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RISK MANAGEMENT FOR EQUITY PORTFOLIOS OF JAPANESE BANKS

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ABSTRACT

This paper verifies the impact of equity portfolio on bank management, underscoring the importance of managing the risks involved and suggesting "management of sensitivity against equity price risk" as one risk management technique that takes into account the correlation between equity price risk and credit risk. To do this, the paper focuses on the high correlation between "expected default probability estimated by the option-approach (Merton method)" using equity price information and "spread over Libor" observed in the bond market. This is used to calculate sensitivity (delta and vega) to changes in equity price and its volatility. According to calculations for a sample portfolio, these two sensitivities have a degree of utility in measuring the distribution of risk exposure and in using equity price index futures and options as hedges. In the hedging of vega risk (which tends to reflect credit risk) in particular, long put positions in equity price index options are shown to be potentially effective.

Keywords: equity portfolio, loan, expected default probability, spread over Libor, equity price risk, credit risk, sensitivity

JEL classification: G14, G21

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1. Preface

The Japanese banks have long acknowledged the price risks in their equity portfolios, but have done little to manage or control those risks. The primary reasons involved in this are: 1) the fact that the equities have been put in their portfolios for the "strategic" purpose of maintaining business relationship with their clients; 2) the fact that high rates of return on investments in the late 1980s gave portfolios large unrealized profits that provided financial stability with the banks; and 3) the fact that there were few tools with which to hedge risks even the banks had wanted to do so for the equities in their portfolios.

However, the prolonged slump in Japanese equity market has caused these same equities to become a factor for instability in the banks' financial health, and the banks are now being forced to reconsider their purposes for holding the equities in their portfolios. Indeed, emergency relief measures had to be brought in for the fiscal year ending March 1998. The measures provided banks with the choice of valuing their stock portfolios at cost and also allowed them to count unrealized gains on real estate towards their capital. These measures are, however, nothing more than temporary accounting manipulations and the banks will probably find themselves pressed to manage and control their exposure to equity price risks from now on. Furthermore, the anticipated expansion in the securities derivatives market, which will provide more hedging tools, can drive this trend.

It is from these perspectives that this paper studies some methods of equity price risk management. One point given particular emphasis in this study is the relationship between equity price risk and credit risk. The banks have for many years both held issued by their clients for strategic purposes and also loaned money to those same clients. There is a positive correlation between equity price risk and credit risk, and both tend to emerge in times of economic downturn. From the perspective of bank management, therefore, it would be better for the banks to consider their business relationship with their clients in such a way as to measure and manage both the risk and the profitability of their clients, integrating credit risk and equity price risk, rather than merely measuring and managing both risks separately.

This paper is as follows: In Chapter 2, we use accounting data disclosed by large banks to quantify their risk exposure and estimate its impact on bank management. This is done to demonstrate how important it is for banks that they manage the risks in their equity portfolios. In Chapter 3, we perform an empirical analysis that demonstrates the high correlation between equity price risk and credit risk. In Chapter 4, using the relationships demonstrated in the previous chapter, we show some techniques that can be used to manage risks in portfolio comprising equities and loans. In Chapter 5, the concluding chapter in this paper, we briefly summarize our findings and suggest future directions in our research.

2. IMPACT OF EQUITY PORTFOLIO ON BANK MANAGEMENT

This chapter uses accounting data disclosed by the Japanese major banks (city banks and long-term credit banks[1]) to quantify their risk exposures and illustrate the impact that this risk has on bank management. In Section 1 we consider the impact on corporate value and accounting profit or loss. In Section 2, we consider the impact on the BIS capital adequacy standards.

- We begin by estimating risk exposures at the end of the next half accounting term (six months hence). In the formula for doing this (shown below), t stands for the length of the term, K for book value at the end of the preceding term, S_0 for prevailing market price at the end of the preceding term, S_t for prevailing market prices at the end of this term, r_E for return on equity, and σ_E for equity price volatility.

$$S_t = S_0 \exp\left[\left(r_E - \frac{{\sigma_E}^2}{2}\right)t + \sigma_E \sqrt{t}\varepsilon\right]\text{、 as } \varepsilon \sim \Phi(0,1) \qquad (1)$$

- The disclosure documents furnished by the banks do not provide details on the specific issues in their equity portfolios or the amounts invested in each. For the purpose of simplicity, therefore, we have assumed that each bank had a portfolio which structure was the equivalent of the TOPIX index. We consider the TOPIX index to be a good approximation because the equity portfolios of city banks and long-term credit banks are generally made up of equities of listed medium and large-size companies with whom these banks have entered into cross-shareholding relations as an outgrowth of lending transactions.
- To demonstrate the increase in risk exposures to equity write-offs, we have compared indexes calculated for two periods: the end of March 1992, which marked the beginning of full-fledged efforts to clean up bad loans after crash of bubble economy, and the end of March 1997, which was the most recent time at which the banks were not given the option of accounting for equities at cost.

2 – 1 Impact on corporate value and accounting profit or loss

(1) Value at risk (VaR)

We will begin by considering the impact on corporate value by calculating VaR (holding period t is a half-year, confidence interval is 99% tile) as shown in Equation (2).

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[1] We have excluded from this study Hokkaido Takushoku Bank (which failed last year) and Japan Credit Bank (which moved to domestic standards for capital adequacy in March 1998). For the pre-merger Bank of Tokyo-Mitsubishi we use simple totals from the financial statistics of Mitsubishi Bank and the Bank of Tokyo.

$$VaR = 2.33 \cdot \sigma_{TOPIX} \sqrt{t} S_t \tag{2}$$

Note: σ_{TOPIX} stands for the daily volatility of TOPIX (calculated using two years of historical data).

Figure 1 contains the results for the calculations. Note that VaR (average per bank) has declined from ¥1,174 billion at the end of March 1992 to ¥778 billion at the end of March 1997 because of a decline in volatility.[2] At the same time, the ratio of VaR to unrealized gains on equities (VaR to URG ratio) rose from 97% at the end of March 1992 to 142% at the end of March 1997 because of the need to take profits on equities in order to write off bad loans, which consequently raised book values.[3]

- Individually, the VaR to URG ratio (at the end of March 1997) was particularly high for Bank G (496%) and Bank A (340%), which were hit harder than other banks by the decline in unrealized gains over recent years. Only Bank E had unrealized gains on equities in excess of VaR (80%).

[Figure1] VaR (billion yen)

	End of Mar. 1992		End of Mar. 1997	
	VaR	VaR to URG ratio	VaR	VaR to URG ratio
Bank A	571	93.2%	382	340.7%
Bank B	1208	129.3%	837	249.8%
Bank C	905	98.4%	650	128.9%
Bank D	1205	104.4%	877	137.4%
Bank E	1838	101.7%	1251	80.0%
Bank F	1547	94.5%	1021	150.7%
Bank G	1006	88.0%	546	496.7%
Bank H	1367	80.5%	748	229.8%
Bank I	1325	98.6%	859	114.3%
Bank J	788	83.3%	567	167.5%
Bank K	1148	106.3%	819	125.1%
Average	1174	97.2%	778	142.4%

2 The daily volatility of the TOPIX declined from 1.39% at the end of March 1992 to 0.94% at the end of March 1997.

3 Average book value was 2,020 billion yen at the end of March 1992 (against market value of 3,230 billion yen), but had risen to 2,630 billion yen at the end of March 1997 (against market value of 2,180 billion yen).

(2) Expected write-off of equities

In this subsection we seek the expected write-off of equities (EW) at the end of the term (six months hence). For the write-off, we posted the difference between the term-end market price and the book value at the end of the previous term as a loss if the market price was less than the book value. Therefore, if the market price was approaching the book value at the end of the previous term, there was a higher likelihood that a write-off would be seen at the end of this term. Working from this mechanism, it is possible to calculate EW as a future value of a put option with a strike price of *K*, which is the book value at the end of the previous term. This is done in Equation (3).[4]

$$\begin{aligned} EW &= \int_{-\infty}^{\infty} Max(K - S_t, 0) f(S_t) dS_t \\ &= K\Phi(-d + \sigma\sqrt{t}) - S_0 e^{rt} \Phi(-d) \qquad (3) \end{aligned}$$

Where,

$$d = \frac{\ln \frac{S_0}{K} + \left(r + \frac{\sigma_E{}^2}{2} \right) t}{\sigma\sqrt{t}}、$$

f : Probability density function of lognormal distribution

Φ: Cumulative density function of standard normal distribution

Figure 2 contains the results of the calculation.[5] At the end of March 1992, EW (average per bank) was tiny, and EW to URG ratio was 0.0%, but the rise in book values caused it to increase to 2.2% at the end of March 1997 (in monetary terms, about a 30-fold increase from the end of March 1992).

