Market Price Analysis and Risk Management for Convertible Bonds

Fuminobu Ohtake, Nobuyuki Oda and Toshinao Yoshiba

This paper discusses pricing methods, comments on matters of concern in market risk management, and analyzes market characteristics of convertible bonds.

Valuation of the conversion option is essential in analyzing the market price of a convertible bond. In this paper, we use a binomial tree pricing model to derive the implied volatility of the conversion option from the past price information (time-series data for individual issues) in the Japanese market. We then use this implied volatility data: (1) to employ a Monte Carlo simulation to measure market risk for a test portfolio of convertible bonds and analyze the factors in price fluctuation; and (2) to perform regression analyses that empirically verify the characteristics of the convertible bond market in Japan.

The implication for market risk management is to underscore the need to be aware of market price fluctuation caused by implied volatility fluctuation. We found that in markets such as Japan is experiencing at the present time, in which most issues have little linkage to share price movements, there is a particular need to be aware of implied volatility in risk management. Moreover, our analysis of market characteristics found that (1) there is a significant negative correlation between implied volatility and underlying equity price fluctuation; (2) implied volatility tends to move in such a way as to reduce divergence from the historical volatility of the underlying equity price; and (3) the use of convertible bonds to raise funds during the "bubble" period in Japan was not necessarily an advantageous form of financing for the issuers.

Key words: Convertible bond; Implied volatility; Historical volatility; Market risk; Arbitrage; Issuing conditions

Fuminobu Ohtake: Market Risk Management Division, Bank of Tokyo–Mitsubishi (E-mail: fuminobu_otake@btm.co.jp)

Nobuyuki Oda and Toshinao Yoshiba: Research Division 1, Institute for Monetary and Economic Studies, Bank of Japan (E-mail: nobuyuki.oda@boj.or.jp, toshinao.yoshiba@ boj.or.jp)

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I. Introduction

It should be axiomatic that anyone trading financial instruments, whether dealers (market makers) or investors (end users) should be concerned with obtaining "fair value" for the trade. Estimates of fair value generally involve the use of some sort of pricing model, and the prices that these models come up with are used by the front office to search for mispricing in the markets, with appropriate hedges for risk. The middle office will also use these prices in risk control and capital allocation. This applies to convertible bonds, the subject of this analysis.

Convertible bonds[1] are hybrid instruments that are part bond and part equity (stock option). The key to pricing them is to apply option price theory (to the equity portion) and credit risk evaluation (to the bond portion). Recent years have seen an increase in the number of complex convertible bond instruments on the market, generally with clauses that provide for revisions in the conversion price. The handling of these instruments requires fairly advanced technology, particularly for the pricing of the option portion. Unfortunately, few papers have attempted to create a systematic methodology for pricing convertible bonds. This paper therefore has three goals: (1) to provide a theoretical explanation of convertible bond pricing and an empirical analysis of that theory; (2) to note points of concern in market risk management; and (3) to consider the implications regarding market characteristics.

The structure of this paper is as follows. Chapter II begins with a discussion of convertible bond pricing theory, followed by examples of pricing models that can be used in practical situations. We use these models for some convertible bonds to analyze market risks and price fluctuation factors, demonstrating that the conversion option in convertible bonds contains elements that cannot be ignored when managing market risks. Chapter III uses implied volatility to perform an empirical analysis of the conversion option in convertible bonds. To this, we add some observations on the characteristics of the Japanese convertible bond market. Finally, Chapter IV provides some brief conclusions.

II. Convertible Bond Pricing Theory and Market Risk Measurements

This chapter contains a theoretical discussion of convertible bond pricing methods, followed by a practical analysis of market risk measurements. We begin with a brief review of the salient characteristics of convertible bonds as financial instruments, and move from there to pricing models that could be used. We then go on to create a test

1. Bonds with warrants are another financial instrument that is often discussed in conjunction with convertible bonds, but we do not deal with them in this paper. Bonds with warrants are generally split into warrants and straight bonds (ex-warrant bonds) when traded, and because the two portions can be priced separately they are much easier to deal with than convertible bonds. Similarly, convertible bonds seem to lend themselves more to exotic instruments with complex features than do bonds with warrants. In light of these considerations, we will concentrate only on convertible bonds in this paper. For a basic discussion of pricing methods for bonds with warrants, the reader is referred to Hull (1997) and Takahashi (1996).

convertible bond portfolio, measuring the market risks in terms of “value at risk,” and elucidating from this some points of concern in risk management.

A. Basic Characteristics of Convertible Bonds

This section provides a brief overview of the basic schemes and product characteristics of convertible bonds.

Convertible bonds are a form of bond issued by companies that comes with the right to convert the bond into ordinary shares in the issuer[2] according to preset conditions (conversion provision). The most common form of conversion provision is to establish a specific conversion period prior to the maturity of the bond (this conversion period corresponds to the exercise period for American options). As long as it is within the designated period, the investor may demand that his bonds be exchanged for ordinary shares at a preset ratio. This ratio is called the “conversion ratio.” The value obtained were the bonds to be exchanged for shares at the present time according to the preset conversion ratio is called “parity.” The price paid per share in terms of the par amount of the convertible bond to buy the common stock is referred to as the “conversion price.” For example, if the convertible bond has a par value of ¥1,000, the current share price is ¥400, and the conversion ratio is two, then parity is ¥800 and the conversion price is ¥500. In other words,

$$\text{Parity} = \text{underlying asset price} \times \text{conversion ratio.}$$
$$\text{Conversion price} = \text{par value/conversion ratio.}$$

The difference between the price of the convertible bond and parity is the “conversion premium”:

$$\text{Conversion premium} = (\text{convertible bond price} - \text{parity})/\text{parity} \times 100.$$

When the market price of a convertible bond is below parity, it is trading at a “conversion discount.”

This is the most basic scheme for this instrument. In recent years, a growing number of convertible bonds have been issued with additional conversion provisions. Below is a discussion of some of the most common of these provisions.

1. Call provision

This provision enables prior redemption of the bond at a set price after the time remaining to maturity falls below a preset threshold (generally about three or four years). This provision has often been added to Japanese convertible bonds, but practice in the market has been to assume that the provision would not in fact be exercised under ordinary circumstances, and there are indeed only a few examples of the provision being used to accelerate redemption (the bonds being “called”).

