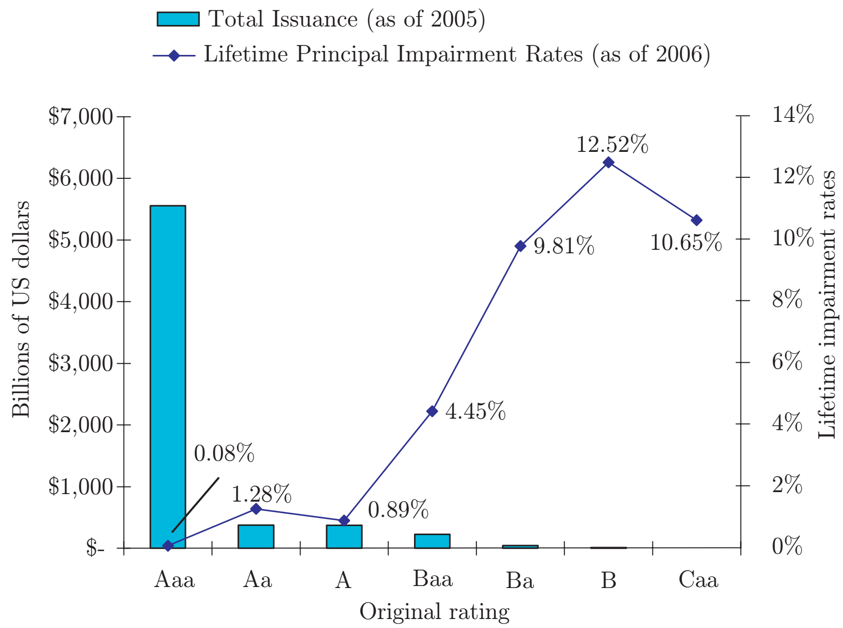

Figure 14: Structured finance: outstanding issuance and impairment rates by rating. Source: Moodys.

Evidence that some of the impetus for collateralized debt obligations is driven by the demand for certain classes of securities, rather than merely by lemon's premia or moral-hazard on the part of the original lender, is the fact that a typical CDO structure incorporates multiple classes of relatively senior tranches that are all "sold out." Under only the incentives associated with moral-hazard or lemon's premia, the intermediate tranches would be retained in different proportions by the issuer.

Just as has long been claimed by CDO asset managers, it is likely the case that the sold-out tranches add value to the CDO structure by feeding clienteles with assets that are highly valued by them and are in relatively short supply. Coval, Jurek, and Stafford [2007] propose that investors in senior CDOs are simply unaware that these instruments are exposed to significant levels of systematic

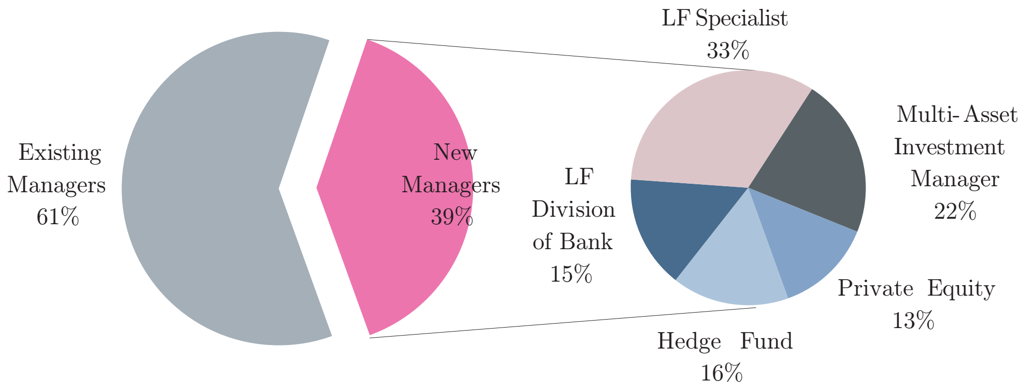

Figure 15: New European CLO issuers in 2006. Source: Fitch.

risk, given that only a significant economic downturn would generate sufficient losses to impair relatively senior tranches. The degree to which the issuance of CDOs is driven by "behavioral" demand, or is based on a shortage of assets with similar risk and return characteristics is an open question. In any case, it is my presumption that sub-tranching of the unretained portions of CDOs is not explained by traditional theories of security design that are based on adverse selection and moral hazard.