- Looking at individual banks, EW to URG ratio was particularly high for Bank G (39%) and Bank A (18%), which corresponds to the large VaR values calculated in Subsection (1).

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4 There will probably be some dispute over whether to use the expected rate of return r_E or the risk-free rate r in calculating the EW. We have decided to use the risk-free rate r (which was assumed to be 1%).

5 In performing these calculations, we assumed, as noted above, that each bank had a portfolio structured to be the equivalent of the TOPIX index, so TOPIX was the only probability variable. However, it is ordinary for individual stocks to decline even if the index itself is rising, so our EW is probably understated.

[Figure 2] Expected Write-Off (billion yen)

	End of Mar. 1992		End of Mar. 1997	
	EW	EW to URG ratio	EW	EW to URG ratio
Bank A	0.0	0.0%	20.4	18.2%
Bank B	2.5	0.3%	26.8	8.0%
Bank C	0.1	0.0%	1.8	0.4%
Bank D	0.3	0.0%	3.6	0.6%
Bank E	0.4	0.0%	0.0	0.0%
Bank F	0.1	0.0%	6.7	1.0%
Bank G	0.0	0.0%	43.1	39.2%
Bank H	0.0	0.0%	20.0	6.1%
Bank I	0.2	0.0%	1.1	0.1%
Bank J	0.0	0.0%	5.8	1.7%
Bank K	0.4	0.0%	1.9	0.3%
Average	0.4	0.0%	12.0	2.2%

(3) 99% tile point of the equity write-off

This subsection calculates the 99% tile point of the equity write-off (99%W); the results will be found in Figure 3. The amount of 99%W (average for per bank) was negligible at the end of March 1992 (3% of the unrealized gains on equities), but had risen to 47% at the end of March 1997. In monetary terms, it was on the order of several hundred billion yen for all except Bank E, which is an indication that the rise in book values has weakened bank's profit structures.

[Figure 3] 99%W (billion yen)

	End of Mar. 1992		End of Mar. 1997	
	99%W	99%W to URG ratio	99%W	99%W to URG ratio
Bank A	0	0.0%	270	240.7%
Bank B	273	29.3%	502	149.8%
Bank C	0	0.0%	145	28.9%
Bank D	51	4.4%	238	37.4%
Bank E	30	1.7%	0	0.0%
Bank F	0	0.0%	343	50.7%
Bank G	0	0.0%	436	396.7%
Bank H	0	0.0%	422	129.8%
Bank I	0	0.0%	107	14.3%
Bank J	0	0.0%	228	67.5%
Bank K	67	6.3%	164	25.1%
Average	38	3.2%	260	47.6%

2 – 2 Impact on BIS capital adequacy standards

This section considers the impact of equity portfolio on the BIS capital adequacy standard ratio (BIS ratio). Unrealized gains on equity portfolio (URG) are, for the BIS purposes, counted into Tier II capital (which allows 45% of unrealized gains on securities, up to the amount of Tier I capital). Uncertainty over term-end equity price therefore translates directly into uncertainty over BIS ratio.

Equation (4) calculates URG to be counted towards Tier II at the end of the term:

$$\begin{aligned} URG &= Min(S_t - K, UL) \\ &= UL - Max(UL - (S_t - K), 0) \end{aligned} \tag{4}$$

Where,

UL : Upper limit of unrealized gains on equities that can be counted

Note that the second term in Equation (4) is a put option that uses market price at the end of the term (S_t) as the underlying asset price and the sum of the upper limit and book value at the end of the previous term ($UL + K$) as the strike price. The expected URG can therefore be sought as the value of this option.

From this it is possible to seek 1) the expected BIS ratio, and 2) the 99% tile point of BIS ratio at the end of the term six months hence (99% BIS ratio). The results are found in Figure 4 and Figure 5.

- In performing these calculations, we assumed that all conditions except those specifically related to equities were unchanged from the end of the previous term. In other words, the only influence assumed for Tier I was from equity write-offs, and the only influence on Tier II from changes in URG. Risk asset was assumed to be unchanged.

These results point to the following characteristics.

[Figure 4] Expected BIS Ratio and 99% BIS Ratio (end of Mar.1992)

	BIS ratio	Expected BIS ratio	difference	99% BIS ratio	difference
Bank A	8.28%	9.61%	+ 1.33%	6.38%	- 1.90%
Bank B	8.04%	9.17%	+ 1.12%	6.37%	- 1.67%
Bank C	8.39%	9.23%	+ 0.84%	6.79%	- 1.60%
Bank D	8.10%	9.47%	+ 1.37%	6.71%	- 1.40%
Bank E	8.18%	9.12%	+ 0.94%	6.82%	- 1.35%
Bank F	7.93%	8.85%	+ 0.92%	6.34%	- 1.59%
Bank G	8.27%	9.55%	+ 1.28%	6.43%	- 1.84%
Bank H	8.33%	9.28%	+ 0.94%	6.45%	- 1.88%
Bank I	8.25%	9.62%	+ 1.37%	6.87%	- 1.38%
Bank J	8.30%	9.92%	+ 1.62%	6.71%	- 1.59%
Bank K	8.43%	9.74%	+ 1.31%	7.20%	- 1.24%
Average	8.23%	9.41%	+ 1.19%	6.64%	- 1.59%

[Figure 5] Expected BIS Ratio and 99% BIS Ratio (end of Mar.1997)

	BIS ratio	Expected BIS ratio	Difference	99% BIS ratio	difference
Bank A	9.02%	8.82%	- 0.20%	5.04%	- 3.99%
Bank B	9.23%	9.24%	+ 0.01%	7.12%	- 2.10%
Bank C	9.09%	9.03%	- 0.06%	7.73%	- 1.36%
Bank D	9.11%	9.05%	- 0.06%	7.93%	- 1.18%
Bank E	9.28%	9.87%	+ 0.58%	8.35%	- 0.93%
Bank F	8.93%	8.85%	- 0.08%	7.26%	- 1.67%
Bank G	9.22%	8.80%	- 0.42%	5.40%	- 3.83%
Bank H	9.04%	9.19%	+ 0.15%	7.00%	- 2.05%
Bank I	8.76%	8.74%	- 0.02%	7.98%	- 0.78%
Bank J	8.70%	8.69%	- 0.01%	6.80%	- 1.90%
Bank K	8.75%	8.90%	+ 0.15%	7.71%	- 1.04%
Average	9.01%	9.02%	+ 0.00%	7.12%	- 1.89%

(1) Expected BIS ratios at the end of the term

At the end of March 1992, the expected BIS ratios at the end of the term were generally about one percentage point higher for all banks, while at the end of March 1997 the rate of increase was widely different for individual banks and had declined generally, ranging anywhere from 0.58% point gain for Bank E to 0.42% point loss for Bank G.[6]

6 Risk asset at the end of March 1997 (average for all banks) was about 34.8 trillion yen, so one percentage point rise in the BIS ratio would require an additional 350 billion yen in capital assuming the amount of risk asset did not change.

The reason for lower growth at the end of March 1997 compared to the end of March 1992 was that Tier I declined while Tier II rose, bringing the two closer together, which resulted in a decline in the upper limit of URG that could be counted into Tier II. Also at work was the rise in book values (K). These factors had the effect of reducing the value of the put option in the second term of Equation (4).

- In point of fact, comparisons of the difference between Tier I and Tier II (average per bank) show a difference of about 650 billion yen at the end of March 1992, which had declined to less than 60 billion yen—not even a tenth those levels—by the end of March 1997. At work in this was an increase in "hybrid capital instrument" (specifically, subordinated debt and the like), which is a Tier II item (see Figure 6).

