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Bond Portfolio Credit Analysis – The CDO Approach

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Table of Contents

I. Introduction

Many corporate bond portfolio managers are experts at the techniques of fundamental analysis for picking bonds. Many also are experts at managing their portfolios to approach the "efficient frontier" – the optimal trade-off of risk and return where risk is specified as the variability of returns. However, those techniques do not help a portfolio manager to consider the *whole distribution* of potential future credit losses on his portfolio.

Now, more sophisticated tools are available that can help a portfolio manager gain additional insight into the credit risk dimension of his portfolio. One such tool is the approach used for analyzing collateralized debt obligations ("CDOs"). Using the CDO analysis, a corporate bond portfolio manager can more completely measure his portfolio's risk and, as a result, may find opportunities to fine-tune his portfolio to improve his overall risk-return posture. In contrast to traditional tools, the CDO analysis focuses on the distribution of potential future credit losses.

While most corporate bond portfolio managers can benefit from using the CDO analysis, we expect that other types of fiduciaries can benefit just as much or even more. For example, a pension plan sponsor may use multiple asset managers who assemble portfolios that have overlapping credit exposures. The CDO approach enables the plan sponsor to measure the effect of the overlap. Based on such an analysis, the plan sponsor may be able to efficiently use credit derivatives to manage overall risk of the plan's assets without having to micro-manage the individual asset managers. Likewise, the CDO analysis can help the manager of a private placement portfolio. Such a portfolio's limited liquidity makes it impractical to manage risk with active trading. Instead, the manager of a private placement portfolio can use the CDO approach to analyze risk management strategies that use credit derivatives.

In addition, with appropriate modifications, the CDO approach reasonably can be extended to lend insight to managers of portfolios of structured finance instruments, such as asset-backed securities (ABS), mortgage-backed securities (MBS), and commercial mortgage-backed securities (CMBS).

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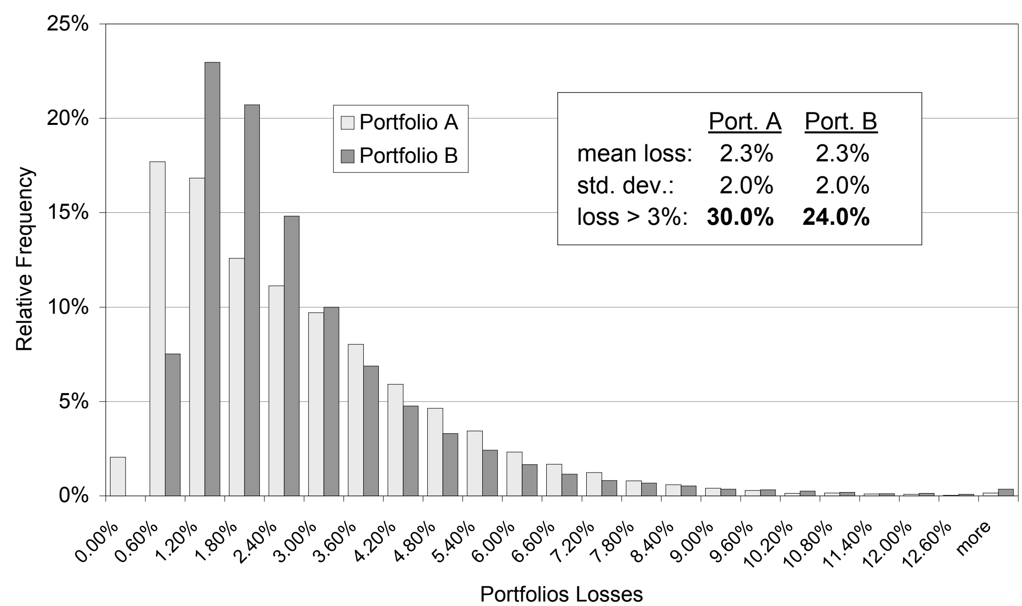
A basic CDO invests in a portfolio of bonds or loans and issues its own bonds. In most cases, a CDO issues multiple classes of bonds with different levels of seniority. Each class protects the ones senior to it from losses on the underlying portfolio. The sponsor of a CDO usually sets the size of the senior class so that it can attain triple-A ratings. Likewise, the sponsor generally designs the other classes so that they achieve successively lower ratings. In a way, the rating agencies are really the ones who determine the sizes of the classes for a given portfolio. The equity of a CDO usually comprises between 1% and 10% of the capital structure.[1]

Market participants often analyze CDOs with computer simulation techniques that highlight the distribution of outcomes that the underlying portfolio might experience. The results of such a simulation allow a portfolio manager to examine the losses that his portfolio might suffer across a range of adverse scenarios – from the moderately unlikely to the extremely remote. With that knowledge in hand, the portfolio manager can make informed decisions about how to adjust his portfolio. In particular, he may find opportunities to use credit derivatives (such as credit default swaps or "CDS") to increase or decrease his exposure at different rating levels.

Exhibit 1 illustrates why it is important for a portfolio manager to focus on the whole distribution of losses, and not merely on a point estimate of "expected losses." Exhibit 1 shows the distribution of projected losses on two portfolios over a five-year time horizon. Expected losses for both portfolios are identical. The standard deviations of both distributions are identical. Yet, the distributions are noticeably different. The likelihood of experiencing losses greater than 3% of market value is 30% for Portfolio A but just 24% for Portfolio B. All else being equal, a portfolio manager who examined the loss distributions for both portfolios likely would prefer portfolio B because of its smaller likelihood of suffering severe losses.

Exhibit 1: Two Portfolios with Different 5-Year Loss Distributions ...
BUT the same Mean and Standard Deviation of Losses



Source: Nomura Securities International

[1] For a basic introduction to CDOs, see *CDOs in Plain English*, Nomura Fixed Income Research (13 Sep 2004).

II. Key Ingredients of the Simulation

A simulation-based CDO analysis treats bonds as having mathematical properties that describe their behavior. More specifically, bond defaults are treated as if the laws of probability govern them. At first blush, the mathematical abstraction may seem repugnant to a traditional corporate bond portfolio manager. After all, in the real world, bonds default because of fundamental factors such as excessive leverage or a recessionary environment. However, for large groups of bonds viewed over extended periods, the mathematical abstraction produces a fair approximation of the real world. Remember, the CDO analysis described here should be viewed as a supplement to other tools, not as their replacement.