Incidentally, the latest available data regarding returns on the equity pieces of CDOs is rather discouraging. Of all 59 CLO deals that had terminated in time for Moodys' January 2007 report on CDO equity returns, the mean across deals of the internal rate of return on the equity pieces of CLOs was estimated by Moodys to be 2.35% with a standard deviation of 21.14%. For collateralized bond obligations, the mean IRR of the equity tranches across 36 terminated deals was −14.2% with a standard deviation of 43.5%.

In general, an issuer has an incentive to design a CDO in such a manner that the issuer sells most or all of the senior tranches and retains a significant portion of one or more subordinate tranches that would be among the first to suffer losses stemming from poor monitoring, servicing, or asset selection.[10] The goal is to demonstrate to investors a degree of confidence in, or commitment of effort for, low default losses. In light of retention by the issuer, investors may be willing to pay more for the tranches in which they invest, and the total valuation to the issuer is higher than would be the case for an un-prioritized structure, such as that of a pass-through security. Innes [1990] has a model supporting this motive for the issuance of a standard-debt senior security, and retention of the equity residual, for the case of costly effort by the issuer to improve the cash-flow performance of the underlying assets. DeMarzo and Duffie [1999] show the optimality of the same security design in a setting of adverse selection.[11]

DeMarzo [2005] further shows natural conditions under which the lender prefers not to sell a passthrough security, merely pooling different assets about which the lender has private information. Rather, the lender prefers to first pool and then issue standard debt (a senior tranche) backed by pooled loans. I am not aware of any research that has addressed the motives for pooling and tranching designs in the case of moral hazard on the part of the issuer.

Franke and Krahnen [2007] analyze the implications of CLO issuance and reinvestment of the sale proceeds for a bank's aggregate default loss distribution. They also indicate that securitization activity by a bank is associated with an increase in the systematic component of the bank's stock return, in terms of beta (second moment). Presumably, however, higher-moment systematic risk is

[10]Likewise, for arbitrage CDOs, a significant portion of the management fees may be subordinated to the issued tranches.

[11]For further work in this direction, see Nicolo and Pelizzon [2005] and Nicolo and Pelizzon [2006].

reduced by securization, because the senior tranches that are sold transfer to other investors the loan-portfolio losses associated with dramatic recessions.

Curiously, possibly driven in part by accounting standards for equity residuals and by the demand by other investors for higher yielding assets, banks seem to have begun selling even the equity residuals of CLOs, or similar synthetic forms of first-loss exposure.[12]

4.2 Specialty Finance Companies

Going beyond CDOs, credit derivative product companies (CDPCs) are special purpose structured finance operating companies whose only permitted line of business is to sell credit protection. Strict contractual risk limits, when breached, force either an immediate liquidation or a freezing of the CDPC portfolio, which essentially converts the CDPC into a CDO. Often cited CDPCs include Primus Financial Products and Athlion Acceptance Corporation. Remeza [2007] reports that in early 2007 Moodys had proposals for ratings by 24 new CDPCs, about 75% of which are U.S.-based. About one third of the CDPC sponsors are banks. The remainder are other asset managers and insurance companies. The CPDC can serve as a flexible and ongoing financing conduit for a sponsor with a pipeline of loan risk. The capital structures of CDPCs are designed for Aaa ratings in order to take advantage of the opportunity to sell protection without posting

[12]See Michael Marray, "First-loss Frenzy," in in *Thomsons International Securitisation Report,* October 1, 2006, and Paul Davies, "Getting Rid of Unwanted Leftovers," *Financial Times,* December 15, 2005. Marray writes: "With wide variations caused by deal structure as well as type and quality of collateral, expected returns on equity pieces may be down from perhaps 13% or 14% 18 months ago to more like 10% to 11% today. That is bringing the investor base more in line with bank originators who wish to sell first-loss pieces in order to avoid the onerous dollar-for-dollar capital deductions under new accounting regulations."

collateral.

A related form of specialty finance company focuses on more structured products, particularly CDOs. These include companies that have proposed to go public, such as Highland Financial Partners and Everquest Financial, whose objective, according to the prospectus of its initial public offering in May, 2007, "is to create, structure and own CDOs and other structured finance assets that will provide attractive risk-adjusted returns to us and our shareholders. We generate earnings primarily through a diversified portfolio of CDOs in which we beneficially own all or a majority of the equity."