2. As exceptions to this rule, some schemes allow conversion to equity from a different company than the issuer. These are called exchangeable bonds. In such schemes, there are no new shares issued as there would be with an ordinary convertible bond; rather, the issuer of the convertible bond delivers shares in another company that it already holds. One example of how an exchangeable bond could be used would be an issuer that wants to liquidate its holdings in an affiliate but does not want to sell the shares directly to the market.

Investors have therefore considered the call provision to have no real economic significance and have not incorporated its effects in pricing.

However, since 1996 there have been several bonds issued with new call provisions (for example, the "130 percent call option"[3]). This provision is set under the assumption that it might actually be exercised, and so this conversion provision should be reflected in the valuation of the option.

2. Provision allowing downward revisions in the conversion price

This provision makes it possible to revise the conversion price downward after a set period of time has elapsed since issue. It therefore has the effect of increasing the conversion potential. For investors, it has the benefit of resuscitating convertible bond prices that have fallen because sliding share prices have reduced the value of the option, while for the issuer it has the benefit of encouraging conversion to take place (assuming that is what the issuer wants). However, it also exposes shareholders to the risk that there will be a dilution in the value of their shares since a revision in the conversion price will change the number of latent shares in the company. Analyses that seek precision must therefore take this dilution effect into account (see Footnote 13).[4]

Convertible bonds with these provisions first emerged in the Japanese market after the 1996 deregulation, and indeed, just under 30 percent of the convertible bonds issued that year had some form of additional feature.[5]

3. Provision providing for forced conversion at maturity

This provision provides for forced conversion to equity at a preset conversion ratio (in some schemes, this ratio may be revised prior to maturity) of all convertible bonds that remain unconverted when the bond matures. The forced conversion provision is exercised regardless of the wishes of convertible bondholders and issuers. It is found on almost all of the convertible bonds, subordinated debt, and preferred shares issued by Japanese banks over the last two or three years.

However, one of the problems with this provision is that if the latent shares are converted all at once, there is a very real potential to harm the supply and demand balance for the stock and spark a crash in its price. To avoid this, some issues have used forced conversion provisions that spread conversion throughout the life of the bond rather than leaving it all for maturity.

B. Pricing Theory

Professionals generally use two kinds of convertible bond pricing model. The first calculates a theoretical fair value at the time of valuation assuming no arbitrage. This corresponds to the Black-Scholes model in stock options. The second model attempts to identify all factors that have an influence on pricing and model their impact. It is

3. This provision only allows the call option to be exercised if parity is at 130 or higher. For example, if Nissho Iwai No. 1 is at a parity of 130 or higher for 20 days running, then the issuer will be able to accelerate redemption at an exercise price of ¥100.
4. For an analysis of the effect on share prices from convertible bonds issued by banks with additional features (the ability to revise the conversion price downward, etc.), see Kamata and Yarita (1997).
5. See *Nikkei Newsletter on Bond & Money* (1997).

therefore called a "multifactor model."[6] Multifactor models are generally used to estimate future price trends. This paper will therefore concentrate on the first type of pricing model.

The equation below provides a more intuitive grasp of the basic framework for pricing:[7]

Convertible bond price (CB) = bond value (B) + equity option value (OP).

The discussion below explains the pricing model that is used to value the right side of this equation. There are many variations to the model, however, and the choice of which to use will involve a trade-off between accuracy of valuation and complexity of calculation. Our discussion will begin with the simplest and most approximate model (the "simple model"), explaining in the course of the discussion which points it approximates on. We will then discuss a revised model that eliminates the approximated elements, though here again we must emphasize that there is no one best way to revise the simple model. To give the reader some idea of the breadth available, we will consider three types of model found in the professional literature.

1. The simple model

The easiest way to price convertible bonds is to value the bond and equity option components separately. The value of the bond component (B) is the total present value of all future cash flow from a discounted interest rate found by adding the spread[8] at the time of valuation on the riskless rate. The value of the equity option component (OP) is handled as the theoretical price (under the Black-Scholes formula) of a call option that uses parity at the time of valuation for the underlying asset price and the par value of the convertible bond as the exercise price. In mathematical form, therefore, the price of the convertible bond (CB) would be

$$CB = B + OP.$$

$$B = \sum_{t=1}^{T} \frac{CF_t}{[1 + R_F(t) + SP(t)]^t}.$$

$$OP = x \cdot N(d) - k \cdot e^{-R_F(T)T} \cdot N(d - \sigma\sqrt{T}).$$

6. Below is the basic form that a multifactor model would take for the rate of return on a security (traditionally, an equity):

$$\tilde{R}_j = R_F + \sum_{k=1}^{M} x_{j,k}\tilde{F}_k + \tilde{e}_j.$$

In this equation, $\tilde{R}_j$ stands for the rate of return on security j, $\tilde{F}_k$ for the value of factor k (the factor return), $x_{j,k}$ for the sensitivity of security j to factor k (the factor exposure), R_F for the riskless interest rate, and $\tilde{e}_j$ for the error. The actual types of factors and exposures that will appear on the right-hand side of the equation depend on the empirical analysis on which the model is based. One common example is the Barra model of the rate of share price returns. The Nikko-Barra CB Risk Model is an example of an attempt to apply this framework to estimates of the rate of return on convertible bonds. For further discussion, see Miyai and Suzuki (1991).

7. In point of fact, convertible bonds never strip the equity option component off the bond component and trade the two separately (in this, they differ from bonds with warrants). The two will affect each other in pricing, so it is not, strictly speaking, appropriate to value them separately. We must therefore emphasize that this discussion (and the many similar discussions found in the literature) is employed merely as a matter of convenience.

8. Appropriate spreads are determined at the time of valuation with reference to the market prices of other bonds of similar credit risk and liquidity risk.

$$d \equiv \frac{\ln\frac{x}{k} + [R_F(T) + \frac{1}{2}\sigma^2]T}{\sigma\sqrt{T}}.$$

In this equation, CF_t stands for the cash flow for term t, $R_F(t)$ for the riskless rate for term t, $SP(t)$ for the spread corresponding to term t, x for parity, k for the par value of the convertible bond, σ for share price volatility, T for the final day in the conversion period, and $N(\bullet)$ for the cumulative probability density function for a standard normal distribution.