[Figure 6] Tier I Capital and Tier II Capital(average, billion yen)

	End of Mar.1992	End of Mar.1997	difference
Tier I	1798	1612	- 185
Tier II	1150	1554	+ 404
Unrealized gain on securities ×0.45	550	288	- 262
Hybrid capital instrument	430	1154	+ 723
I − II	648	58	- 589

- Equation (4) indicates that the expected value of URG counted into Tier II at the end of the term will be larger if UL is given and $S_t - K$ is larger than UL ($\fallingdotseq K$ [book value at the end of the previous term] is sufficiently small).

(2) 99% BIS ratios at the end of the term

At the end of March 1992, 99% BIS ratios were about 1.5 percentage points lower for all banks, but at the end of March 1997 there were substantial differences from bank to bank in the amount of decline (the smallest decline was for Bank I at 0.78% points; the largest, for Bank A at 3.99% points).

- At the end of March 1997, 99% BIS ratios had declined to the 5% level for Bank A (5.04%) and Bank G (5.40%). Among the other banks, the only one that was still above 8% was Bank E (8.35%).

The reason for the differences among banks in 99% BIS ratios stems from the differences in the ratio of write-offs to URG (from 0% to almost 400%) that was seen in Section 1. In other words, the larger the write-off, the more of a decline there will be on Tier I, which has the effect of reducing the upper limit for Tier II (because

Tier II capital can be counted only up to the amount of Tier I capital) and leads to a substantial drop in BIS ratios.

2 – 3 Implications

One might be able to conclude that equity portfolio in the past had a positive effect on bank management by providing the banks with unrealized gains, though this stability assumed that equity prices would continue to grow. From a risk management perspective as well, one could be tempted to believe that there was little need to pay attention to the risk in equity portfolio as long as book values were low and equity prices were growing steadily. However, as we have seen, equity prices have slumped and repeated profit taking has raised book values, and this has increased the possibility that equity portfolio will have large negative impacts on accounting profit and loss, corporate value, and BIS ratio.

These insights lead us to conclude that equity price risk can no longer be ignored in bank management, and therefore that a process must be developed for measuring and dealing with risk exposure—in other words, that risk management needs to be practiced. Indeed, as referred by Yoshifuji[1997], "now is the time that bank management must reconsider their own philosophy of management—the significance of holding equities in bank's portfolio".

3. CORRELATION BETWEEN EQUITY PRICE RISK AND CREDIT RISK

In Chapter 2 we examined the impact on bank management of the equity price risk in equity portfolio. However, we must underscore that these equities are held for strategic purposes, that is, banks hold the equities because they have long-term lending relationship with these clients, and this urges us to consider the magnitude of the credit risk exposure from these loans as well. This chapter looks at the correlation between equity price risk and credit risk, thereby setting the groundwork for comprehensive management of risks from both equities and loans.

The high correlation between the two can be seen from a cursory examination for the equity price index and the default probability,[7] but in this paper we use as

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7 For the period 1986 to 1997, the correlation coefficient between the equity price index (TOPIX) and the default probability (calculated by Teikoku Data Bank) was – 0.829, which as large in comparison to other factors.

< Correlation Coefficients >

	TOPIX	Default probability	Yen/dollar rate	10yr JGB
TOPIX	1.000			
Default probability	- 0.829	1.000		
Yen/dollar rate	0.433	- 0.337	1.000	
10yr JGB	0.523	- 0.778	0.668	1.000

Unfortunately, there are few empirical studies of the correlation between equity price risk and credit risk in Japan. One recent study, Suzuki [1998], provided an empirical analysis of the relationship between bond ratings and equity returns, and found ratings to be a statistically significant factor in explaining equity returns.

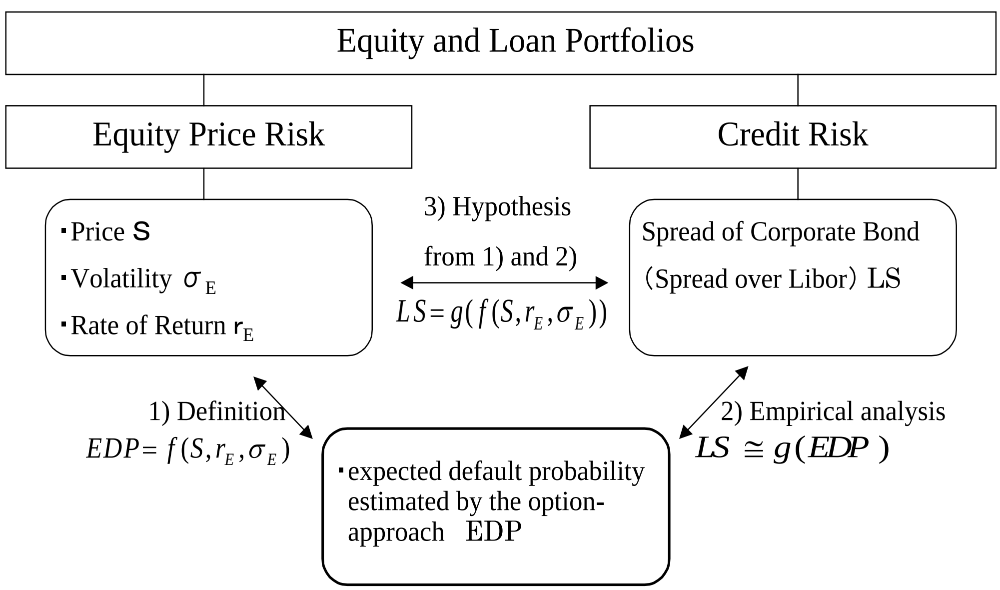
our measures of equity price risk and credit risk: (1) the default probability as calculated from equity price information "and" (2) the spread calculated from bond price information. The specific mechanisms involved are outlined in Figure 7: 1) the expected default probability (EDP) estimated by the option-approach is defined, and EDP is considered a function of equity price information (equity price S, rate of return r_E, volatility σ_E) (Equation (5)); 2) the spread over Libor of corporate bond (LS)[8] is used to seek the relationship between EDP and LS in terms of actual equity price and bond price (Equation (6)); and as the result from the first two steps, 3) LS is assumed to be a function of equity price information (Equation (7)).

$$EDP = f(S, r_E, \sigma_E) \quad \cdots \text{ Definition} \tag{5}$$

$$LS \cong g(EDP) \quad \cdots \text{ Empirical analysis} \tag{6}$$

$$LS = g(f(S, r_E, \sigma_E)) \quad \cdots \text{ Hypothesis} \tag{7}$$

[Figure 7] Relationship between Credit Risk and Equity Price Risk



8 Libor is the interest rate for Inter-Bank money transactions between banks and is therefore calculated as the risk-free rate plus a spread commensurate to the credit risk of the bank involved. When handling credit risks of bonds from the perspective of spreads, it is essentially better to do so in terms of spread over the risk-free rate (i.e., spread over government bonds). We have chosen to use the spread over Libor in this paper because of yield curve distortions caused by the nature of individual issues among Japanese government bonds yield. As will be discussed in more detail in Chapter 4, this paper is more concerned with the change in spread (dLS) rather than the absolute value of the spread, so we recognize there are no particular problems with not using spread over government bonds yield.

3 – 1 Expected default probability calculated by the option-approach

The expected default probability calculated by the option-approach deems a company to be default when the value of its asset falls below the value of its liability. It can therefore be defined as an "in the money (ITM) rate" for a put option using corporate asset as the underlying asset and liability value as the strike price.[9] The KMV model is one well-known use of this expected default probability. Kealhofer [1995] discusses the concepts involved, and Moridaira [1997] examines problem points and observation parameter estimation methods. Saito and Moridaira [1998] calculate and analyze recent EDPs for Japanese banks and find that EDP is a sufficiently useful measure of the state of corporate health.

In this paper, we use the Merton [1974] method to calculate EDP and basically follow the Saito-Moridaira [1998] method for estimating parameters. Below is an outline of the calculations involved.