Many niche specialty finance companies now provide services that combine traditional lending with securitization. For example, in 2005, C.B. Richard Ellis announced the formation of a new specialty finance company that focuses on originating, purchasing, financing, and managing a diversified portfolio of commercial real-estate-related loans and securities. In another example, Consumer Portfolio Services, according to its own publicity, "is a specialty finance company that provides indirect automobile financing to individual borrowers with past credit problems, low incomes, or limited credit histories. The Company purchases retail installment sales contracts primarily from factory franchised automobile dealers. The contracts are secured by late model used cars and to a lesser extent, new cars. The Company accumulates the contracts into pools, and finances the pooled contracts through the issuance of 'AAA' rated asset-backed securities."

Consistent with the remarks of Geithner [2007], the development of the markets for default swaps and collateralized debt obligations may have enabled specialty finance companies to take on some of the roles of banks in providing both intermediation and financing of credit. The implications for the banking system and banking regulation are not clear.

4.3 Default Correlation: Roadblock Ahead?

Default correlation across a pool of loans forming the collateral of a CDO can have a significant impact on the risks and market values of individual CDO tranches. Raising default correlation raises the volatility of the cash flows from the collateral pool. At one extreme, if defaults are perfectly correlated, then either all default or none default. At the other extreme, if defaults are independent across a relatively large homogeneous collateral pool, then the law of large numbers implies that the average default rate is close to the mean expected default rate.

A senior CDO tranche is effectively "short a call option" on the cash-flow performance of the underlying collateral pool. The market value of a senior tranche therefore decreases with risk-neutral default correlation. The value of the equity piece, which resembles a call option on the collateral-pool cash flows, increases with default correlation. There is no clear effect of optionality, however, for the valuation of intermediate tranches. Each of the intermediate tranches has given up an option to the tranches below it in priority, and has taken an option from the tranches above it. The over-collateralization of a tranche is the principal amount of debt below it. With sufficient over-collateralization, the option given to the lower tranches dominates, but it is the other way around for sufficiently low levels of over-collateralization.

Currently, the weakest link in the risk measurement and pricing of CDOs is the modeling of default correlation. There is relatively little emphasis in practice on data or analysis bearing on default correlation. When valuing CDOs, somewhat arbitrary "copula" default correlation models are typically calibrated to the observed prices of CDS-index tranches, a class of derivatives that behave much like CDOs, as explained in the Appendix. Some of the industry-standard calibrated correlation models are internally inconsistent, as we shall see by example, in that the correlation model that matches the price of one tranche of a CDO structure is typically much different than that of another tranche of the same structure. Although these differences are sometimes eliminated in practice with proprietary copula models that have a richer set of parameters, the additional parametric details are usually not based on information that bears realistically on default correlation. A model with enough flexibility can be made to match market prices, without necessarily capturing reality in any significant way. Risk managing the mark-to-market valuation of CDOs, moreover, is not treated directly by the current copula approach to valuation, which has no place in its modeling framework for uncertain changes in credit spreads.

The dependence of the market on CDO valuation methodology is particularly weak in the case of bespoke CDOs, those based on a customized portfolio of names. Bespoke CDO correlation assumptions tend to be based on extremely slender analysis, largely extrapolation of CDS-index-tranche-implied correlation parameters, with little evidence or analysis of the degree to which common risk factors are present in the actual bespoke portfolio.

Institutional investors tend to rely on the ratings of structured credit products, including CDOs, when making investment decisions. Methodologies for rating CDOs, however, are still at a relatively crude stage of development. Correlation parameters used in ratings models tend to be based on rudimentary assumptions, for example treating all pairs of names within a given industrial sector as though they have the same default correlation, and treating all pairs of names not within the same industrial sector as though they have the same default correlation. As opposed to valuation models often used for dealing, investment and hedging decisions, ratings decisions place at least some emphasis on data bearing directly on correlation.

An appendix reviews the current valuation methodology for CDS index tranches, and some of its pitfalls. The appendix discusses the impact of the May 2005 GM downgrade on the CDX index tranche market as an illustrative example.