The heart of the CDO analysis is a Monte Carlo simulation[2] of a portfolio's credit performance over a specific time horizon (*e.g.*, one year). The analysis requires assumptions about certain properties of the underlying bonds: (1) their probabilities of default, (2) recovery rates following defaults, and (3) the correlation of default risk among different bonds.

Probability of Default: The simulation process requires that each bond in the portfolio have an assigned probability of default. For riskless securities, such as Treasury bonds, the probability of default would be zero. For all other bonds, the probability of default would be between zero and one. One easy way to assign default probabilities to bonds is to use their credit ratings from the rating agencies. For example, the historical default rate for Baa3-rated bonds arguably supplies a reasonable estimate of the probability that such bonds default in the future.

Moody's and S&P regularly publish default rates for corporate bonds. Exhibits 2 and 3 show the average default rates for bonds in different rating categories over various time horizons.

Exhibit 2: Moody's Average Issuer-Weighted Cumulative Default Rates by Alphanumeric Rating, 1983-2004 (percent)

Cohort Rating	Time Horizon (years)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Aaa	0.00	0.00	0.00	0.06	0.18	0.24	0.32	0.40	0.40	0.40
Aa1	0.00	0.00	0.00	0.15	0.15	0.25	0.25	0.25	0.25	0.25
Aa2	0.00	0.00	0.04	0.13	0.28	0.34	0.40	0.48	0.57	0.67
Aa3	0.00	0.00	0.05	0.11	0.18	0.26	0.26	0.26	0.26	0.33
A1	0.00	0.00	0.19	0.30	0.38	0.47	0.50	0.58	0.67	0.84
A2	0.03	0.08	0.22	0.47	0.68	0.89	1.05	1.34	1.59	1.69
A3	0.03	0.21	0.37	0.50	0.65	0.86	1.19	1.38	1.55	1.69
Baa1	0.17	0.50	0.84	1.14	1.46	1.69	1.92	2.05	2.21	2.31
Baa2	0.12	0.40	0.81	1.52	2.11	2.74	3.39	3.98	4.62	5.49
Baa3	0.41	1.07	1.70	2.66	3.60	4.49	5.36	6.15	6.68	7.20
Ba1	0.66	2.07	3.55	5.23	6.76	8.67	9.70	10.85	11.61	12.38
Ba2	0.62	2.22	4.48	6.84	8.82	10.11	11.85	13.13	14.20	14.66
Ba3	2.23	6.10	10.62	15.03	19.14	23.05	26.56	30.00	33.35	36.24
B1	3.03	8.89	14.81	20.09	25.27	30.29	35.69	39.97	43.98	47.43
B2	5.93	13.73	20.58	26.58	31.24	34.54	37.39	39.60	42.19	44.48
B3	10.77	20.43	29.01	36.82	43.55	49.74	54.46	58.40	61.02	62.32
Caa-C	22.24	35.80	46.75	54.60	60.40	65.15	68.30	72.36	75.38	78.81

Source: Hamilton, D., et al., *Default and Recovery Rates of Corporate Bond Issuers, 1920-2004*, Moody's special report, p. 17 (Jan 2005) (Exhibit 19).

[2] A Monte Carlo simulation is a technique for solving a problem by generating random numbers as the inputs to a modeled process and then observing the distribution of results over many trials. The technique is most useful for obtaining numerical solutions to problems that are too complicated to solve analytically. Weisstein, E., 1999. *CRC Concise Encyclopedia of Mathematics*. Chapman & Hall/CRC.

Exhibit 3: Standard & Poor's Cumulative Average Default Rates by Rating Modifier, 1981 to 2004 (percent)

Cohort Rating	Time Horizon (years)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
AAA	0.00	0.00	0.03	0.06	0.10	0.17	0.24	0.36	0.41	0.45
AA+	0.00	0.00	0.00	0.08	0.16	0.25	0.34	0.34	0.34	0.34
AA	0.00	0.00	0.00	0.07	0.15	0.23	0.35	0.50	0.63	0.77
AA-	0.02	0.10	0.23	0.36	0.52	0.68	0.83	0.91	1.00	1.11
A+	0.05	0.11	0.27	0.48	0.64	0.82	1.02	1.20	1.45	1.68
A	0.04	0.12	0.17	0.25	0.42	0.65	0.87	1.13	1.41	1.80
A-	0.04	0.16	0.32	0.54	0.86	1.18	1.61	1.87	2.20	2.44
BBB+	0.22	0.63	1.21	1.72	2.30	2.90	3.36	3.76	4.25	4.65
BBB	0.28	0.62	0.91	1.52	2.17	2.76	3.31	4.01	4.58	5.27
BBB-	0.39	1.28	2.29	3.65	4.94	6.08	6.93	7.69	8.25	8.97
BB+	0.56	1.68	3.57	5.15	6.47	7.84	9.25	9.84	10.88	11.74
BB	0.95	2.99	5.47	7.78	9.98	12.19	13.84	15.31	16.51	17.34
BB-	1.76	5.16	8.78	12.14	15.03	17.75	19.82	21.87	23.65	24.97
B+	3.01	8.40	13.46	17.79	20.86	23.15	25.34	27.16	28.63	30.15
B	8.34	16.68	22.60	26.60	29.44	31.88	33.36	34.44	35.40	36.29
B-	12.15	22.09	29.64	34.35	37.71	40.31	42.52	43.88	44.52	45.05
CCC/C	28.83	37.97	43.52	47.44	50.85	52.13	53.39	54.05	55.56	56.45

Source: Vazza, D., et al., *Annual Global Corporate Default Study: Corporate Defaults Poised to Rise in 2005*, Standard & Poor's special report (31 Jan 2005) (Table 13).

Bonds in the highest rating categories display zero defaults over time horizons of just one or two years. Therefore, for purposes of a simulation analysis, it is advisable to use default frequencies measured over longer time horizons and to convert those frequencies into equivalent one-year frequencies. For example, a five-year default rate can easily be translated into an equivalent one-year default rate with the following formula:

$$Equivalent\,One\text{–}Year\,Defalut\,Rate = 1 - \sqrt[5]{1 - (Five\text{–}Year\,Default\,Rate)}$$

Thus, the 43.55% five-year default rate for bonds rated "B3" corresponds to an equivalent one-year default rate of 10.80%.