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9 The option-approach was first developed as a theory for valuing bonds. In the early 1970s, Merton [1974], Black and Scholes worked from the idea that "bonds are a contingent claim against corporate assets" to develop a theory for valuing bonds assuming steady interest rates. More recently, Duffie-Singleton [1994], Jarrow-Turnbull [1995], Jarrow-Lando-Turnbull [1997], and Longstaff-Schwartz [1995], among others, have added interest rate fluctuation and default probability paths to this model to create a valuation model for discount bonds with default risk that meet the no-arbitrage condition. In the Longstaff-Schwartz model, which is an extension of the Merton model, the price of a discount bond with default risk is as follows (details omitted):

$$P(X,r,T) = D(r,T) - wD(r,T)Q(X,r,T) \qquad \text{(a)}$$

Where,

P: *Price* of discount bond with default risk
D: Price of discount bond with no default risk
w: Write-off rate
Q: Expected value for the cumulative default rate until T
V: Value of net asset
K: Default threshold value
X: V/K
r: Short-term interest rate
T: Time to maturity of bond

Defining the bond spread (= SP) as the difference between the yield on the bond in question and the yield on a risk-free discount bond (in this case, the spread is the difference between bond yield and the risk-free rate, which differs from LS defined above), then it follows:

$$SP(X,r,T) = -\ln(1 - wQ(X,r,T))/T \qquad \text{(b)}$$

If we then use equity price information to estimate $Q(X,r,T)$, which is an expression of the expected default rate, then it is possible to use the theoretical spread calculated with Equation (b) and the actual spread observed in the bond market to analyze the relationship between equity price information and spreads. However, Equation (a) says that the theoretical spread is a function of the bond's term to maturity T, so the length of the term to maturity will have an impact on the theoretical spread. But the term structure of spreads observed in the current Japanese bond market is almost flat (see Ieda and Ohba [1998]), so we can expect some divergence from theoretical spreads. From these considerations, this paper calculates EDP for individual issues and then seeks the relationship between EDP and LS through direct empirical analysis without resorting to Equation (a).

(1) Assumptions

The balance sheet of a company at time t is comprised of asset A_t, one kind of fixed-interest liability B_t and equity E_t on the basis of market value (present time is time 0, maturity is time T).

$$A_t = B_t + E_t \quad (t = 0, \cdots, T) \tag{8}$$

We assume that asset A_t follow the stochastic process below ($\tilde{A}_t$).

$$\left(\frac{d\tilde{A}_t}{A_t}\right) = r_A dt + \sigma_A d\tilde{z}_t \tag{9}$$

Where,

r_A : Expected growth rate for asset

σ_A : Volatility of the asset growth rate

$d\tilde{z}_t$: Wiener process

At this point, the logarithm of asset at maturity T is normally distributed with mean $\ln A_0 + (r_A - \sigma_A{}^2/2)T$ and variance $\sigma_A{}^2 T$.

$$\ln \tilde{A}_T = \ln A_0 + (r_A - \sigma_A{}^2/2)T + \sigma_A d\tilde{z}_t \tag{10}$$

(2) Calculation of the expected default probability EDP

Default is defined as "the value of asset is less than the value of liability at maturity T" (in other words, $\tilde{A}_T < B_T$). In equation form, the expected default probability(EDP) is expressed as:

$$\begin{aligned} EDP &= \Pr(\tilde{A}_T < B_T \mid A_0) \\ &= \Pr(\ln \tilde{A}_T < \ln B_T \mid \ln A_0) \\ &= \Phi\left(\frac{\ln B_T - \left[\ln A_0 + (r_A - \sigma_A{}^2/2)T\right]}{\sigma_A \sqrt{T}}\right) \end{aligned} \tag{11}$$

(3) Estimation of parameters[10]

Equation (11) contains five parameters ($B_T, T, A_0, \sigma_A, r_A$). We will assume that maturity of liability (T) is one year and B_T is the book value of the interest-bearing

10 See Moridaira [1997] for a discussion of the problems inherent in estimation.

liability[11] reported for the most recent accounting term. The other three parameters (current value of asset A_0, volatility of asset σ_A and expected growth rate of asset r_A) are calculated from the following simultaneous equations (Equation (12), Equation (13), and Equation (14)):[12]

$$E_0 = e^{-r_A T} \int_{-\infty}^{\infty} Max\left(\tilde{A}_T - B_T, 0\right) f(\tilde{A}_T) d\tilde{A}_T$$

$$= A_0 \Phi(d_1) - B_T e^{-r_A T} \Phi(d_2) \tag{12}$$

Where,

$$d_1 = \frac{\ln(A_0 / B_T) + (r_A + \sigma_A{}^2 / 2)T}{\sigma_A \sqrt{T}}$$

$$d_2 = d_1 - \sigma_A \sqrt{T}$$

f : Probability density function of lognormal distribution

Φ : Cumulative density function of standard normal distribution

$$\sigma_A = \frac{E_0}{A_0 \Phi(d_1)} \sigma_E \tag{13}$$

$$r_A = \frac{E_0}{A_0} r_E + \left(1 - \frac{E_0}{A_0}\right) r_B \tag{14}$$

Where,

σ_E : Equity price volatility

E_0 : Equity

r_E : Expected growth rate of equity

r_B : Expected growth rate of market value of liability

11 We assumed there would be little change in the book value of liability over the relatively short period of one year. Interest-bearing liabilities were defined as the total long and short-term borrowings, bonds, convertible bonds, employee deposits and bills discountable shown on the financial statements.

12 Equation (12) uses option theory to value E_t from Equation (8).

- To solve these simultaneous equations, we used equity price information observed in the market for the following constants:
  - Equity E_0 : Number of stocks issued N × Stock price S (N is assumed to be constant)
  - Equity price volatility σ_E :Annualized weekly historical volatility (observation period of one year)
  - Expected growth rate of equity r_E : Annualized average value (observation period of one year) for weekly rates of return
  - Expected growth rate of market value of liability r_B :Assumed to be zero.[13]
- If, as we have done above, B_T, N , and r_B are assumed to be constant, then the only EDP variables are S, r_E and σ_E, as seen in Equation (5).[14]

3 – 2 Spread of bond yield

The spread of domestic straight bond yield used in this analysis is the "spread over Libor".

The "spread over Libor" is defined as LS in Equation (15) when the cash flow from the bond is swapped for floating interest rate (Libor + LS), and it can be calculated by valuing discount factors sought from the swap.

$$LS = \frac{(1-V) + \sum_{j=1}^{m} \left(\frac{Cp}{2} - \frac{Sw \cdot n_j}{365} \right) \cdot D(t_j) - AI}{(V + AI) \cdot \sum_{j=1}^{m} \frac{n_j}{360} \cdot D(t_j)} \tag{15}$$

Where,

V : Secondary market value of the bond (per ¥1 par value)

Cp : Coupon rate on the bond

Sw : Swap rate for the same term to maturity as the bond[15]

t_j : Date of the j-th payment on the bond

$D(t_j)$: The t_j discount factor

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13 It is basically impossible to obtain information from the markets on the market value of liability, which makes it impossible to estimate its growth rate either. This will have an impact on the expected growth rate of asset through Equation (14), but the expected growth rate of asset itself does not have that much influence on the valuation of EDP in Equation (11), so we have assumed that the expected growth rate of liability was zero.

14 This corresponds to 1) of Figure 7.

n_j : Number of days between t_{j-1} and t_j

m : Number of payments until maturity

AI : Accrued interest

3 – 3 Data used

For equity prices, we used closing prices from the First Section of either the Tokyo Stock Exchange or the Osaka Securities Exchange; for bond prices, we used "the OTC (Over-the-Counter) standard bond quotations" published by the Japan Securities Dealers Association;[15] for financial data, the data published in financial reports. The bond issues in our analysis met three conditions: 1) had bond price quote and closing equity price throughout the period analyzed (see below), 2) had a term to maturity of less than 10 years, and 3) had issuing values of more than ¥10 billion each (total of 735 issues).

- We analyzed the period May 1997 to March 1998, using data from the final trading day of each week (48 weeks).

3 – 4 Analysis of expected default probability and bond spreads

Equation (16) contains a regression analysis that uses a time series of 48 weeks worth of pooling data for a cross section of 735 issues. This regression illustrates the relationship between EDP and LS.

15 The "OTC standard bond quotations" system (revised April 1997) is summarized as follows.

- Types of issues: government bonds, municipal bonds, government-guaranteed bonds, bank debentures, corporate bonds, and yen-denominated foreign bonds.
- Standard bond quotation issues: In principle, all issues that meet all of the following conditions –(a) unlisted, domestic, publicly offered public and corporate bond issues (with a remaining maturity of at least one year), (b) issues with a fixed interest rate from issuance through redemption, and (c) issues with lump-sum redemption upon maturity. (Under the revised system, the number of issues covered by the OTC standard bond quotations increased by approximately three times.)
- Calculation method for the OTC standard bond quotations: arithmetic mean of the quotations received from the reporting companies (these quotations represent yield indicators for transactions with a face value of approximately 500 million yen as of 3:00 PM on the business day before public release).