4.4 CLO Design Illustration

In order to visualize the implications of moral hazard for CLO design and retention, I present an illustrative example showing how the credit quality of the borrowers can deteriorate if the issuer is under moral hazard to make costly efforts to control the borrowers' default risks. These results are from forthcoming research by the author and Andreas Eckner.

Assuming that the cash flows to be issued from a collateral pool are increasing with the pool-level cash flows, under technical regularity conditions, the optimal security to retain is pure equity, according to the results of Innes [1990]. The main questions are: what is the equilibrium level of equity to retain, how much effort does the issuer make to control credit quality, and what is the market spread on the issued CLO?

We consider a basic CLO design for a collateralizing pool of loans of equal amounts to each of 125 obligors, whose modeled default correlations are calibrated to the corporations underlying the CDX.NA.IG4 default swap index, in that the risk-neutral stochastic default intensity dynamics are calibrated to jointly fit 1-year and 5-year CDS, as well as 5-year CDX tranche spreads as of December 5, 2005.

The CLO issue is a 5-year note whose principal is a fraction $1-q$ of the total principal of the 125-loan collateral pool. The note pays investors a coupon at a contractual yield with some spread S over the risk-free rate on the current principal. Any default recoveries are paid to note investors, with a corresponding reduction in principal, as defaults occur. We assume that S is chosen so as to price the note at par (that is, giving the note a market value equal to its initial principal). The remaining cash flows go to an equity tranche retained by the issuer. The issuer's design problem therefore consists in choosing the "retention fraction" q and the effort level x so as to maximize the market value of what is sold plus the value of what is retained, net of the costs of reducing borrowers' default risks and the cost of pinning down capital to support the retained portion of the structure.[13]

Adopting the portfolio default process model proposed by Duffie and Gârleanu

[13]We assume a default recovery rate for each borrower of 40% of principal. As for the CLO "waterfall" that allocates loan cash flows to the note issued and the retained equity tranche, we assume no reserve account. That is, all excess interest payments from the collateral pool are immediately paid to the equity tranche (with no interest coverage or over-collateralization tests). Risk-free interest rates are assumed for simplicity to be independent of default risk, and determined by market yields as of December, 2005.

[2001], we assume that any surviving borrower's default intensity (risk-neutral conditional mean arrival rate of default) is of the form, for borrower i at time t,

$$\lambda_{it}^{\mathbb{Q}} = 0.5^{x} \left(X_{it} + a_i Y_t \right), \tag{5}$$

for an idiosyncratic component X_i and systematic (common to all borrowers) component Y. Here, x can be viewed as the "proportional" reduction in default intensity that is achieved through effort by the issuer. The processes $X_1, \ldots, X_n, Y$ are assumed to be, risk-neutrally, independent "basic affine jump diffusions," a class of jump diffusion processes that provides a significant amount of analytical tractability. For any two issuers i and j, the common-factor weighting coefficients a_i and a_j determine the structure of default correlation between issuers i and j. The parameterization of basic affine processes is provided in Duffie and Gârleanu [2001]. We exploit the results of Mortensen [2006] and Eckner [2007], who provide Fourier transform methods for computing portfolio loss distributions and pricing CDS index tranches in this framework.

In order to model the issuer's incentive to sell assets in exchange for cash or for a reduction in regulatory capital, we assume that retained cash flows are discounted more heavily than they would be in the market, at an extra spread of $\delta > 0$.

We assume for notational simplicity a total collateral principal of 1. For a given retention fraction q and spread s, the issuer chooses an effort level x that maximizes

$$U(q, x) = W(q, x, S(q, x)) - \pi x, \tag{6}$$

where π is the assumed cost per unit of effort and $W(q, x, s)$ is the market value of the equity residual, assuming effort level x, and assuming that the note issued has a contractual spread of s and an initial principal of $1-q$. Here, $S(q,x)$ is the par spread, given q and x. The issuer's effort level x influences the contractual coupon of the security that is issued.

Investors in the note understand that, given the retention fraction q, the issuer's effort level $X(q)$ is that solving $\max_x U(q,x)$. The design problem is therefore to choose some retention fraction q^* solving

$$V(q) = \sup_q \{U(q, X(q)) + 1 - q\}, \tag{7}$$

which is the value to the issuer of the equity residual, less the cost of effort, plus the par value $1-q$ of the note issued. For a given CLO structure, we calculate the value of the equity residual and senior note using Fourier transform techniques developed by Mortensen [2006] and Eckner [2007]. We then solve for the optimal CLO structure by using a search algorithm over the set of all possible CLO structures.