If a portfolio manager has a specific view about whether corporate bond defaults are likely to increase or decrease, he can use higher or lower default probabilities to suit his view. For example, he could select the historical default rates of a specific year as the basis for assigning default probabilities. Exhibit 4 shows how annual default rates have varied over time for bonds rated in different rating categories by Moody's.

Beyond historical default rates, a portfolio manager has other potential sources for assigning default probabilities to specific bonds. For example, the portfolio manager can use equity prices, credit spreads, or other market data to estimate default probabilities. There are several third-party products, such as CreditEdge™ from Moody's KMV, that provide estimates of default probability based on such approaches.

Exhibit 4: Moody's Annual Issuer-Weighted Default Rates by Alphanumeric Rating, 1983-2004																		
Cohort Year	Cohort Rating																	
	Aaa	**Aa1**	**Aa2**	**Aa3**	**A1**	**A2**	**A3**	**Baa1**	**Baa2**	**Baa3**	**Ba1**	**Ba2**	**Ba3**	**B1**	**B2**	**B3**	**Caa-C**	**ALL**
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.61	0.00	10.00	17.91	40.00	0.97
1984	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.06	1.16	1.61	0.00	5.84	18.75	2.90	100.00	0.93
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.63	2.83	4.38	7.69	13.59	0.00	1.01
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.82	0.87	1.20	3.44	7.61	16.67	15.79	23.53	1.91
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.68	0.95	2.95	4.93	4.30	10.22	20.00	1.51
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.56	4.29	7.02	10.96	28.57	1.37
1989	0.00	0.00	0.00	1.34	0.00	0.00	0.00	0.00	0.79	1.06	0.79	1.82	4.69	5.73	9.66	18.05	25.00	2.27
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.67	2.82	3.91	8.50	22.36	28.93	58.82	3.64
1991	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.00	0.00	1.06	0.00	9.97	5.86	12.74	28.42	36.84	3.28
1992	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	1.00	1.56	24.54	26.67	1.33
1993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.76	3.21	4.96	11.29	28.57	0.95
1994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	1.87	3.70	8.05	5.13	0.57
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.73	4.31	6.42	4.06	11.57	1.04
1996	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.16	0.00	3.28	13.99	0.52
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	1.53	7.22	14.67	0.66
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.57	1.10	2.07	7.96	5.57	15.09	1.24
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.45	0.00	1.96	3.25	6.65	10.00	19.27	2.16
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.96	0.88	0.61	1.54	3.40	3.94	10.74	19.24	2.41
2001	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.26	0.25	0.00	0.50	1.29	2.90	3.54	10.47	16.32	33.27	3.82
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.42	1.23	0.69	1.72	1.52	1.32	1.53	1.88	6.31	6.67	30.29	3.04
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.68	1.41	0.75	2.41	5.98	21.36	1.70
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.66	1.52	12.33	0.72
Mean	0.00	0.00	0.00	0.06	0.00	0.02	0.02	0.11	0.09	0.45	0.68	0.66	2.19	3.34	7.53	11.91	21.92	1.68
Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.29	1.64	3.33	6.54	10.48	20.68	1.35
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.52	0.00	0.52
Max	0.00	0.00	0.00	1.34	0.00	0.41	0.42	1.23	0.79	4.82	3.68	2.82	9.97	8.50	22.36	28.93	58.82	3.82
StDev	0.00	0.00	0.00	0.29	0.00	0.09	0.09	0.30	0.23	1.09	0.95	0.81	2.16	2.44	5.88	7.89	13.62	1.01

Source: Hamilton, D., et al., *Default and Recovery Rates of Corporate Bond Issuers, 1920-2004*, Moody's special report, p. 15 (Jan 2005) (Exhibit 16).

<u>Recovery Rates</u>: As with default rates, historical data provides a reasonable basis for assumed recovery rates in a simulation. Exhibit 5 shows historical recovery rates reported by Moody's:

Exhibit 5: Moody's Annual Average Issuer-Weighted Defaulted Bond Recovery Rates by Seniority Class, 1982-2004 (percent)						
Default Year	**Senior Secured**	**Senior Unsecured**	**Senior Subordinated**	**Subordinated**	**Junior Subordinated**	**All bonds**
1982	72.50	34.40	48.10	32.30	NA	35.00
1983	40.00	52.70	43.50	41.40	NA	50.10
1984	NA	49.40	67.90	44.30	NA	44.40
1985	83.60	60.20	30.90	42.70	48.50	39.90
1986	59.20	52.60	50.20	42.90	NA	44.30
1987	71.00	62.70	46.50	46.20	NA	61.70
1988	55.30	45.20	33.40	33.00	36.50	42.90
1989	46.50	43.80	33.10	26.80	16.90	32.80
1990	35.70	37.00	26.70	19.50	10.70	27.50
1991	50.10	38.90	43.80	24.10	7.80	39.10
1992	62.70	52.10	47.90	37.80	13.50	45.50
1993	NA	37.10	51.90	43.70	NA	48.00
1994	69.30	53.70	29.60	33.70	NA	44.50
1995	63.60	47.60	34.30	39.40	NA	45.80
1996	47.60	62.80	43.80	22.60	NA	43.60
1997	76.00	55.10	44.70	38.40	30.60	51.80
1998	51.80	39.50	44.20	14.10	62.00	40.40
1999	43.30	38.30	29.10	35.50	NA	37.60
2000	41.70	24.40	20.30	31.90	15.50	25.70
2001	41.70	23.10	20.90	15.90	47.00	34.30

Exhibit 5: Moody's Annual Average Issuer-Weighted Defaulted Bond Recovery Rates by Seniority Class, 1982-2004 (percent)						
Default Year	**Senior Secured**	**Senior Unsecured**	**Senior Subordi-nated**	**Subordi-nated**	**Junior Subordi-nated**	**All bonds**
2002	49.30	30.50	25.30	24.50	NA	34.60
2003	63.50	41.40	39.60	12.30	NA	43.10
2004	80.80	50.10	44.40	NA	NA	58.50
Mean	57.40	44.90	39.10	32.00	28.90	42.20
Median	55.30	45.20	43.50	33.40	23.70	43.10
Min	35.70	23.10	20.30	12.30	7.80	25.70
Max	83.60	62.80	67.90	46.20	62.00	61.70
StDev	14.30	11.20	11.40	10.50	18.90	8.70

Source: Hamilton, D., et al., *Default and Recovery Rates of Corporate Bond Issuers, 1920-2004*, Moody's special report, p. 34 (Jan 2005) (Exhibit 27).