  --- The OTC standard bond quotations are not necessarily based on actual transactions (one of the reasons is that the outstanding volume of certain issues is insignificant), so there are problems with the reliability of the data. Nevertheless, the OTC standard bond quotations have the widest coverage of any public data in Japan, and they are considered to be optimal data for the analyses.
- Price unit intervals: .01 yen per 100 yen par value.
- Public release of the OTC standard bond quotations: Daily (excluding holidays).
- Number of companies reporting quotations: 28 companies as of April 1997 (previously 15 companies).

$$LS_{ij} = \alpha_0 + \alpha_1 EDP_{ij} + \varepsilon_{ij} \qquad (16)$$

Where,

LS_{ij} : LS of issue i at point in time j (in percentage units)

EDP_{ij} : EDP of issue i at point in time j (in percentage units)

ε_{ij} : Error term

α_0, α_1 : Constants

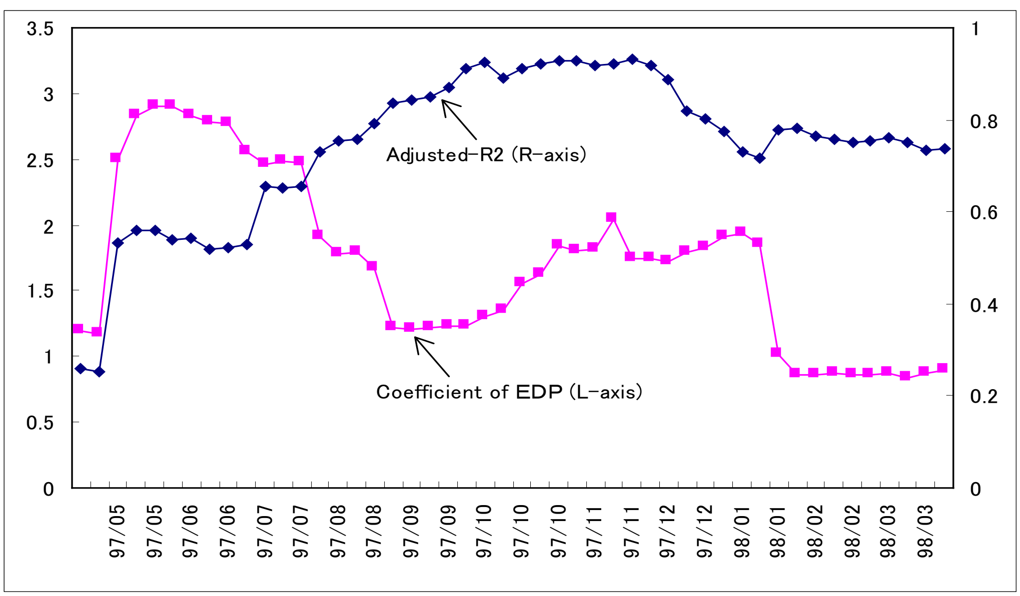
The results (Figure 8) show EDP to have a generally high explanatory power. The EDP coefficient indicates that one percentage point rise in EDP will produce 104 basis point expansion in LS.

[Figure 8] Regression Results (lower row : t-value)

Adjusted-R^2	Intercept	EDP
0.70	0.22 30.53	1.04 286.32

To examine the changes in the relationship between LS and EDP during the period analyzed, we performed the regression in Equation (16) for each cross section in the 48-week period. Figure 9 contains the coefficients of determinants and the coefficients of EDP for the period.

[Figure 9]Adjusted-R^2 and Coefficients of EDP(α_1)



Since September 1997 the adjusted-R^2 has been at generally high levels, usually around 0.8. This indicates that LS was more likely to be determined by EDP. Note also that the coefficient of EDP has fluctuated between 0.8 and 2.0 since summer of 1997 (though it stabilized in 1998).

The results from this analysis indicate that in a relatively short period of time, it is possible to assume that LS fluctuation will be proportional to EDP fluctuation, as shown in Equation (17).[16,17]

$$\frac{dLS_i}{dEDP_i} = \alpha_1 \tag{17}$$

The next chapter assumes that the constant relationship shown in Equation (17) is observable in the equity and bond markets, and therefore that LS is a function of equity price information.[18]

4. Risk Management Techniques with Emphasis on Sensitivity to Equity Price Fluctuations

This chapter assumes the relationship between the expected default probability and the spread over Libor explored in Chapter 3 to be given, and works from there to examine techniques for comprehensively managing the bank portfolio, which comprises loans to the clients and equities issued by the same clients. Section 1 explains the importance of measuring and managing sensitivity. Section 2 discusses the types of assets and sensitivities to be managed. Section 3 looks at delta and vega, which are two concepts of sensitivity. The final Section 4 creates an sample portfolio and calculates actual risk exposure, analyzing the effects of hedge operations in the process.

4 – 1 Measuring and managing sensitivity

One method of managing the risks in a portfolio that contains both equity price risk and credit risk is to calculate an integrated risk exposure (VaR) adjusted for the correlation between them. A risk exposure calculated in this manner could become an important measure in the process of determining appropriate level of capital for the operation of the bank. But portfolio management requires more than just a measurement of risk exposure. One must also be aware of the portfolio's sensitivity to different risk factors so that when biases are found one is able to select the exposure to be increased or not and determine the specific control techniques that will be used to do this. In other words, measuring and managing sensitivity to risk factors is an extremely basic process in dynamically managing a portfolio.

In Chapter 2, we observed that equity price fluctuations had a large impact on the corporate value of bank, and this, combined with the high positive correlation quantifiably observed between equity price risk and credit risk,

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16 Corresponds to Equation (6) and 2) of Figure 7.

17 It would be conceivable to estimate a nonlinear function that would provide a more stable relationship.

18 Corresponds to Equation (7) and 3) of Figure 7.

indicates that the basic objectives in managing a bank's equity and loan portfolio should be, 1) to control sensitivity to equity price fluctuations, and 2) to control sensitivity to interest rate fluctuations. In addition, the idea that sensitivity to equity price fluctuations is central to risk management has other major advantages, since it can also be expected to produce a wider variety of hedge tools[19] and it provides managers with a very easily understandable measure.

Once we have posited our two basic objectives in portfolio management—to control sensitivity to equity price fluctuation and to control sensitivity to interest rate fluctuation—the question turns to the specific management techniques to be used. In recent years there has been the emergence of many techniques for managing sensitivity to interest rate fluctuation, but there do not appear to be any specific methodologies established for managing sensitivity to equity price fluctuation in relation to credit risk. We therefore focus on this latter as we examine specific management techniques that might be used.

- This paper assumes that assets are valued in terms of present value and that portfolios are managed for the short term based on this valuation. Originally, investment horizon is long for portfolios of equities and loans, but given the magnitude of the risk observed in Chapter 2, we consider there to be a high need for short-term risk control (trading and hedging) based on present value.

4 – 2 Assets and sensitivities to be managed

(1) Assets

The assets to be managed in this discussion are loans and equities. Management will require the twin perspectives of "financial instruments" and "client companies." The loans and equities in bank portfolio are not invested with separate, individual decisions. Rather, they are generally controlled by the extent of the relationship with the "client companies".

Figure 10 categorizes the client companies of banks in terms of whether companies went public and whether bonds were issued. The banks generally have business relationship with companies in all four categories. And there are three forms that individual relationship taken: lending only, equity-holding only and both. The sensitivity management discussed in this paper observes the relationship between EDP and LS (Equation (16)) in the market for companies in Category 1), and then applies this relationship to companies in other categories as well. Therefore, the focus of management will be on companies in Category 1) for which information on equity prices and other factors can be observed in the market; management of companies in Categories 2)-4) will require separate estimation from such equity price and other available information.

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19 Securities derivatives will be fully liberalized in Japan in December 1998.