For a base-case numerical example, we take $\delta = 0.01$ and $\pi = 0.001$. As shown in Figure 16, the optimal retention fraction is $q^* = 3\%$. The associated the par spread $S(q^*, X(q^*))$ is 5 basis points and the optimal effort level $X(q^*)$ is 0.75, corresponding to a proportional reduction in risk-neutral default intensity, from the base case of no effort, of approximately 40%.

Figure 17 shows how the optimal effort level $X(q)$ depends on the retention fraction q. Table 2 shows how the optimal retention fraction q^* varies with the excess discount rate δ associated with retained assets and the cost π per unit of effort. The response to increasing δ is of course for the issuer to retain less.

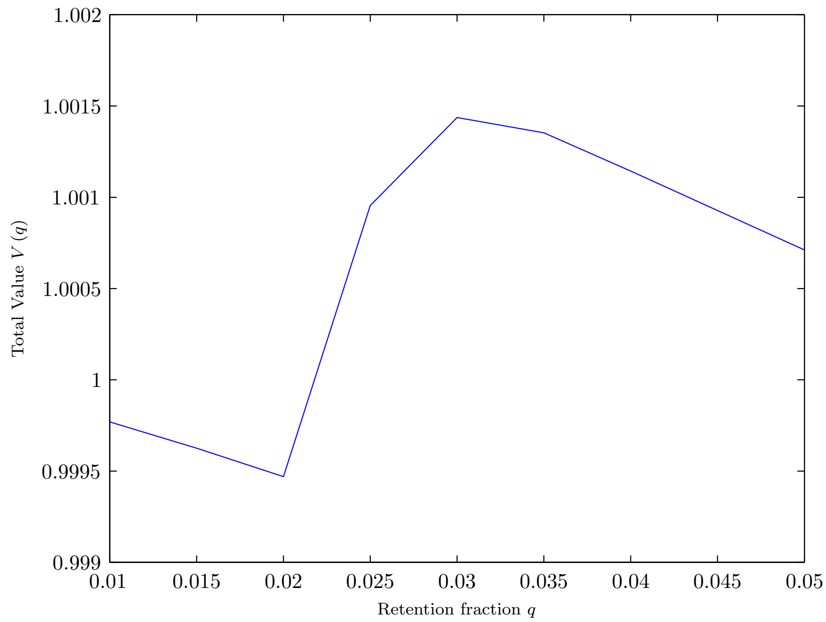

Figure 16: Total value $V(q)$ of the CLO structure to the issuer (retained and issued), net of effort costs.

The response to increasing the cost π of effort is, at first, for the issuer to retain more risk in order to "convince" investors that the issuer has enough at stake to make the effort worthwhile, thereby lowering the spread necessary to price the note issued at par. After the cost of effort gets sufficiently high, however, Tables 2 and 3 show that it becomes so costly for the issuer to demonstrate a commitment to control the borrowers' default risks that the issuer simply sells the entire loan portfolio, making minimal effort. Indeed, banks have recently been selling equity residuals of CLOs to specialty finance companies.