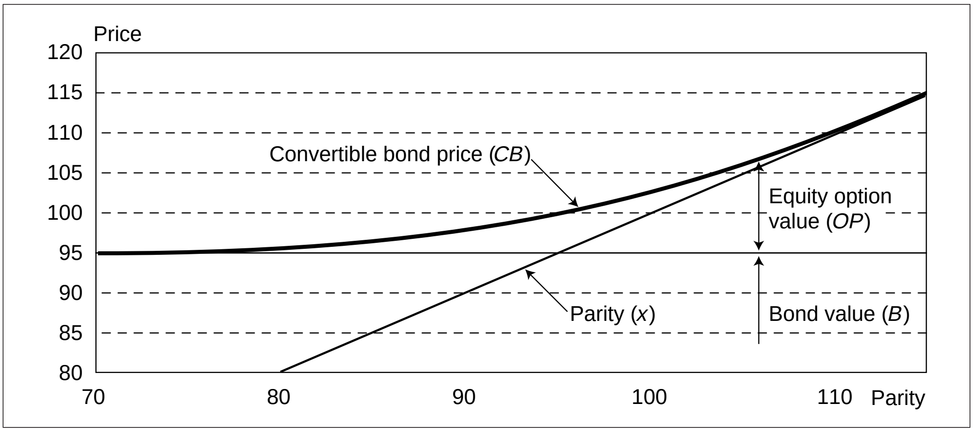
Should the share price be far above the conversion price (parity far higher than the par value of the convertible bond),then $x/k \gg 1$, which will make the relationship $N(d) \approx 1$, $N(d - \sigma\sqrt{T}) \approx 1$ true. From this, we can conclude

$$CB \approx x + (B - k \cdot e^{-R_F(T)T}).$$

When the effect of the coupon and spread for the bond component is sufficiently smaller than the equity option component, it is possible to abstract the second clause in the equation above to give the relationship $CB \approx x$. What this expresses is that when the equity option component is "deep in the money," then the convertible bond price will be roughly at parity (Figure 1). On the other hand, if the share price is far below the conversion price (if parity is far below the par value of the convertible bond), then the option price will be close to zero so the relationship $CB \approx B$ will hold. What this expresses is that when the equity option component is "far out of the money," then the convertible bond price will more or less match the price of the bond component. This behavior is indeed observed in the markets and holds true apart from the limits to the simple model described below.

Next we would explain the limits to the simple model. We would underscore the fact that it uses approximation on two basic points.[9]

Figure 1 Convertible Bond Price Curve



9. In point of fact, there are reports that a method of convenience like the simple model provides unsatisfactory results when it is necessary to calculate extremely accurate prices (for example, Shoda [1996]).

(1) It fixes the exercise price when valuing the equity option

In convertible bonds, the exercise of the option enables one to receive a value equivalent to parity (in the form of shares), in exchange for which one pays a value equivalent to the bond (in the form of the bonds themselves). The value of the bond will depend on interest rates (term structure) and spreads at the time of exercise and cannot be forecasted with any certainty ahead of time. In spite of this, the simple model assumes that bonds are at par value at the time of exercise (that the bond price is equal to the par value).

To remedy this approximation, it is necessary to use a model that allows both the exercise price (bond price) and the underlying asset price (share price) to fluctuate over the stochastic process. Generally speaking, modeling the stochastic process of future bond prices requires the use of some form of yield curve model.[10] Note that when a relatively simple model is used in which bond prices themselves follow the lognormal process, it is possible to apply exchange option pricing theory.[11]

The credit risk premium is one factor in determining the price of the bond at the time of exercise, but this will also be related to trends for the underlying shares (or parity).[12] For example, if the underlying shares have dropped in price after the convertible bond was issued, then the credit risk spread will be larger than it originally was (assuming there has been no change in the riskless rate), so the bond price that serves as the exercise price will also be falling. This linkage is abstracted in the simple model.

(2) It assumes European options for the equity options

Convertible bonds generally allow options to be exercised within a set conversion period, which makes them suited to valuation as American-style options. However, for analytical convenience, the simple model treats them as if they were European-style options.

Accurate valuation of American options generally requires the use of lattice methods (binomial trees or finite difference methods).

The model below attempts to remedy these approximated elements.[13]

10. For a discussion of yield curve models, see Hull (1997).

11. An exchange option is defined as an option that exchanges two different assets (for our purposes, stocks and bonds). If it is assumed that both asset prices will follow a lognormal process, then it is known that there is an analytic solution, particularly for European options (Margrabe [1978]). However, attempting to use a lognormal process for bond prices, as we do in this example, involves making some rather strong assumptions, for instance, it leaves one unable to take account of the mean reversion of interest rates. It may therefore produce unrealistic results, especially if it is used for analyses with long time horizons.

12. For an analysis of the relationship between bond ratings and share prices, see Suzuki (1998).

13. Actually, there are other approximations in the simple model besides the two discussed. For example, it does not take account of dilution effects. We will not delve too deeply into this issue here, but to provide a brief explanation, there are three basic patterns by which the issue of new shares can affect the share price (for our purposes here, we will not consider the signaling effect of new share issues): (1) issues above market will raise the share price; (2) issues at market will have no impact on the share price; and (3) issues below market will lower the share price. Convertible bond options are only exercised (bonds are only converted into shares) when parity (or the share price) is below the par value of the convertible bond (or the conversion price), so this is basically an issue of (3) above. Because of this, a higher expectation of conversion will produce downward pressure on the share price. This is known as the "dilution effect." The size of the dilution effect will depend on the spread between the share price and the conversion price at the time of conversion and on the number of new shares converted.