The simplest approach is to use a single recovery rate assumption for all bonds in a portfolio. Because most corporate bonds represent senior unsecured debt or senior subordinated debt, a reasonable starting point is to apply a recovery assumption of 40%. However, a simulation model becomes only slightly more complex by adding different assumed recovery rates for bonds at different levels of seniority (or for bonds at different rating levels).

In the most elaborate simulations, recovery rates can be tied to (*i.e.*, correlated with) default rates, so that recoveries decline when there are many defaults (*e.g.*, during a recession). There is some evidence of an inverse correlation between default rates and recovery rates.[3]

Correlation: Correlation is the trickiest part of a CDO analysis. There are many mathematical approaches for tackling correlation. Some are quite complicated and require a portfolio manager to assign a correlation factor to each separate pairing of bonds in the portfolio (*i.e.*, construct a whole "correlation matrix"). A somewhat simpler approach is to assign correlation factors based on the specific industrial classifications of the bonds' issuers. Fitch uses that approach in its CDO rating analysis. An even simpler approach, and the one used by S&P, is to assume a single correlation factor between bonds from issuers in the same industry and a somewhat lower factor for the correlation between bonds from issuers in different industries. For example, S&P generally assumes 30% correlation between issuers in the same industry and 0% correlation between issuers in different industries.[4] An even simpler approach is to use a single correlation factor to describe all correlations within a portfolio. That is the approach used by many trading desks for managing their risk from trading credit derivatives.[5]

For purposes of simulating the credit risk dimension of a corporate bond portfolio, it is reasonable to balance the desire for detailed realism with the benefits of simplicity. We recommend using a framework with two correlation factors: one defining the correlation among bonds from issuers in the same industry and one defining the correlation among bonds from issuers in different industries. A fair starting point is 15% inter-industry correlation and 35% intra-industry correlation. That provides a somewhat more conservative correlation assumption than the ones used by Moody's and S&P in their CDO rating analyses.

Once we have the three key ingredients – default probabilities, recovery rates, and correlations – we need one more item before it we can really perform a CDO analysis: a simulation model.

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[3] Vazza, D., et al., *Annual Global Corporate Default Study: Corporate Defaults Poised to Rise in 2005*, Standard & Poor's special report (31 Jan 2005) (Chart 17 and accompanying text).

[4] *Global Cash Flow and Synthetic CDO Criteria*, Standard & Poor's special report (21 Mar 2002), p. 44.

[5] *Correlation Primer*, Nomura Fixed Income Research (6 Aug 2004).

III. The Simulation Model

The simulation model for a CDO analysis takes the three key assumptions and processes them to generate a distribution of simulated outcomes for the subject portfolio. The simulation process consists of numerous "iterations" of the main calculations, often 10,000 or more. In each iteration, the computer generates random numbers and uses them, together with the key assumptions, to calculate simulated losses on the subject portfolio. Then, the simulation aggregates the results for all iterations and reports the distribution of outcomes.

The calculation process in each iteration can be either simple or complex. Simplicity offers the advantages of high speed and low cost. Greater complexity offers the *potential* advantage of greater realism. We generally favor a balance between the two extremes. Many financial professionals possess the skills to create their own simple simulations using either Microsoft Excel by itself or in combination with specialized simulation add-ins such as @Risk from Palisade Corporation. Complex simulation models may require programming work by specialists, which can have the effect of distancing a portfolio manager from his simulation model.

We described a simple simulation model last year in our paper titled *Correlation Primer* (6 Aug 2004). At the risk of repeating ourselves, here is quick rundown on how it works:

The simulation uses the notion of "default time," which is usually designated with the Greek letter Tau (τ). In essence, the key idea is that all risky issuers *eventually* default, at some point between now and the end of the world. The converse of an issuer's default probability is its survival probability. For example, if an issuer's default probability is 5% annually, its survival probability for one year is 95%. Its survival probability for two years would be 90.25%, which is 95% squared. The issuer's survival probability for τ years would be 95% raised to the power of τ (*i.e.*, 0.95^{τ}).

To simulate the default time for bonds of a particular issuer, generate a uniform random variable, u, and solve the following formula for τ:

$$0.95^{\tau} = u$$

If τ is longer than the maturity of a given bond from the related issuer (or longer than the time horizon of the simulation), the bond does not default. If τ is shorter than the bond's maturity, a default occurs.

Correlation: For a good model, it is not enough to simply simulate the default times of individual bonds in a portfolio. It is further necessary to address the correlation of default risk among the bonds. To do this, we use techniques to link the default times of different issuers. For our own purposes, we use a model that allows us to specify *individual* correlation coefficients between each pair of issuers. A somewhat simpler way is to use a "single factor" approach with just *one* correlation coefficient (ρ) that describes the correlation among all pairs of bonds in the portfolio.

For example, a single-factor "Gaussian copula" approach uses four steps to produce correlated default times (τ) for different issuers in a portfolio:

1. First, for a portfolio of n bonds from different issuers, generate n+1 independent, normally distributed random variables. Designate one of them y and the rest of them ε_1 through ε_n.

2. Second, combine the correlation coefficient (ρ) with the variables from the previous step to generate n correlated, normally distributed random variables (designated x_1 through x_n) by using the following formula:

$$x_i = \sqrt{\rho}\, y + \sqrt{1-\rho}\, \varepsilon_i$$

3. Third, use the cumulative distribution function of the standard normal distribution to convert each of the x_i variables into a corresponding uniformly distributed random variable in the range from 0 to 1, designated u_i.