[Figure 10] Categorization of Client Companies

		Going-public	
		Yes	No
Bond issuance	Yes	1)	3)
	No	2)	4)

(2) Sensitivities

Our approach in this subsection is to measure the degree of sensitivity to equity price fluctuations for each "client company," and to add these up to get a total sensitivity for the portfolio. We will begin by examining the degree of sensitivity to equity price information of different classes of assets.

For loans, we assume that EDP is influenced by three variables, including equity price (Equation (18)). Therefore, EDP has three forms of sensitivity, but given the fact that EDP is calculated by the option-approach, special attention must be paid to sensitivity towards equity price and its volatility.

$$EDP = f(S, r_E, \sigma_E) \tag{18}$$

Where,

S : Equity price

r_E : Expected equity price growth rate

σ_E : Equity price volatility

Equity is sensitive to equity price S and its volatility σ_E (sensitivity to equity price fluctuations is a function of the number of equities held[20]).

We are now able to define two sensitivities to equity price fluctuations for a portfolio of loans and equities:

1) Delta: Percentage change in asset price for a unit change in equity price S.
2) Vega: Percentage change in asset price for a unit change in equity price volatility σ_E.

20 Taking the number of equities held as N, the market value is NS. When this is differentiated for S (when solved for sensitivity), the result is N.

4 – 3 Calculating delta and vega

(1) Delta and vega for specific client companies

$DELTA_i$ will stand for the delta of loan and equity about the i-th company, which can be expressed as follows:

$$DELTA_i = \text{Loan} + \text{Equity}$$

$$= DELTA(debt)_i + DELTA(stock)_i \qquad (19)$$

$$DELTA(debt)_i = -Amt(debt)_i \cdot Du_i \cdot \frac{dLS_i}{dEDP_i} \cdot \frac{dEDP_i}{dS_i} \qquad (20)$$

Where,

$Amt(debt)_i$: Total principal lent to the i-th company[22]

Du_i : Duration of the above

LS_i : LS of the above

EDP_i : EDP of the above

$\frac{dLS_i}{dEDP_i} = \alpha_1$: estimated from the empirical analysis in Equation (16)

$$DELTA(stock)_i = N_i \qquad (21)$$

Where,

N_i : Number of the i-th company's equities held

If we likewise use $VEGA_i$ to stand for the vega of dealings with the i-th company, then the following equations will hold:

$$VEGA_i = \text{Loan} + \text{Equity}$$

$$= VEGA(debt)_i + VEGA(stock)_i \qquad (22)$$

$$VEGA(debt)_i = -Amt(debt)_i \cdot Du_i \cdot \frac{dLS_i}{dEDP_i} \cdot \frac{dEDP_i}{d\sigma_{Ei}} \qquad (23)$$

$$VEGA(stock)_i = 0 \qquad (24)$$

(2) Delta and vega for the portfolio as a whole

Let us consider delta and vega for a portfolio comprising loans and equities from n client companies (expressed as $DELTA(portfolio)$ and $VEGA(portfolio)$). If one considers sensitivity to be the degree that the market prices and volatilities of individual equities will move in the same direction, then the sensitivity of the portfolio as a whole will be a simple total of the sensitivity of individual equities. It would probably be appropriate, however, to think in terms of sensitivity to a equity price index in light of the correlations between movements of individual equities and the resulting diversification effects.

We will assume that the rate of return on equity of the i-th company R_i can be expressed in the form of the following single factor model.[21]

$$R_i = \beta_{0i} + \beta_{1i} \cdot R_M + \varepsilon_i \tag{25}$$

$$\sigma_{Ei}{}^2 = \beta_{1i}{}^2 \cdot \sigma_M{}^2 + \sigma_{\varepsilon i}{}^2 \tag{26}$$

Where,

R_i, σ_{Ei} :Rate of return and its volatility of the i-th company's equity

R_M, σ_M :Rate of return and volatility of equity price index

$\varepsilon_i, \sigma_{\varepsilon i}$:Error term and its volatility

β_{0i}, β_{1i} :Constants

$$DELTA_i(index) = DELTA_i \cdot \frac{dR_i}{dR_M} \tag{27}$$

$$VEGA_i(index) = VEGA_i \cdot \frac{d\sigma_{Ei}}{d\sigma_M} \tag{28}$$

Note,

$$\frac{dR_i}{dR_M} = \beta_{1i} \quad \text{(From Equation (25))} \tag{29}$$

$$\frac{d\sigma_i}{d\sigma_M} = \beta_{1i}{}^2 \cdot \frac{\sigma_M}{\sigma_{Ei}} \quad \text{(From Equation (26))} \tag{30}$$

This allows us to express the sensitivity to the equity price index of the portfolio as follows:

$$DELTA(portfolio) = \sum_{i=1}^{n} DELTA_i(index)$$

---

21 There have been many studies of factor models that explain the rate of return on individual equities, and they have progressed to the point that the findings may be of practical utility. However, we have used the simplest model available in order to avoid needless complexity in our discussion here.

$$= \sum_{i=1}^{n} DELTA_i \cdot \beta_{1i} \tag{31}$$

$$VEGA(portfolio) = \sum_{i=1}^{n} VEGA_i(index)$$

$$= \sum_{i=1}^{n} VEGA_i \cdot \beta_{1i}^{\ 2} \cdot \frac{\sigma_M}{\sigma_{Ei}} \tag{32}$$

4 – 4 Risk management using delta and vega

In this section, we create a simple sample portfolio and apply a risk management technique based on sensitivity (as discussed above) to demonstrate the specific effects that can be achieved with this technique.

(1) Creation of a sample portfolio and assumptions underlying risk exposure calculations

We selected one issue at random from among the issues for each debt rating, as shown in Figure 11. We then created a sample portfolio comprising loans and equities for five clients.

[Figure 11] Details of the Sample Portfolio

Company	Rating	March 27th,1998		Loan (billion yen)	Equity (billion yen)	
		LS(bps)	EDP(%)	Book value	Book value	Market value
a	AAA	27.3	0.02	100	10	12.5
b	AA	51.0	0.69	100	10	12.5
c	A	97.7	0.97	100	10	12.5
d	BBB	294.2	2.34	100	10	12.5
e	BB	2,894.2	13.05	100	10	12.5
Total				500	50	62.5

The following assumptions underlie our sensitivity calculations:[22]

1) Ratio of loans and equities

We set the ratios for market values and book values with reference to averages for city banks and long-term credit banks at the fiscal year to March 1997.[23]

22 The suffix "i" in the formulas indicates the client.

2) Calculation of differential coefficients

$dLS_i \diagup dEDP_i (= \alpha_1)$: Calculated from the regression analysis in Equation (16) (we use 1.04 from Figure 8, which contains the results of regression analysis in the Chapter 3).

$dEDP_i \diagup dS_i, dEDP_i \diagup d\sigma_{E_i}$: Calculated from the amount of change in present value when S_i and σ_{Ei} are moved one unit.

3) Others

Duration Du_i: Set at one year throughout.

Beta of individual stocks β_{1i}: Calculated from weekly data for the year to March 27, 1998.

For sensitivity, we have used sensitivity to the index as was done in Equation (27) and Equation (28). To facilitate measurement in monetary terms, we have made the following measurements.

Equity price 1% value (Price1%v)

= Change in present value from a 1% rise in TOPIX

= $DELTA_i$ × TOPIX value at the time × 1% × β_i

Volatility 1% value (Volatility1%v)

= Change in present value from a 1% rise in TOPIX volatility

$$= VEGA_i \times 1\% \times \beta_{1i}^{\ 2} \cdot \frac{\sigma_M}{\sigma_{Ei}}$$

(2) Measurement of exposure distribution

Figure 12 contains the results of portfolio sensitivity as defined above when measured for individual clients. Note that it is long for Price1%v and short for Volatility1%v, which means that present value will decline against declines in TOPIX or rises in TOPIX volatility. In this case, there are few differences in Price1%v among clients, though there are wide discrepancies in Volatility1%v. Note, for example, the relatively large exposure towards BB-rated Company e, and the fact that exposure to Company b (AA rating) is larger than that to Company c (A rating).