2. Calculations using binomial trees

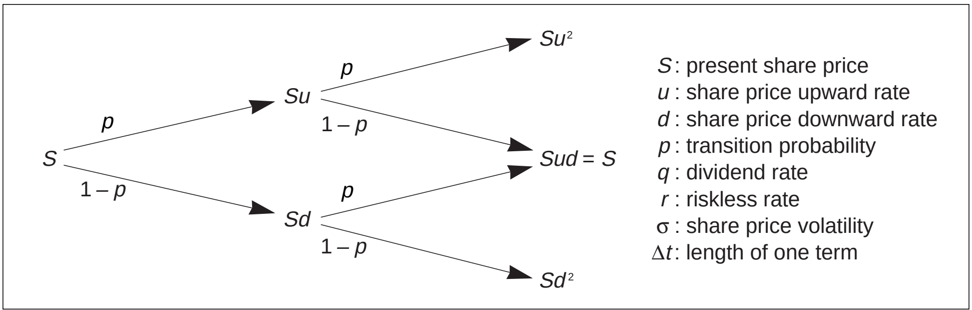
Binomial trees can be used to overcome part of the first problem and all of the second.

The framework for this method involves valuing the price of a convertible bond by rolling back through a comparison of the value when the conversion option is exercised (parity) and the value when the convertible bond is held for each node (an expression designating a time-state pair) along a tree. This technique makes it possible to value convertible bonds with issuer call provisions. Below is an explanation of the process in more detail.

Step 1: Create a parity tree

For a convertible bond with no conversion price revision features, there will be no change in the conversion ratio, which makes it easy to create a parity tree just by creating a share price tree and performing a few simple calculations. First, one creates a share price tree under risk-neutral probability (Figure 2).

Figure 2 Binomial Tree of Share Prices



This allows us to calculate u, d, and p using the following equations:

$$u = \exp(\sigma\sqrt{\Delta t}).$$

$$d = \exp(-\sigma\sqrt{\Delta t}).$$

$$p = \frac{\exp[(r-q)\Delta t] - d}{u - d}.$$

That is enough to build the share price tree. From there, it is just a matter of multiplying the share price by the conversion ratio to create a parity tree (see Section II.A).

Step 2: Calculate the convertible bond price for each node

(a) Calculate price at maturity

Comparisons of bond prices and parities at the time the convertible bond matures will give the value for each node at the time of maturity. The following equation is used to do this in order to take into account the impact of call and put provisions.

$$FVCB(T, i) = \max[Z(T, i), P(T), \min(C(T), B(T, i))].$$[14]

Note that the suffix t designates time (t = 0, 1, . . . T, T = maturity) and the suffix i indicates state (i = 1, . . . , t + 1), so that the convertible bond price, parity, put price, and call price at each node (t, i) are expressed as $FVCB(t, i)$, $Z(t, i)$, $P(t)$, and $C(t)$, respectively, and the bond price at maturity is expressed as $B(T, i)$.

(b) Roll back through the node calculations

Use the maturity values (at each state i) found in sub-step (a) to calculate the expected present value for the node one time period prior. If the maturity state is "bond," then calculate present value (PV_t^i) using a discount rate that takes account of credit risk by adjusting the riskless rate for a credit spread; if it is equity conversion, then use a simple riskless rate for the discount rate. Following this, use transition probability (p) to calculate the expected price as a bond ($X(t, i)$). Then calculate the conversion price for each node using the same methods as for sub-step (a):

$$X(t, i) = pPV_t^i(FVCB(t+1, i)) + (1-p)PV_t^{i+1}(FVCB(t+1, i+1)).$$

$$FVCB(t, i) = \max[Z(t, i), P(t), \min(C(t), X(t, i))].$$

A backward induction that repeats these steps until the present time (t = 0) is arrived at will yield the present price.

The binomial tree method is better, but not without its problems since it still does not account for the possibility of changes in the future riskless rate, and it treats the credit risk spread as if it were certain.[15]

3. Pricing models that consider firm values

Another model that remedies part of the first problem and all of the second problem in the simple model described above is the OVCV convertible bond model developed and provided by Bloomberg.[16] This pricing model focuses on firm values, and its approach is to consider the convertible bond to be an option underlaid by the firm values.[17] What sets this model apart is that it explicitly values the extent of net debt in the event of default, and in doing so makes the credit risk on the bond component of the convertible bond endogenous to the model. Still, this model has problems too, since it assumes Brownian motion for corporate values and reverts to the simple model in order to simplify calculations to the point of practical utility.[18]

14. This assumes that if the issuer, as a rational course of action, exercises its right to accelerate redemption under the call provision, the investor who recognized this would exercise the conversion option (or exercise the put provision) prior to actual redemption.
15. Another pricing model that uses a binomial tree is found in Cheung and Nelken (1994), which draws on exchange option concepts. This is a two-factor model that treats both share prices and interest rates as random variables. In its use of trees for American options, it is similar to the model described in Section II.B.2, but because it uses two random variables, the image is one of creating two differing binomial trees.
However, it also assumes that interest rates and share prices are independent of each other, and it applies the measured credit risk spread at the present time as a fixed value in the future.
16. See Oi (1997), Gupta (1997), and Berger and Klein (1997a, b) for outlines of the OVCV.
17. See Brennan and Schwartz (1977) and Ingersoll (1977) for further discussion.
18. See Takahashi et al. (1990).

4. Methods of valuing exotic convertible bonds

In Section II.A, we noted that a growing number of convertible bonds in Japan were issued with additional features attached. It appears that many nonfinancial issuers attach conversion price revision features, while bank issuers attach not only conversion price revision features but forced conversion at maturity provisions as well. Bank convertible bonds, in particular, are issued primarily as a means of raising capital that can be counted toward Bank for International Settlements (BIS) capital-adequacy standards, and this provides much of the motivation for the forced conversion provision.[19]

Pricing theory finds it ineffective to use recombination lattice methods for path-dependent instruments (derivatives that follow non-Markov processes). General practice is to use Monte Carlo simulation instead. On the other hand, Monte Carlo simulation (which assumes forward induction) is unsuited to American-style options (which require backward induction), so standard practice for American-style options is to use lattice methods. Unfortunately, the instruments we are dealing with in this subsection are path-dependent American-style options, so further extensions will be required. Among the possible approaches to dealing with this would be to follow Hull (1997) in creating an approach that takes account of path-dependence while also attempting to reduce calculation burdens within the grid framework. Another would be to create a grid model that does not recombine and, if dealing with a clause permitting only downward revisions to the conversion price, use a Monte Carlo simulation that does not assume that investors will exercise prior to term.

However, we should point out that there are a wide variety of methods used to determine conversion prices (particularly with convertible bonds issued by Japanese banks), so models will have to be customized to individual issues if precision is desired in pricing.