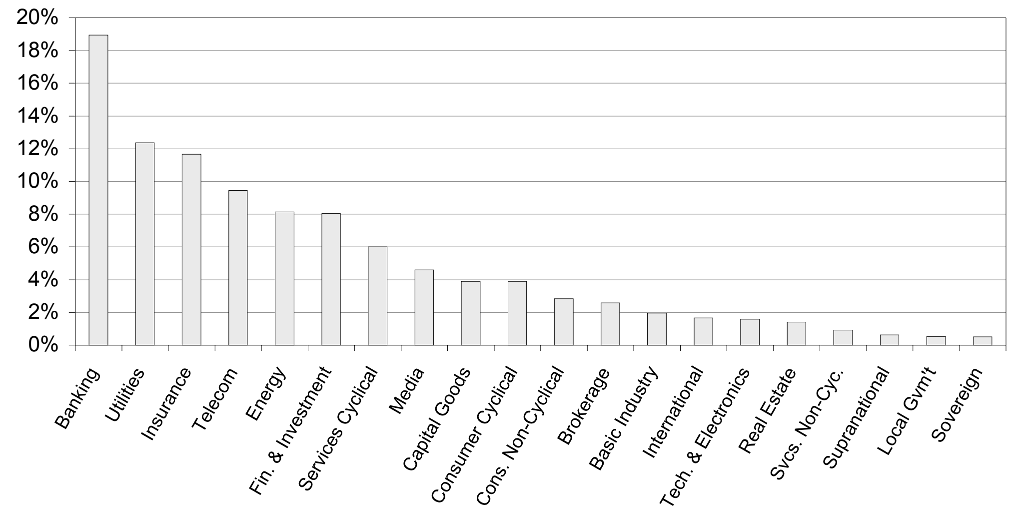
4. Fourth, use the u_i variables and the default time formula above to calculate τ_i values, where τ_i is the default time of the i^{th} issuer of the portfolio.

Each iteration of the simulation uses simulated default times to tell whether bonds of each issuer default. That is, the simulation uses τ_i to tell whether bonds of the i^{th} issuer default. For each bond that defaults, the portfolio losses the principal amount of the bond less the recovery. Summing the losses for all defaulted bonds gives the total portfolio loss for that iteration. Repeating the process thousands of times provides a whole distribution of portfolio losses that a portfolio manager can examine and analyze.

IV. Running the Simulation

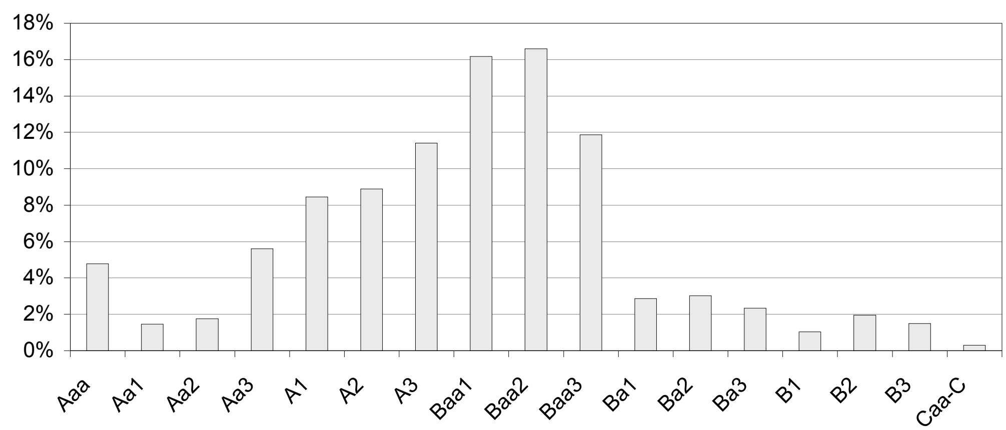
Suppose a hypothetical portfolio manager manages a portfolio comprising corporate bonds from around 200 issuers. Suppose that the average rating of the issuers is around Baa3/BBB- and that the portfolio is slightly over-weighted in certain industries. Exhibit 6 shows the industry diversification of the portfolio and Exhibit 7 shows the rating distribution:

Exhibit 6: Portfolio Industry Diversification



Source: Nomura Securities International

Exhibit 7: Portfolio Credit Quality Distribution



Source: Nomura Securities International

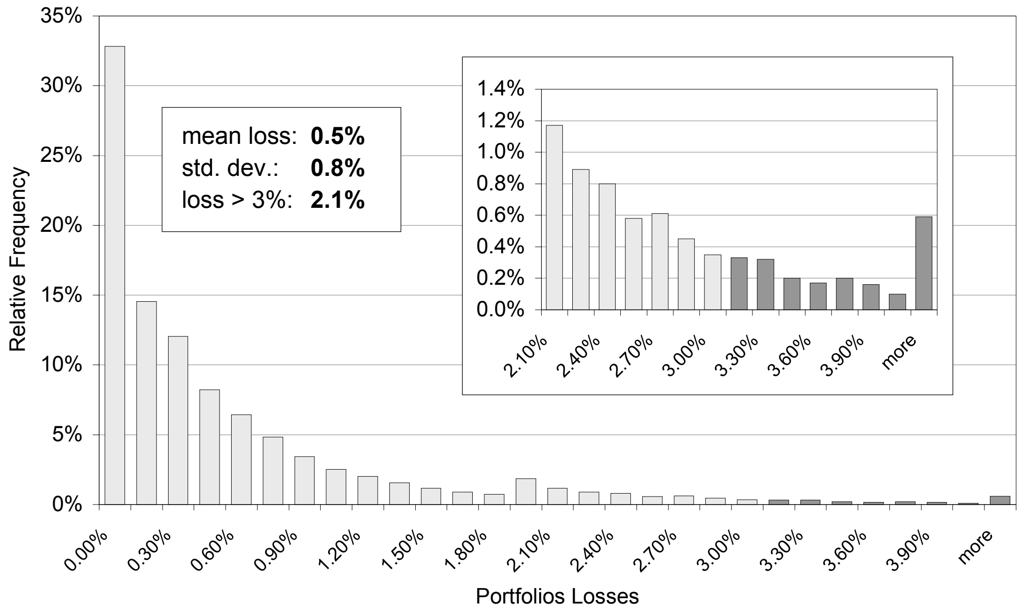
The portfolio manager could run simulations on his portfolio to graph the distribution of simulated losses, expressed as a percentage of market value. Suppose that he uses default probabilities based on Moody's historical default rates and assumed inter-industry correlation of 15% and intra-industry correlation of 35%. Suppose further that he assumes recovery rates that vary according to rating category – that is, that bonds with higher ratings experience higher recovery rates following default than bonds of lower ratings.