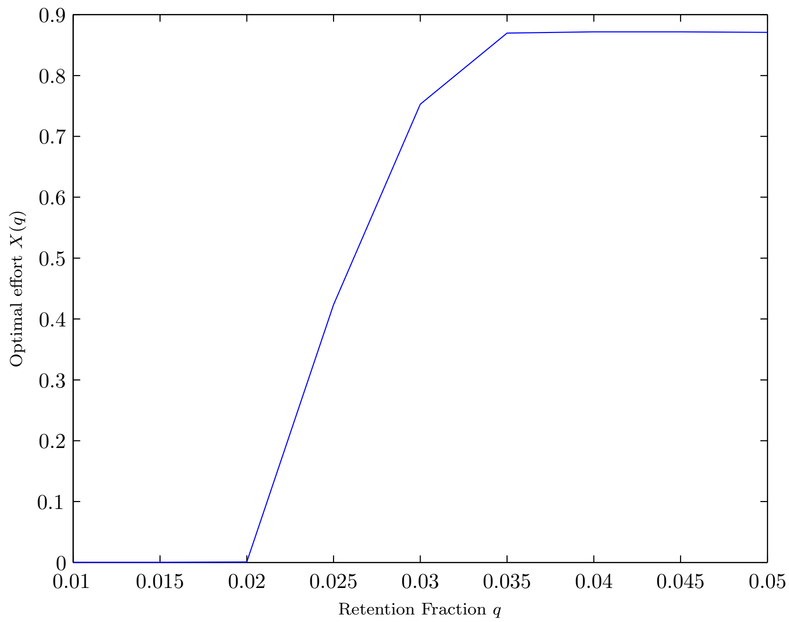

Figure 17: Optimal effort level $X(q)$ as it varies with retention fraction q.

Appendix: CDS Index Tranches

Much of the growth in credit derivative trading volumes in recent years has been in default-swap index products. An example is the "CDX" class of products. The most popular of these is the "CDX.NA.IG 5 year," which is essentially a portfolio of 125 5-year default swaps, covering equal principal amounts of debt of each of 125 named North American investment-grade issuers. Each six months, a new index is constructed. Each new series of 125 issuers is selected by polling a consortium of dealers that make markets in this product. There exist similar index products based on alternative maturities and credit qualities, and based on various issuer domiciles, including North American, Europe, Asia, and certain emerging markets.

There also exist a family of tranched index products. As illustrated in Figure

Table 2: Optimal retention fraction q^* for various combinations of excess discount rate δ and unit cost π of effort.

q^*	$\pi = 0.0008$	$\pi = 0.001$	$\pi = 0.0012$	$\pi = 0.0014$
$\delta = 0.5\%$	3.2%	3.4%	4.5%	0.0%
$\delta = 1\%$	2.8%	3.1%	3.2%	0.0%
$\delta = 1.5\%$	2.3%	2.8%	0.0%	0.0%

Table 3: Optimal effort level $X(q^*)$ for various combinations of excess discount rate δ and unit price π of effort.

u^*	$\pi = 0.0008$	$\pi = 0.001$	$\pi = 0.0012$	$\pi = 0.0014$
$\delta = 0.5\%$	1.09	0.83	0.69	0.00
$\delta = 1\%$	0.96	0.76	0.41	0.00
$\delta = 1.5\%$	0.71	0.71	0.00	0.00

18, the seller of protection on each such tranche products is responsible for all default losses on an underlying index portfolio of default swaps in excess of a stipulated "attachment point" up to a stipulated "detachment point." Thus, a tranched index product has essentially the same risk characteristics as a collateralized debt obligation.

Consider, for example, tranches on a notional \$250 million dollar position in the CDX.NA.IG 5-year index, covering \$2 million on each of the 125 firms. The seller of protection on the 0%-to-3% tranche, known as the "equity" tranche, pays all default losses for 5 years up to $0.03 \times \$250$ million = \$7.5 million that result from sale of protection on the underlying \$250 million portfolio of default swaps. Consider for example a scenario in which 3 of the named 125 firms default within the 5-year maturity, with respective losses given default of 50%,

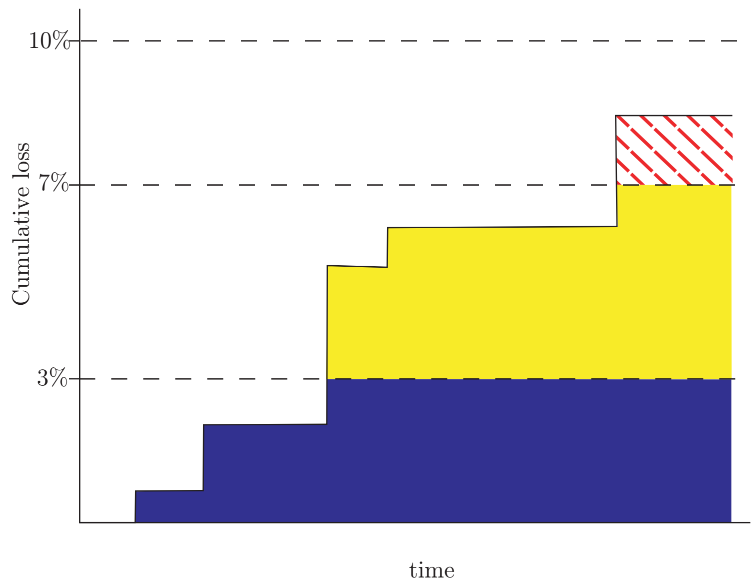

Figure 18: Tranching total default losses on a portfolio. The "first-loss" tranche absorbs the first 3% of default losses on the underlying CDS portfolio. The next tranche absorbs the next 4% of default losses, and so on.