C. Calculating Value at Risk (VaR) for Market Risks

In this section, we analyze the market risk associated with convertible bonds. More specifically, we utilize value at risk (VaR) concepts, which are the normal method employed in quantitative models of market risk, to perform calculations on a test portfolio. We then go on to note several concerns to be aware of when valuing the market risk of convertible bonds.

1. Basic points in calculating the market risk of convertible bonds

Convertible bonds are a hybrid of bonds and equities, so measurements of their market risk will need to take account of share prices, interest rates, and implied volatility as risk-generative factors. In addition, the convertible bond price is non-linear with respect to share price movements,[20] so among the various methods available to calculate VaR, Monte Carlo simulation stands out as the best in terms of accuracy, since it uses the convertible bond pricing model to calculate risk values for

19. Nor is it just convertible bonds (bonds with conversion options) that banks are issuing. They are also issuing preferred shares and subordinated debt with conversion options. For the sake of convenience, we shall refer to all of these instruments as “convertible bonds” in this paper.

20. Strictly speaking, it also has nonlinear elements (i.e., convexity) with respect to interest rates too.

changes in risk factors (differential calculations). However, Monte Carlo simulation has the drawback of unacceptably heavy calculation burdens, so there may be cases in which some simpler method is the better choice. An example of an alternative, simpler method would be to deem the convertible bond to be a delta-equivalent share price, and only calculate share price movement risk (with no attempt to value the convertible bond itself). In this paper, we use this "simple method" alongside Monte Carlo simulation and compare the results obtained from both.

Driven by the bull market for stocks, the convertible bond market saw its number of listed issues and market capitalization grow consistently in the late 1980s, but the market began to weaken at roughly the same time that share prices peaked out; and more issues went from being driven by share prices to being driven by interest rates. This history was behind our decision to calculate VaR for post-"bubble" issues at two points in time (1994 and 1998) and use these calculations to observe the market risk inherent in convertible bonds.

2. Portfolio analysis

Below are outlines of the Monte Carlo simulation and simple method used to calculate VaR in this analysis.

Monte Carlo simulation

(1) Risk categories and risk factors

We posit three risk categories: share prices, interest rates, and implied volatility. As risk factors for share prices and implied volatility, we use data on individual issues; for interest rates, we use the yield on Japanese government bonds (0.5, 1, 2, . . . , 10 year).

(2) Generation of random numbers

We generate multivariate normalized random numbers for each risk factor and use Monte Carlo simulation techniques to measure VaR. The multivariate normalized random numbers were generated by multiplying normalized random numbers created using the Box-Muller method by a series obtained from a Cholesky decomposition[21] of a correlation matrix calculated from weekly rate of return data for a one-year observation period for each risk factor. Linear

21. The calculation of multivariate ordinary random numbers requires breaking down a positive definite and symmetric correlation matrix $C(\rho_{ij})$ using a matrix $A(a_{ij})$ that meets the condition

$$C = AA^T.$$

For each A that satisfies this, a vector y multiplied by an ordinary random number vector x will produce a correlation series C with the same correlation structure. One simple method for seeking series A is Cholesky decomposition, in which the components of series A are calculated as follows:

$$a_{11} = \sqrt{\rho_{11}} = 1, \qquad a_{i1} = \rho_{i1} \quad i = 2, 3, \ldots, n$$

$$a_{jj} = \sqrt{\rho_{jj} - \sum_{k=1}^{j-1} a_{jk}^2} \qquad j = 2, 3, \ldots, n$$

$$a_{ij} = \frac{1}{a_{jj}}(\rho_{ij} - \sum_{k=1}^{j-1} a_{ik}a_{jk}) \qquad j < i, \qquad j = 2, 3, \ldots, n-1$$

$$a_{ij} = 0, \quad 1 \le i < j \le n.$$

This method assumes that C is a positive definite matrix.

interpolation was used to seek interest rates when the time to maturity for the convertible bond contained fractions of years (5.5 years, etc.).

(3) Number of simulations
10,000.

(4) VaR calculation method
We input to the pricing model the multivariate normalized random number vector generated in step 2 and calculated the difference from the market value on the base date.

Expressing the risk factors (share prices, implied volatility, interest rates) for issue i as S_i, IV_i, and R_i, respectively, the portfolio value as P, the value of individual convertible bonds as $V_i(S_i, IV_i, R_i)$, and the multivariate normalized random number vector for k items generated in step 2 as X_k, then

$$X_k = (S_{1,k}, S_{2,k}, \ldots, S_{i,k}, IV_{1,k}, IV_{2,k}, \ldots, IV_{i,k}, R_{1,k}, R_{2,k}, \ldots, R_{i,k}).$$

$$\Delta P_k = \sum_i \Delta V_{i,k} = \sum_i [V_i(S_{i,k}, IV_{i,k}, R_{i,k}) - V_i(S_{i,0}, IV_{i,0}, R_{i,0})].$$

$$k = 1, 2, \ldots, 10{,}000.$$

$V_i(S_{i,0}, IV_{i,0}, R_{i,0})$ is the convertible bond price on the base date.

For the pricing model, we use a binomial tree.

(5) VaR calculation criteria
VaR assumes a holding period of two weeks, and a bottom 99th percentile price fluctuation rate against the base date price (ΔP_k/total market value on the base date).

(6) VaR calculation base dates[22]
July 1, 1994 and March 31, 1998.

The simple method

(1) Risk categories and risk factors
The only risk category is share prices, and the only risk factor is individual share prices.

22. To briefly summarize the convertible bond market trends for 1994 that served as the basis for our selection of these base dates:
(1) After the collapse of the "bubble," there were large drops in equity financing (capital increases, convertible bonds, bonds with warrants), but in 1994 the stock market turned upward and this set the stage for renewed financing through convertible bonds.
(2) Institutional investors and personal investors began to buy convertible bonds in the expectation that share prices would rise, so the convertible bond market was solid until about July.
(3) Companies actively issued new equity-linked bonds to provide themselves with the resources to redeem old equity-linked bonds and to raise funds for new capital investments.
(4) In August, the convertible bond market turned downward as the increase in issues began to undermine supply and demand and the fall in coupons made convertible bonds less attractive as investments. Many issues saw their initial listing at below-par prices. The convertible bond market was slack for the rest of the year.
This environment led us to build a portfolio on the assumption that we had purchased convertible bonds at a mix reflective of the market and at a stage immediately prior to a softening of the market (stage 2).
The other base date (March 31, 1998) was selected as the most recent date for which analytical data were available.