V. Interpreting the Results

Suppose that the portfolio manager simulates the performance of the portfolio over a period of one year and gets the loss distributions shown on Exhibit 8. He would observe that the loss distribution for the portfolio has a "tail" extending out to the right. The loss distribution in Exhibit 8 shows that there is roughly a 2.1% chance of losing more than three percent of the portfolio's value in one year. The portfolio manager must decide whether that likelihood is within acceptable bounds. If not, he can experiment with various strategies for fine-tuning the portfolio to alter its exposure to high-loss scenarios.

Examining Exhibit 8, the portfolio manager would observe a slight "bump" in the loss distribution at the 1.95% bucket.[6] That bump reflects the impact of the portfolio's lumpiness – it has bonds from only around 200 issuers. Without performing simulations, the portfolio manager probably could not discern that losses in the 1.95% bucket are somewhat more likely than losses in the 1.80% or 1.65% buckets.

Exhibit 8: Simulated Portfolio Loss Distribution
Base Case; One-Year Time-Horizon



Source: Nomura Securities International

To explore the implications further, suppose that the portfolio manager performs simulations over a longer time horizon, such as five years. The results are shown in Exhibit 9. Here, the simulated frequency of suffering losses of more than three percent increases to 30%.

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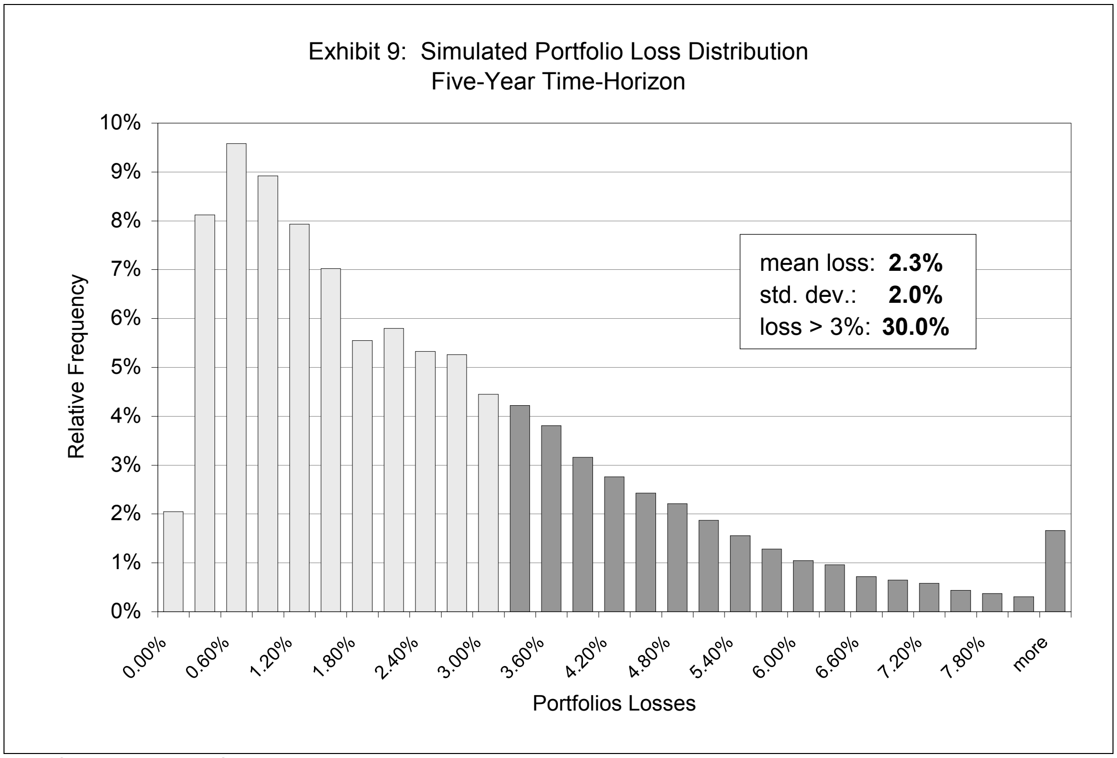
[6] The 1.95% bucket represents the frequency with which simulated losses are <u>greater than</u> 1.80% and <u>less than or equal</u> to 1.95%.



Source: Nomura Securities International

The simulation results shown in Exhibits 8 and 9 treat the portfolio as entirely static. While that may be a reasonable basis for a one-year time horizon, it may be unrealistic for an actively managed portfolio over a longer interval; the portfolio manager might trade out of some positions that would otherwise have subsequently defaulted. One the other hand, for portfolios comprised of illiquid securities, such as private placements, it may be not be possible to trade out of deteriorating credits. In that case, treating the portfolio as static over longer time horizons is entirely reasonable (and prudent).

In addition, the results shown in Exhibits 8 and 9 show losses on a gross basis. That is, they do not show the offsetting effect of incremental spread that the portfolio earns from investing in risky securities. Indeed, as shown on Exhibit 7, nearly 58% of the portfolio is rated below single-A and slightly over 13% is rated double-B or lower.

VI. Acting on the Results

If the portfolio manager feels that the portfolio has too much exposure to the risk of severe losses (*i.e.*, >3%) he can consider several options. One possibility would be to sell some of the portfolio's weaker credits. Alternatively, the portfolio manager might use credit derivatives to adjust the distribution of losses. For example, techniques for tuning performance may include any of the following:

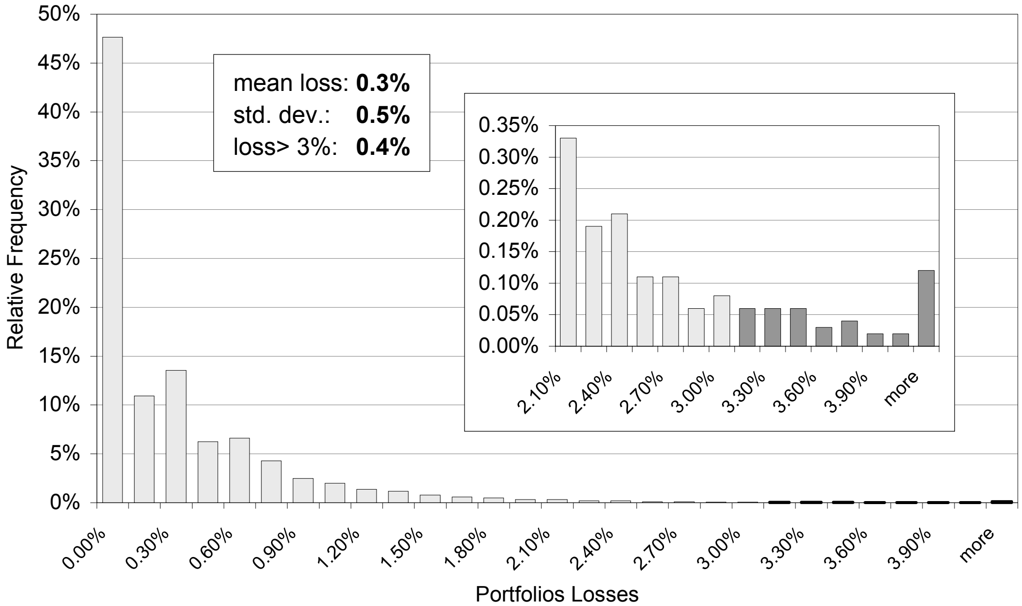
- buying protection through a CDS index (*e.g.*, DJ CDX.NA.IG or DJ CDX.NA.HY) to reduce *macro* risk,[7]
- buying protection through a CDS sub-sector index (*e.g.*, DJ CDX.NA.ENRG or DJ CDX.NA.INDU) to reduce *sector-specific* risk, or
- buying single-name CDS to reduce *name-specific* risk.

[7] *Credit Default Swap (CDS) Primer*, Nomura Fixed Income Research (12 May 2004).

The portfolio manager could buy protection for a five-year time horizon using standard contracts. Alternatively, he could purchase protection for a shorter period with the intention of adjusting the hedge periodically. Another option for the portfolio manager would be to re-balance his portfolio toward stronger credits by *selling* protection on issuers that are not already included in the portfolio.

Suppose that the portfolio manager uses CDS to buy protection on the single-B-rated issuers in the portfolio. Chart 5 shows the distribution of simulated losses on the portfolio after giving effect to protection on the single-B-rated issuers. Comparing Exhibit 10 with Exhibit 8, the portfolio manager would see that the tail of the distribution is *much* thinner. In fact, by hedging the single-B exposures, the simulated frequency of suffering losses of more than three percent declines to just 0.4%, compared to 2.1% in the base case (Exhibit 8). In addition, the mean simulated loss on the portfolio drops 23 basis points with the hedge, compared to the base case.

Exhibit 10: Simulated Portfolio Loss Distribution
Hedging Single-B Exposures; One-Year Time-Horizon

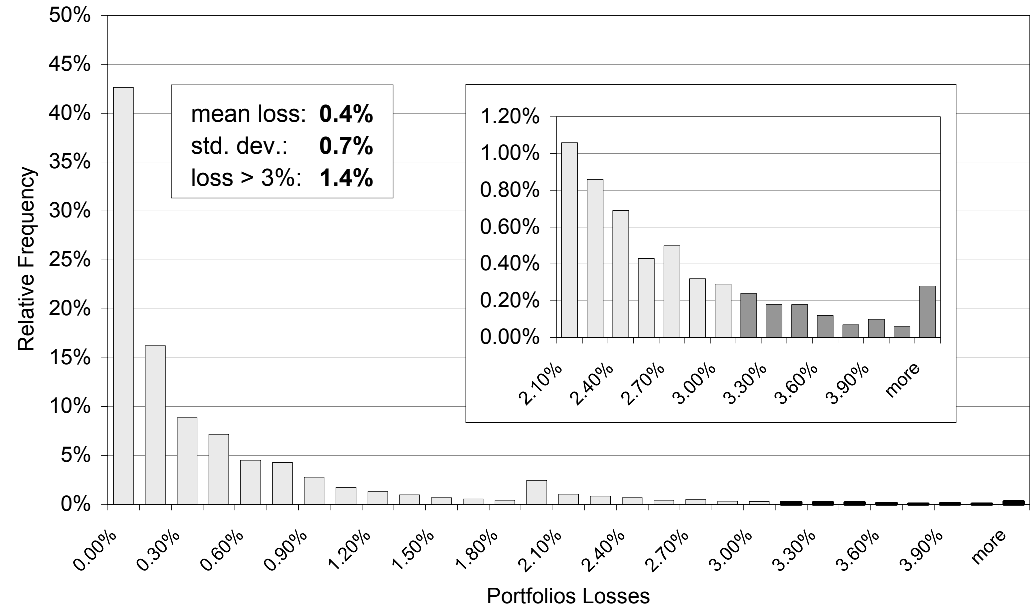


Source: Nomura Securities International

Suppose that the cost of hedging the single-B credits is about 330 basis points on the single-B portion of the portfolio (on a running basis). The single-B credits compose roughly 4.5% of the whole portfolio. Therefore, on an overall basis, the cost of hedging the single-B credits translates into 15 basis points on the total portfolio. Thus, the benefits of the hedge – 23 basis point reduction in mean losses and a thinner tail on whole distribution of expected losses – appear to fully justify the cost of 15 basis points.

Alternatively, The portfolio manager might consider hedging the double-B credits in the portfolio. Exhibit 11 shows the distribution of simulated losses on the portfolio after giving effect to protection on the double-B-rated issuers. Comparing Exhibit 11 with the base case (Exhibit 8), the portfolio manager would see that the tail of the distribution is somewhat thinner; the simulated frequency with which losses exceed three percent is 1.4%, compared to 2.1% in the base case. In addition, the mean simulated loss on the portfolio drops 11 basis points with the hedge, compared to the base case.