[Figure 12] Sensitivity by Client: 1%v (0.1 billion yen)

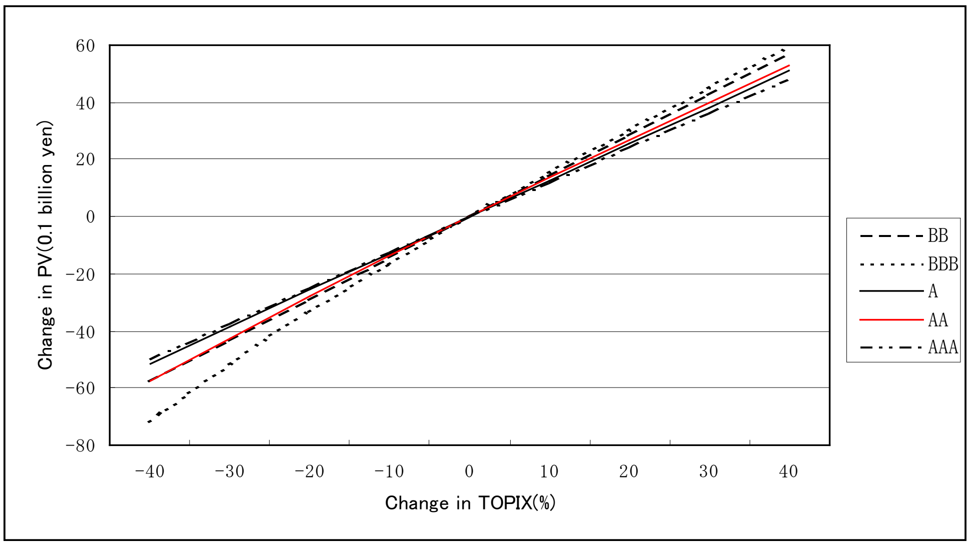
Company	Rating	Price1%v	Volatility 1%v
a	AAA	1.21	- 0.07

23 Loans 27.4 trillion yen, book value of equities 2.5 trillion yen, market value of equities 3 trillion yen.

b	AA	1.34	- 0.73
c	A	1.27	- 0.47
d	BBB	1.57	- 0.76
e	BB	1.42	- 2.91
Total		6.80	- 4.94

Figure 13 and Figure 14 contain the results of client-by-client simulations of the change (these are defined as “delta risk” and “vega risk”) in present value (PV) when TOPIX and its volatility are allowed to fluctuate over a fairly broad range (respective ratings are shown in the table). These results also show a relatively high degree of unevenness for vega risk. Note also that vega risk is more nonlinear than delta risk.

[Figure 13] Simulation of Delta Risk



[Figure 14] Simulation of Vega Risk

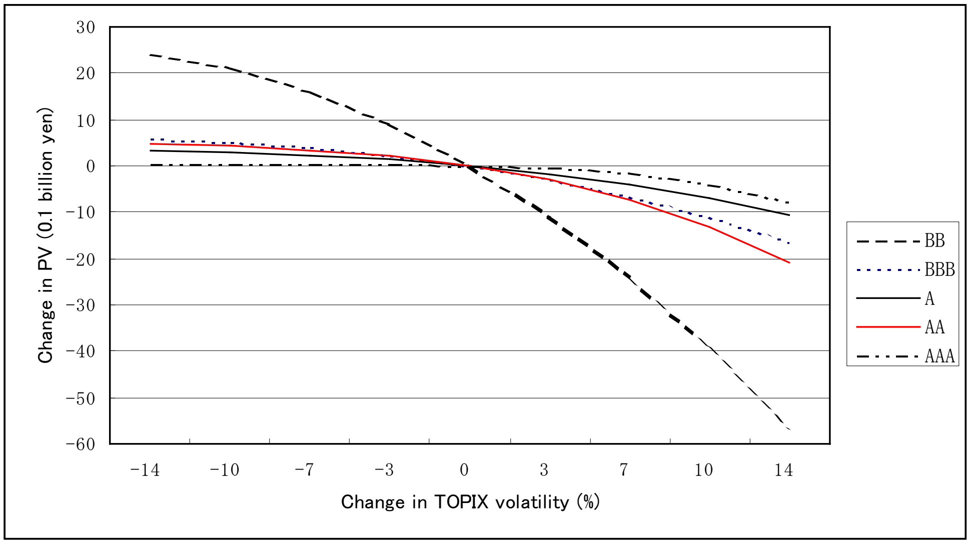


Figure 15 contains approximations[24] of risk exposure taking account of the degree of change in risk factors. This shows the change in present value from a change of one standard deviation[25] in TOPIX and its volatility. A comparison of delta risk and vega risk shows the latter to be larger (in absolute numbers) for all except Company a (rated AAA). It is possible to make quantifiable comparisons between interest rates and other risk exposures if we use risk exposures that take account of these degrees of change in risk factors.

[Figure 15] Sensitivity by Client: σ %v (0.1 billion yen)

Company	Rating	Price σ %v	Volatility σ %v
a	AAA	1.21	- 0.60
b	AA	1.34	- 6.22
c	A	1.27	- 3.96
d	BBB	1.57	- 6.50
e	BB	1.42	- 24.70
Total		6.80	- 41.97

(3) Hedging

In this subsection we examine hedging transactions that can be used to control the risk exposure of the portfolio without changing business relationship

24 Calculated linearly from 1%v without using simulations.

25 We have calculated TOPIX and its implied volatility from the daily volatility found in historical data (one year). This was calculated at σ (price) = 1.0 %, σ(volatility) = 8.5 %.

with clients (i.e. without changing the book values of loans and equities).[26] We envision TOPIX futures and option[27] as hedging tools, and we assume that it was possible to make the following hedges under the following conditions on March 27, 1998.

1) TOPIX index futures

Price change is same as for spot transaction, with costs assumed to be zeros.

2) TOPIX index option[28]

Form: European put option

Exercise price: 1100 (the underlying asset price was 1258.55 on March 27, 1998)

Term to maturity: 120 days

Cost: Premium paid at time of contract

Assuming, for example, that one third of the risk exposure in the portfolio were to be hedged, the objective could be almost achieved by 600 contracts of short futures and 15,500 contracts of long put options, as shown in Figure 16.

[Figure 16] Hedge Operation (0.1 billion yen)

	Before Hedge	Hedge Transaction		After Hedge	Hedge Ratio
		Put option (15500 long)	Futures (600 short)		
Price1%v	6.80	- 1.51	- 0.76	4.53	33.3%
Vol1%v	- 4.94	1.63	0	- 3.30	33.1%
Cost		7.02	0		

In Figure 17 and Figure 18, we have allowed TOPIX and its volatility to fluctuate over a comparatively broad range and observed the results for a one third hedge on the portfolio in terms of the change in present value. The Figures indicate that for delta risk the hedged portfolio is over-hedged for a fairly large decline in TOPIX. This is because of the non-linearity of the options, and it points to the need for dynamic adjustments in the hedges. For vega risk, it shows that a fairly high hedge effect can be expected.

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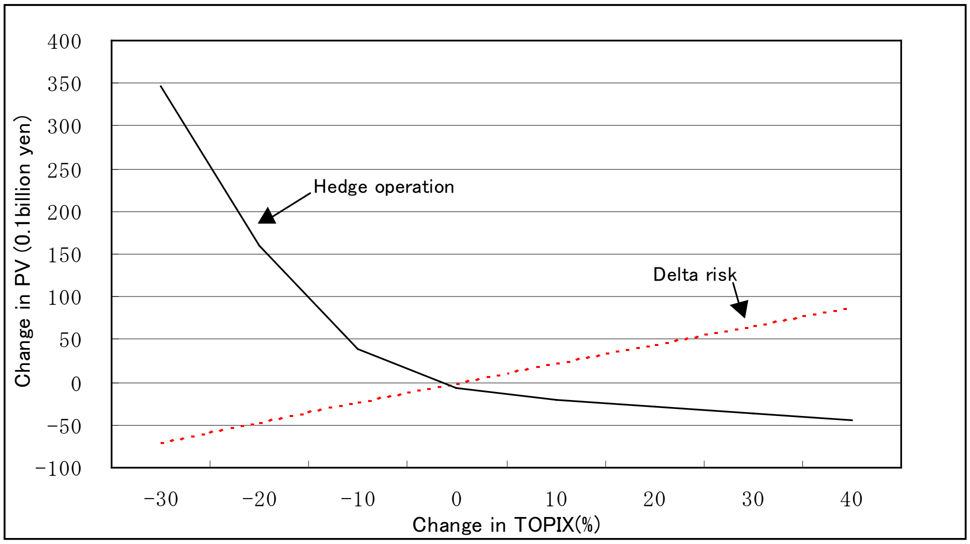
26 One concept for determining the "amount of the hedge" would be to set objectives for measures of business performance as discussed in Chapter 2 and then find an optimum hedge to achieve this. Rather than deepen this discussion here, however, we have opted to provide "hedge techniques" that reflect the correlation between equity price risk and credit risk.