(2) Generation of random numbers
Multivariate ordinary random numbers for each share price were generated using the same method as in Monte Carlo simulation.
(3) Number of simulations
10,000 (same as Monte Carlo simulation).
(4) VaR calculation method[23]
We calculated the amount of change in share prices from a multivariate normalized random number vector of share prices and then found the multiplication of the vector of sensitivities to share prices for individual convertible bond prices. In mathematical form, this is expressed as

$$\Delta P_k = \sum_i \Delta V_{i,k} = \sum_i [S_{i,k} - S_{i,0}] \frac{\partial V_{i,0}}{\partial S_{i,0}}.$$

Unlike Monte Carlo simulation, the simple method does not require that convertible bonds be revalued because risk is valued in terms of share prices. Sensitivity is calculated analytically from the Black-Scholes formula.
(5) VaR calculation criteria
Same as Monte Carlo simulation.
(6) VaR calculation base dates
Same as Monte Carlo simulation.

3. Description of portfolio

Appendix Table 1 (found at the end of this paper) contains the issues comprising the test portfolio analyzed.[24] We further divided this portfolio, based on information on July 1, 1994, into a high-parity, low-premium "Sub-portfolio A" and a low-parity, high-premium "Sub-portfolio B" to calculate VaR for each and compare the market risk of their convertible bonds. The reason for using sub-portfolios was to confirm whether the market risk for convertible bonds differed according to parity and other similar factors.

Appendix Table 1 shows changes in market value on the two base dates (the bottom two lines of the table). For Sub-portfolio A, which comprises issues with a high degree of equity-linkage, there was a ¥16 (0.97 percent) drop, while for Sub-portfolio B, which had a high degree of interest-rate-linkage, there was a

23. It would also be possible to use the variance-covariance method as a delta-based simplified method of measuring VaR. In order to avoid any influences from the difference in methodologies (between Monte Carlo simulation and the variance-covariance method), we have used the same multivariate ordinary random number simulation in the simple method as was used in Monte Carlo simulation. The only difference between the two methods, therefore, is in their definitions of the source of risk and their method of calculating value changes to changes in risk factors (ΔP).
24. We referred to Nomura Securities Financial Center (1997) when building this portfolio. The center's handbook provides 14 years of year-end indicators for the convertible bond market (issues listed on the Tokyo Stock Exchange [TSE]). Our portfolio attempts to mimic the convertible bond market as of March 1994 in terms of the market weight of industrial sectors, parities, premiums, and unit prices. As an example, the table below contains a comparison between the market and portfolio for unit prices.

Percent

	Under ¥100	¥100–¥150	Over ¥150
TSE	62.73	36.16	1.11
Test portfolio	57.98	42.02	0.00

¥129.4 (9.69 percent) rise. This confirms that performance differed according to the structure of the portfolio. For reference, Appendix Figure 1 contains parities and premiums on the base dates. Table 1 shows the Nikkei 225 index and Japanese government bond futures interest rates (10 year) for the base dates.

Table 1 Share Prices and Interest Rates on Base Dates

	Nikkei 225 index (yen)	JGB futures (10Y) (percent)
July 1, 1994	20,543.41	4.577
March 31, 1998	16,527.17	2.290

4. Results of VaR calculation and related observations

Tables 2 and 3 contain VaR calculation results for Sub-portfolio A and Sub-portfolio B for July 1, 1994 and March 31, 1998. Both tables also contain coefficients indicating the degree of contribution of each risk category to the VaR for each issue (and each sub-portfolio).

The following characteristics are observed for the calculated VaR.

Characteristics specific to Sub-portfolio A (Table 2)

(1) The results from the base date of July 1, 1994 show many individual issues for which the degree of contribution of implied volatility fluctuation in Monte Carlo simulation VaR (IV-VaR[25]) was roughly as high as that of share price fluctuation (S-VaR). (In some cases, it was actually higher than S-VaR, for example, Hitachi No. 5.) What this means is that implied volatility fluctuation risk cannot be ignored even for issues with high parities and a large degree of share price-linkage.

(2) The results from the base date of March 31, 1998 indicate that the degree of contribution of share price fluctuation (S-VaR) declined as share prices themselves declined, but for many issues the degree of contribution of implied volatility fluctuation (IV-VaR) remained high. What this indicates is that when share prices declined and convertible bonds began to move from being share-price-driven to interest-rate-driven,[26] implied volatility was a factor impacting price fluctuation on both base dates.

(3) Among the changes from one base date to the other was the decline in the VaR for this sub-portfolio from 4.00 percent on July 1, 1994 to 1.74 percent on March 31, 1998. The breakdown by risk category indicates that there were substantial declines in the degrees of contribution of both share price fluctuation and interest rate fluctuation (S-VaR went from 4.09 percent to 2.12 percent; R-VaR from 1.13 percent to 0.42 percent). From the perspective of individual issues, the degree of contribution of implied volatility fluctuation did decline (for example,

25. IV-VaR is a VaR calculated using only implied volatility as a source of risk. More specifically, it fixes the underlying asset price and interest rate at the values found on the base date and then changes only implied volatility (generating multivariate ordinary random numbers) to calculate VaR according to Monte Carlo simulation. Similarly, S-VaR changes only share prices and R-VaR only interest rates, fixing the other two risk categories to calculate VaR.
26. The decline in share prices caused parity to decline, but prices in the convertible bond market did not decline until well after share prices. Because of this, the decline in parity caused the premium to rise, which made issues more driven by interest rates.