Exhibit 11: Simulated Portfolio Loss Distribution
Hedging Double-B Exposures; One-Year Time-Horizon



Source: Nomura Securities International

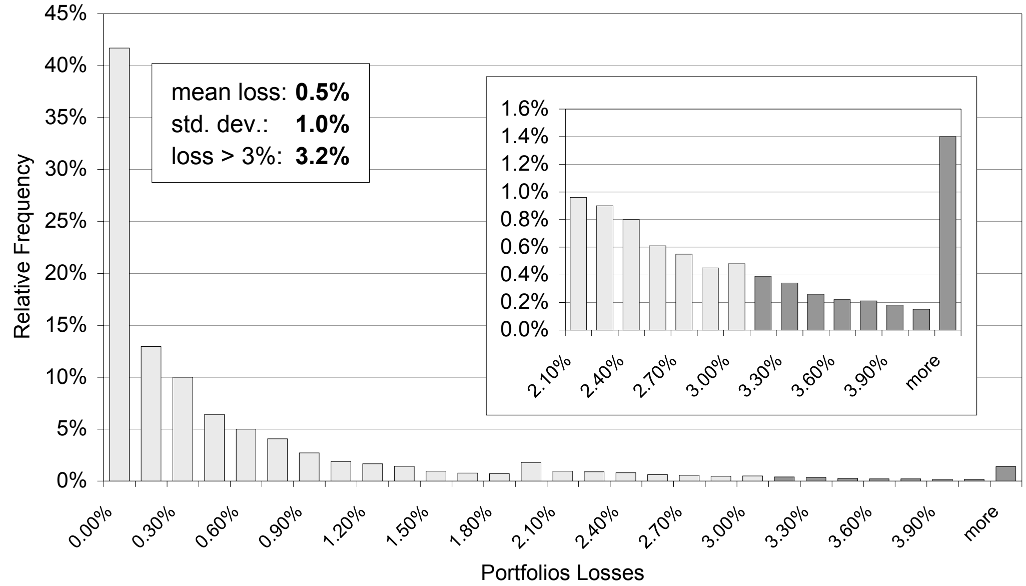
Suppose that the cost of hedging the double-B credits is about 170 basis points on the double-B portion of the portfolio (on a running basis). The single-B credits compose roughly 8.2% of the whole portfolio. Therefore, on an overall basis, the cost of hedging the double-B credits translates into 14 basis points on the total portfolio. Thus, the benefits of the double-B hedge – 11 basis point reduction in mean losses and a slightly thinner tail – may not justify the 14 basis point cost of the hedge. Thus, hedging the single-B portion of the portfolio would be a better strategy.

VII. Reality Check

A key aspect of any simulation based analysis is sensitivity testing. A cautious portfolio manager generally would consider how his simulation results would be affected by changing the initial assumptions of his model. Doing so is an essential step toward establishing confidence in the model.

For example, the portfolio manager might experiment by testing higher levels of correlation among issuers. Exhibit 12 shows the effect of assuming inter-industry correlation of 25% and intra-industry correlation of 45%:

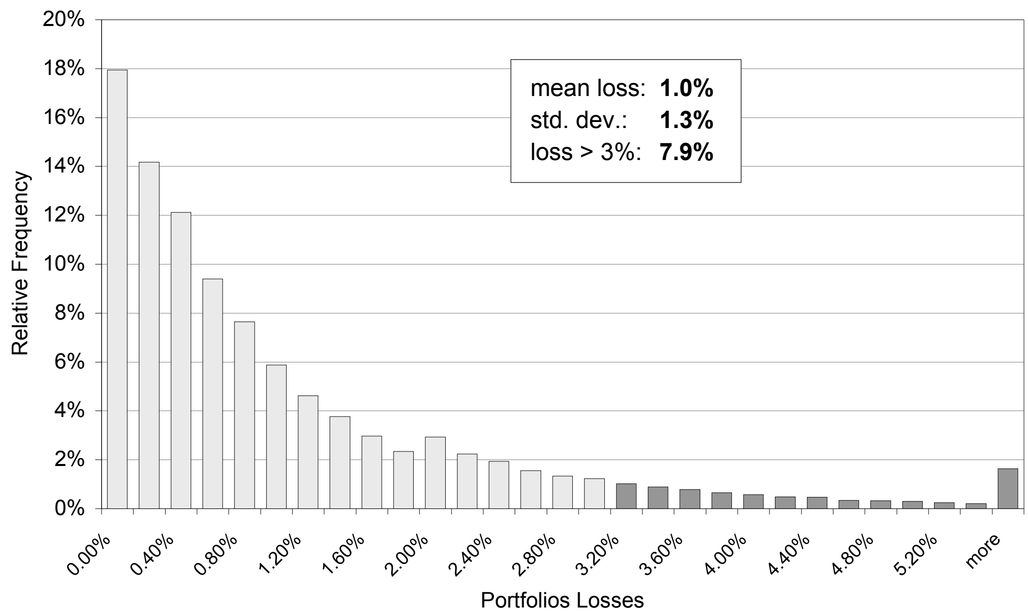
Exhibit 12: Simulated Portfolio Loss Distribution
Higher Correlation (25% inter-industry, 45% intra-industry); One-Year Time-Horizon



Source: Nomura Securities International

In Exhibit 12, there is a 3.2% frequency of losses exceeding three percent of the portfolio's value. That is somewhat higher than the 2.1% frequency of the base case assumptions (Exhibit 8). Likewise, the portfolio manager might test a simulation where all default probabilities are increased by one percentage point. The result is shown in Exhibit 13. Increasing all the default probabilities has a very pronounced impact. The frequency with which losses exceed three percent rises to roughly 7.9%.

Exhibit 13: Simulated Portfolio Loss Distribution
Higher Default Probabilities (+1.0%); One-Year Time-Horizon



Source: Nomura Securities International

By experimenting with different assumptions, the portfolio manager learns the model's sensitivities while simultaneously gaining insight into the risk dimension of the portfolio.

VIII. Conclusion

The CDO analysis is a supplement to a portfolio manager's other tools. It does not replace either fundamental bond analysis or other types of portfolio optimization (efficient frontier) analyses. Nor does it replace experience, judgment, and insight as key ingredients for success in managing a corporate bond portfolio.

The CDO analysis enables a corporate bond portfolio manager to explore and analyze the whole distribution of potential future performance. The analysis ascribes mathematical properties to bonds and then uses computer simulations to illuminate the implications. The key benefit of the CDO analysis is that it provides a whole distribution of future results, rather than just the "most likely" scenario. In addition, it offers the benefits of internal consistency, repeatability, ease of use, and results that can provide the basis for concrete action. It is a useful and powerful instrument that a corporate bond portfolio manager should eagerly add to his financial toolkit.

— E N D —

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