40%, and 70%. In this scenario, the seller of protection on the equity tranche will make three successive protection payments of $1 million, $0.8 million, and $1.4 million, for a total of $3.2 million. The mezzanine tranche, covering all losses above 3% ($7.5 million) up to 7% ($17.5 million) on the underlying $250 million principal, did not suffer any losses in this scenario. In another scenario in which total default losses on the $250 million position reach $10.5 million, the equity-tranche protection seller pays $7.5 million of these losses. The 3%-to-7% ("mezzanine") tranche protection seller would pay the remaining $3 million of losses in this scenario.

In return for covering these losses, protection sellers receive fees from protection buyers. The fees are quoted in two parts, an "up-front fee," and a "running spread." Both of these are quoted as a fraction of the maximum amount of loss for that tranche. For example, in the previous example, the maximum loss for the mezzanine tranche is \$10 million. A running spread of 100 basis points means that the buyer of protection would begin paying \$100,000 per 360-day year (in quarterly amounts that are roughly \$25,000 each, based on the actual/360 daycount convention for dollars). Once defaults occur, however, the notional amount upon which the running spread is charged is reduced, dollar for dollar, with losses. For instance, if the cumulative default losses paid on the mezzanine tranche reach \$4 million, the running spread of 100 basis points is paid on the remaining \$6 million, for a payment rate of \$60,000 per year.

For the CDX.NA.IG series of tranche products, all tranches have an assigned running spread, but only the equity tranche also has an up-front fee. In fact, the equity tranche has a contractually set running spread of 500 basis points and an up-front fee that is negotiated in the market. For the other tranches of the CDX.NA.IG, there is no up-front fee; quotation is in terms of running spreads only.

Table 4 indicates pricing for the latest series (known as Series 7) of the CDX.NA.IG 5-year tranches, in terms of up-front fees and running spreads as a fraction of maximum loss on each tranche. The table also shows how the total risk-neutral expected loss rate of 31 basis points on this CDX index was allocated to the sellers of protection of each of the tranches. The equity tranche bears about 85% of the risk-neutral expected losses. The mezzanine tranche is estimated to bear 8.2% of the 31 basis points of risk-neutral loss rate, or 2.54 basis points. The running spread of $64 = 2.54/0.04$ basis points on the mezzanine tranche is represented as a fraction of the maximum loss on that tranche, which is $7\% - 3\% = 4\%$ of the notional on the index.

Table 4: CDX NA IG 5-year Series 7 tranche premia, fraction of risk-neutral expected total loss rate borne by each tranche, and base Gaussian copula correlations to the respective detachment points. (Source: Morgan Stanley data for February 19, 2007.)

Tranche	Up-front fee (%)	Running spread (b.p.)	Fraction of total loss	"hedge" (Δ)	Base corr.
0-3%	19.25	500	84.9%	23.8	14%
3-7%	0	64	8.2%	4.6	27%
7-10%	0	12	1.2%	1.1	35%
10-15%	0	5	0.9%	0.5	46%
15-30%	0	2	1.8%	0.2	71%
30-100%	0	1	3.1%	0.1	na
CDX	0	31.0	100%	1.0	na