Table 2 Results of VaR Simulation for Sub-Portfolio A

Base date: July 1, 1994

Issuer	No.	MS-VaR (percent)	S-VaR (percent)	IV-VaR (percent)	R-VaR (percent)	Uncorrelated VaR (percent)	Simple VaR (percent)
Sekisui House	15	8.13	3.85	7.39	1.63	8.49	4.54
Shin-Etsu Chemical	5	9.77	9.86	0.97	0.29	9.91	10.65
Sumitomo Bakelite	5	5.61	2.66	5.54	1.85	6.42	4.46
Japan Energy	4	4.93	3.21	3.61	1.77	5.15	4.94
Ebara	2	7.86	5.98	5.27	0.91	8.02	6.65
Hitachi	5	10.13	6.21	7.42	1.13	9.74	7.19
Toshiba	6	6.89	6.13	3.06	0.73	6.89	7.55
Sharp	11	7.25	6.53	1.88	0.37	6.81	7.32
Kyushu Matsushita Electric	3	7.41	6.94	2.49	0.90	7.43	8.03
Matsushita Electric Works	7	5.91	3.67	3.47	1.26	5.20	5.11
Dai Nippon Printing	5	7.52	6.09	5.35	1.26	8.21	7.24
Mitsui & Co.	3	6.47	6.04	3.42	1.04	7.02	6.82
Daimaru	12	9.93	7.71	7.77	1.80	11.09	7.45
Nippon Express	4	8.32	6.36	5.57	0.95	8.51	7.01
Chubu Electric Power	1	3.48	0.79	1.69	2.26	2.93	1.36
Sub-portfolio		4.00	4.09	1.69	1.13	4.57	4.76
Positive correlation VaR		—	5.57	4.27	1.17	—	6.54

Base date: March 31, 1998

Issuer	No.	MS-VaR (percent)	S-VaR (percent)	IV-VaR (percent)	R-VaR (percent)	Uncorrelated VaR (percent)	Simple VaR (percent)
Sekisui House	15	0.88	0.32	0.37	0.71	0.86	0.32
Shin-Etsu Chemical	5	10.75	11.20	1.32	0.02	11.28	12.74
Sumitomo Bakelite	5	0.15	0.01	0.01	0.15	0.15	0.11
Japan Energy	4	0.62	0.05	0.05	0.62	0.62	0.00
Ebara	2	4.40	4.08	5.12	0.59	6.58	4.14
Hitachi	5	6.85	3.87	6.21	0.46	7.34	4.74
Toshiba	6	2.96	1.77	2.93	0.41	3.45	2.29
Sharp	11	0.20	0.06	0.06	0.20	0.21	0.00
Kyushu Matsushita Electric	3	0.65	0.07	0.07	0.65	0.65	0.00
Matsushita Electric Works	7	4.68	3.85	4.77	0.25	6.14	4.30
Dai Nippon Printing	5	6.53	6.55	3.06	0.29	7.23	6.91
Mitsui & Co.	3	4.92	4.00	2.40	0.45	4.69	5.15
Daimaru	12	1.69	0.66	1.04	1.18	1.71	0.67
Nippon Express	4	6.23	4.03	5.46	0.80	6.83	4.13
Chubu Electric Power	1	0.29	0.04	0.04	0.28	0.28	0.00
Sub-portfolio		1.74	2.12	1.08	0.42	2.41	2.29
Positive correlation VaR		—	3.05	2.25	0.45	—	3.43

Notes: MS-VaR is the VaR measured by Monte Carlo simulation.
S-VaR is the contribution of share price fluctuation to MS-VaR.
IV-VaR is the contribution of implied volatility fluctuation to MS-VaR.
R-VaR is the contribution of interest rate fluctuation to MS-VaR.
Uncorrelated VaR is the VaR calculated with correlation of zero between risk categories assumed.
Positive correlation VaR is the VaR calculated assuming a correlation of one between issues.
For each issue (and sub-portfolio), the risk category which has the largest contribution is shaded.

Table 3 Results of VaR Simulation for Sub-Portfolio B

Base date: July 1, 1994

Issuer	No.	MS-VaR (percent)	S-VaR (percent)	IV-VaR (percent)	R-VaR (percent)	Uncorrelated VaR (percent)	Simple VaR (percent)
Sekisui House	3	6.78	2.02	6.75	2.18	7.37	2.06
Sapporo Breweries	1	10.11	1.78	9.82	2.36	10.26	1.89
Teijin	7	6.99	3.25	6.80	2.04	7.81	3.71
Asahi Chemical Industry	7	8.60	3.66	9.49	2.16	10.39	3.66
Mitsubishi Chemical	6	5.28	1.78	4.18	2.56	5.22	1.94
Nippon Oil	4	8.95	2.45	8.78	2.23	9.39	2.45
Nippon Oil	5	5.05	1.06	4.44	2.15	5.05	1.21
Mitsubishi Electric	4	6.84	2.94	5.98	1.95	6.94	3.32
NEC	6	7.01	3.65	6.21	2.11	7.51	3.94
Daiwa Securities	7	10.44	4.27	10.17	2.02	11.21	4.98
Nikko Securities	4	9.50	3.13	9.30	2.09	10.03	3.32
Nikko Securities	8	8.67	3.70	8.23	1.83	9.20	3.73
Nomura Securities	7	5.66	1.75	5.05	2.08	5.74	2.22
Mitsubishi Estate	16	8.01	2.26	7.92	2.48	8.61	2.45
All Nippon Airways	4	6.95	2.51	6.10	2.24	6.96	2.87
Sub-portfolio		3.30	1.86	2.65	2.17	3.89	1.92
Positive correlation VaR		—	2.69	7.28	2.16	—	2.93

Base date: March 31, 1998

Issuer	No.	MS-VaR (percent)	S-VaR (percent)	IV-VaR (percent)	R-VaR (percent)	Uncorrelated VaR (percent)	Simple VaR (percent)
Sekisui House	3	1.70	0.74	1.41	0.66	1.72	0.72
Sapporo Breweries	1	0.70	0.04	0.05	0.67	0.68	0.09
Teijin	7	2.08	1.43	1.71	0.67	2.33	1.38
Asahi Chemical Industry	7	1.59	0.71	1.40	0.81	1.77	1.10
Mitsubishi Chemical	6	0.75	0.18	0.21	0.70	0.75	0.21
Nippon Oil	4	1.15	0.56	0.72	0.83	1.23	0.41
Nippon Oil	5	0.66	0.39	0.39	0.33	0.65	0.30
Mitsubishi Electric	4	1.44	0.34	1.22	0.87	1.54	0.65
NEC	6	2.89	1.68	2.49	0.62	3.06	1.79
Daiwa Securities	7	1.12	0.43	0.70	0.72	1.09	0.40
Nikko Securities	4	0.58	0.07	0.10	0.61	0.62	0.10
Nikko Securities	8	0.34	0.00	0.00	0.34	0.34	0.00
Nomura Securities	7	0.35	0.00	0.00	0.34	0.34	0.07
Mitsubishi Estate	16	3.01	1.74	2.70	0.77	3.30	1.69
All Nippon Airways	4	0.80	0.00	0.00	0.86	0.86	0.01
Sub-portfolio		0.76	0.34	0.52	0.64	0.89	0.36
Positive correlation VaR		—	0.56	0.88	0.65	—	0.60