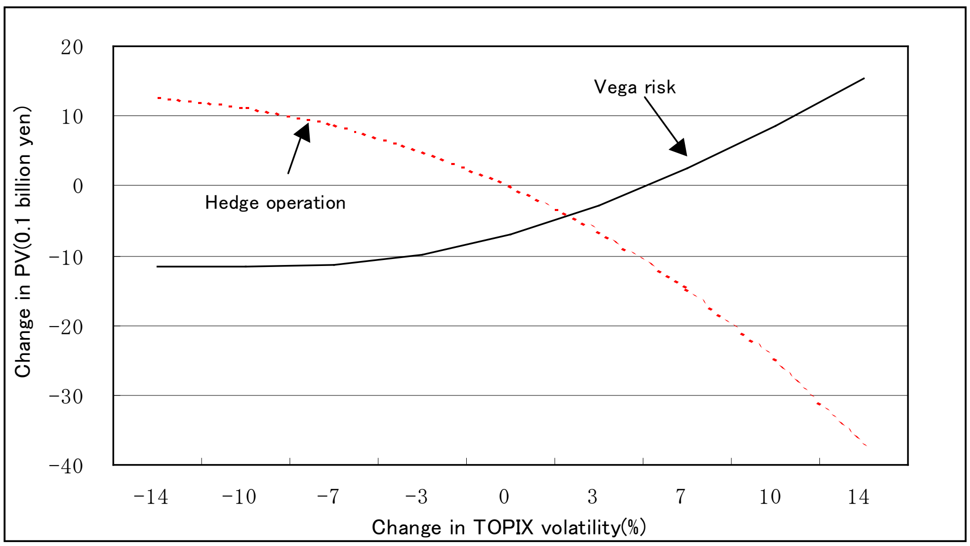
27 In light of the actual depth of market trading, it would be more realistic to use options on the Nikkei 225 rather than options on TOPIX. We have used TOPIX here merely as a matter of convenience.

28 For pricing, we used a simple Black-Scholes model with no dividend payments.

[Figure 17] Delta Risk and Hedge Operation



[Figure 18] Vega Risk and Hedge Operation



5. Conclusions

This paper has verified the impact of equity portfolio on bank management, underscoring the importance of managing the risks involved and suggesting "management of sensitivity to equity price risk" as a risk management technique that takes into account the correlation between equity price risk and credit risk.

We verified that equities have a large impact on measures of business performance, specifically accounting profit or loss and BIS capital adequacy ratios. Assuming that there will be no reason to expect consistent increase in equity prices in the future, it is difficult to see how the holding of equities for the purpose of maintaining business relationships would give the bank a stronger financial footing or contribute to its stability. We therefore see the need for banks to appropriately manage the equity price risk for their entire portfolio, including loans, and to take steps to actively control that risk.

As a specific means for doing so, we have discussed the management of portfolios based on a degree of sensitivity that takes account of the correlation between equity price risk and credit risk. In doing this, we focused on the high correlation between the "expected default probability" calculated using equity price information, and "spread over Libor" which is observed in the bond market. This enabled us to calculate sensitivity (delta and vega) to changes in equity price and its volatility which was defined as risk factors. The first of these two sensitivities is an indication of the equity price risk for equities, the second of credit risk for loans. According to estimations for our sample portfolio, these two sensitivities have a degree of utility in measuring the distribution of exposure and in using equity price index futures and options as hedge tools. In the hedging of vega risk which tends to reflect credit risk in particular, long put positions in the equity price index options were shown to be potentially very effective. We anticipate that the liberalization of securities derivatives in December 1998 will further improve the availability of hedges in Japan.

Below are some of the questions to be resolved in subsequent research.

1) Correlation between equity price risk and credit risk

Data constraints forced us to estimate the correlation between equity price risk and credit risk using equity price data and bond price data for a very limited period of time (fiscal year 1997). This was a somewhat peculiar period, however, since it was at this time that the slumping economy caused credit risks to begin to emerge in the markets. On-going risk management will require further analysis of the relationship between the two risks in other economic environments. As a measure of credit risk, we used the spread over Libor of corporate bonds, but we would note that the secondary market for bonds is still developing in Japan, and there will therefore need to be further study of measurement selection and analytical methods as credit risk-related markets develop, including the expected expansion in the market for liquidated credits. Finally, additional study will be needed into the acceptability of the various assumptions underlying our estimate of expected default probability, and the handling of clients for whom there is no equity price or bond price information observable in the markets.

2) Analysis of term profit or loss sensitivity

This paper discussed a sensitivity analysis technique that focused on short-term changes in asset value. However, from the perspective of risk management in medium and long-term bank operations, there will also need to be sensitivity analysis that focuses on accounting profit or loss for the term. One example of an approach that might be taken would be to posit asset and liability change scenarios that take account of funding costs of equities, reserves and write-offs of loans for the term. One could then create scenarios in which risk factors change based on the correlation between equity price fluctuations and default probability, and work from there to estimate term profit or loss sensitivity.

There have been few examples in Japan of other studies in risk management techniques that link equity price information and bond price information. We look forward to additional theoretical and quantifiable studies on the issues we have suggested and on other questions in this field.

REFERENCES

[1] Ieda, A. and Ohba, T.: *"Kokunai Futu Shasai no Ryutu Shijo ni okeru Libor supureddo no Saikin no Doko"* ["Recent Trends in the Spread over Libor on the Domestic Straight Bond Trading Market in Japan"], *IMES Discussion Paper Series 96-J-13,* Bank of Japan, 1998.

[2] Saito, H. and Moridaira, S.: *"Ginko no Saimu Choka (Tosan) Kakuritsu: opushon apurochi ni yoru Suitei"* ["Default Probability of Japanese Banks: Estimation by the Option-approach"], *Nihon Kinyu Shoken Keiryo Kogaku Gakkai 1998 Kaki Taikai Yokoshu,* 1998.

[3] Suzuki, M.: *"Saiken Kakuduke to Kabuka (return) ni Kansuru Kousatu"* ["A Study of Bond Rating and Rate of Return on Equity"], *Shoken Analyst Journal*, April 1998.

[4] Moridaira, S.: *"Tosan Kakuritsu Suitei no opushon apurochi"* ["The Option-approach for Estimating Default Probability"], *Shoken Analyst Journal*, October 1997.

[5] Yoshifuji, S.: *"Seisakukabu Toshi ga kakaeru Maketto Risuku Ryo no Shisan: EaR moderu o Tekiyo shite"* ["The Trial Calculation of Market Risk Associated with Equity Investment by Banks: An Application of EaR model"], *Kin'yu Kenkyu* (Monetary and Economic Studies), 16 (3), Bank of Japan, 1997.

[6] Duffie, Darrell and Kenneth J. Singleton: "Econometric Modeling of Term Structures of Defaultable Bonds," Working Paper, Graduate School of Business, Stanford University, 1994.

[7] Jarrow, Robert A. and Stuart M. Turnbull: "Pricing Options on Financial Securities Subject to Credit Risk," *Journal of Finance* 50(1), 1995, pp.53-86.

[8] ———, David Lando and Stuart M. Turnbull: "A Markov Model for the Term Structure of Credit Risk Spreads," *Review of Financial Studies* 10(2), 1997, pp.481-523.

[9] Kealhofer, Stephen: "Managing of Default Risk in Portfolio of Derivatives," *Risk*, (August,1995), 49-63.

[10] Longstaff, Francis A. and Eduardo S. Schwartz: "A Simple Approach to Valuing Risky Fixed and Floating Rate Debt," *Journal of Finance* 50(3), July, 1995, pp.789-819.

[11] Merton, Robert C.: "On the Pricing of Corporate Debt : The Risk Structure of Interest Rates," *Journal of Finance* 29, 1974, pp.449-70.