The predominant industry approach to pricing and hedging CDOs and tranched index products is known as the "copula." A key parameter for the Gaussian copula model, the version of the copula model most commonly used for quotation purposes, is known as the "base correlation." Table 4 shows the base correlations implied by the market pricing of the respective detachment points 3%, 7%, 10%, 15%, and 30%. For a particular detachment point, say 7%, the base correlation of 27% reported in the table is the Gaussian copula correlation for pairs of firms in the underlying pool of 125 firms. The correlation parameter of 27% is chosen to match the copula model's valuation of default losses between 0 and 7% of the notional underlying with the market valuation of these losses. The fact that the base correlation varies dramatically across the detachment points makes it clear that the Gaussian copula model does not provide consistent pricing across the various tranches. The copula correlation parameter is in theory a property of the underlying pool of debt, not a property of the tranches. If the pool correlation parameter necessary to price one set of tranches is not close to the pool correlation parameter necessary to price another set of tranches, then the model is not appropriate. In practice, firms use proprietary variants of the Gaussian copula model that are sufficiently flexible to fit most of the tranche prices. As explained in the main text, however, these more flexible models are not necessarily effective, as they are not typically based on information bearing directly on default correlation, other than the CDO prices to which they are calibrated.

Because hedging depends on accurate pricing, the lack of reliable industry models for CDO pricing is especially problematic for dealers in tranche products, or levered hedge funds, who tend to hedge their mark-to-market exposures to certain tranche products with positions in other products. The deltas shown in Table 4 are based on a Gaussian copula model that is calibrated with the base correlation estimates shown for each tranche. The weaknesses of this copula model from the viewpoint of pricing are a source of concern from the viewpoint of hedging. The current lack of reliable default correlation models also leaves significant doubt about the quality of pricing of "bespoke" tranches, those based on a pool of collateralizing debt that is tailored to the specifications of investors. (The term "bespoke" means "custom made.") The tranche pricing implications of default correlation within bespoke collateral pools is difficult to infer by reference to CDX or other benchmark tranche pricing because of the often limited overlap of the sets of firms underlying bespoke and index products.

A notorious example of the ineffectiveness of delta hedging of tranches occurred with the rating downgrade of General Motors (GM) debt in May, 2005.

Theoretically, the loss that occurred to a seller of protection on the equity CDX tranche should have been largely offset by buying protection with a mezzanine tranche position, sized to offset the delta exposure of one tranche with the delta exposure of the other. For example, the deltas shown in Table 4 would have implied buying mezzanine protection for $71.4/18.4 = 3.9$ times the total CDX debt principal underlying the equity tranche position. Some market participants who took this Delta-based approach to hedging equity tranche positions with mezzanine tranche positions suffered significant losses when the mezzanine tranche price did not respond to the GM downgrade as suggested by the delta estimates that were used at the time of the downgrade. Indeed, the mezzanine tranche prices responded much less vigorously than predicted by the copula-based Delta models available at the time, and in fact responded in the *opposite* direction to that suggested by standard models. Rather then reducing their losses, hedgers following this approach slightly *increased* their losses! In mid-2007, a hedge fund managed by Bear Sterns suffered significant losses on CDOs backed in part by sub-prime mortgages.

Even when theoretically correct, delta hedging need not be especially effective in the face of large sudden price changes. In the case of the GM downgrade, standard copula-based delta models were inadequate to the task. Reporters also questioned whether efficient market pricing was a reliable approach during the GM downgrade, given the limited amount of capital available to take advantage of tranche price distortions caused by a rush by some market participants to exit their losing positions.

The situation was further exacerbated by the fact that the rating downgrade moved GM debt from investment grade to speculative grade. Investors specializing in investment grade debt (by design or by contractual limitation) would have needed to sell an exceptionally large amount of GM debt relative to the entire size of the speculative grade bond market. The associated price impact, or at least anticipation by traders of the potential price impact, could have further pushed market prices away from their efficient-market levels.

Some, however, believe that the large pool of capital now dedicated to CDO trading will mitigate future market disruptions. In "Tranches of Trepidation," (RISK, May, 2007) Navroz Patel writes that "Dealers are correct in their assertion that they have a much broader base of clients to whom they can lay off equity correlation risk, says BlueMountain's Siderow. But in his opinion, there remains a big open question over this evolution: 'How many of these newer players truly understand correlation risk, and will they stay in the market at a time of great stress?' If newer, perhaps less savvy, players do bolt for the exit door at a time of market stress, some of the major players are waiting in the wings to snap up equity tranches when correlation levels bottom out. As one correlation trader puts it, a number of major hedge funds are 'still kicking themselves' for not buying cheap equity tranches during the correlation crisis of 2005. 'I know for a fact that they would dive in and put their capital to work massively if we see that kind of dramatic price action again,' he says."

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