Notes: MS-VaR is the VaR measured by Monte Carlo simulation.
S-VaR is the contribution of share price fluctuation to MS-VaR.
IV-VaR is the contribution of implied volatility fluctuation to MS-VaR.
R-VaR is the contribution of interest rate fluctuation to MS-VaR.
Uncorrelated VaR is the VaR calculated with correlation of zero between risk categories assumed.
Positive correlation VaR is the VaR calculated assuming a correlation of one between issues.
For each issue (and sub-portfolio), the risk category which has the largest contribution is shaded.

Sekisui House No. 15 saw a decline from 7.39 percent to 0.37 percent), but when viewed from the perspective of the sub-portfolio, the dispersion effect prevented the impact from being felt in individual issues (the sub-portfolio as a whole went from 1.69 percent to 1.08 percent).

Characteristics specific to Sub-portfolio B (Table 3)

(1) The results from the base date of July 1, 1994 show that implied volatility fluctuation had a higher degree of contribution (IV-VaR) than share price fluctuation or interest rate fluctuation (S-VaR, R-VaR). This indicates the importance of managing implied volatility risks.

(2) The results from the base date of March 31, 1998 show that for many issues, S-VaR declined to below 1.00 percent, so that the major risk factors became implied volatility and interest rates. Implied volatility tended to be a particularly important risk factor for issues with comparatively long terms to maturity.

(3) Among the changes from one base date to the other for all issues were declines in the values for Monte Carlo simulation VaR (the sub-portfolio went from 3.30 percent to 0.76 percent), S-VaR (from 1.86 percent to 0.34 percent), IV-VaR (from 2.65 percent to 0.52 percent), and R-VaR (from 2.17 percent to 0.64 percent).

Characteristics common to both sub-portfolios (tables 2 and 3)

(1) To observe the influence of different risk categories on each other, we calculated VaR with a correlation of zero between risk categories (uncorrelated VaR[27]), which we found to be higher than Monte Carlo simulation VaR for both sub-portfolios on both base dates. (For example, in Table 2, the sub-portfolio Monte Carlo simulation VaR on July 1, 1994 was 4.00 percent, while the uncorrelated VaR was 4.57 percent.) This relationship was also commonly observed for individual issues, and what it indicates is that the correlation between different risk categories (the negative correlation between share price fluctuation and implied volatility fluctuation,[28] and the positive correlation between share price fluctuation and interest rate fluctuation) had the effect of reducing risk values of the whole.

(2) To observe the influence of different issues on each other, we calculated VaR with the correlation between issues set at one (positive correlation VaR[29]). We found that within risk categories, the positive correlation grows weaker in a category for interest rates, share prices, and implied volatility, in that order (the correlation is smaller the larger the difference between the positive correlation VaR and the sub-portfolio VaR). Note that implied volatility fluctuation is highly

27. Below is the uncorrelated VaR formula for issue i (or for a sub-portfolio):

$$(\text{Uncorrelated } VaR_i)^2 = (S\cdot VaR_i)^2 + (IV\cdot VaR_i)^2 + (R\cdot VaR_i)^2.$$

28. See Section III.A for a statistical analysis of the negative correlation between share prices and implied volatility.

29. A positive correlation VaR is the VaR found when share price fluctuations corresponding to the 99th percentile of each issue occurred simultaneously. In other words, we can express the 99th percentile value for share price fluctuation for issue i because of fluctuation in risk category j as $\Delta V_i(99\%)_j$. This allows us to calculate a positive correlation VaR for risk category j as follows:

$$\text{Positive correlation } VaR_j = \sum_i \Delta V_i(99\%)_j / \sum_i V_{i,0},$$

where $V_{i,0}$ is the market price on the base date for issue i.

dependent on individual issue factors, which means that there is little correlation between issues.

These findings have three implications for Monte Carlo simulation VaR calculations.

(1) There are cases in which implied volatility is the major factor in market risk (as on the July 1, 1994 base date for Sub-portfolio B).

(2) Implied volatility risk is present even when parity is low and there is little linkage to share prices. Attempts to value only interest rate risk may understate the risks involved (as on the March 31, 1998 base date for Sub-portfolio B).

(3) The VaR for implied volatility fluctuation provides fairly large risk values for individual issues, but the use of portfolios has the effect of reducing this risk.

We also performed calculations under the simple method, which considers only share price risk. Below is a summary of how the characteristics of these results differ for those from the Monte Carlo simulation.

First, at the individual issue level, the risk values found with the simple method were not more conservative than those with the Monte Carlo simulation except for a few issues with an extremely high degree of share price-linkage (issues with deltas of 0.8 or more and vegas of 0.7 or less).

At the portfolio level, the simple method produced more conservative VaRs than the Monte Carlo simulation for Sub-portfolio A on both base dates. These results imply the following about the simple method:

(1) The simple method is an effective tool for managing individual issues as long as their deltas are high (for example, over 0.8) and their vegas relatively low (under 0.7). For other issues, however, the implied volatility fluctuation risk cannot be ignored, so it will be necessary to estimate the risks associated with implied volatility fluctuation (and also the risks associated with interest rate fluctuation) separately.

(2) The simple method may be an effective tool for portfolio-level management even if the simple method only considers delta risk. This is because effects of the risks associated with implied volatility fluctuation are relatively small at the portfolio level thanks to the issue diversification effect.

5. Analysis of risk factors in convertible bonds

This subsection analyzes the degree of sensitivity that individual issues have to share prices, implied volatility, and interest rates. In the preceding analysis of market risk, we saw that the three risk categories changed with some degree of correlation. In this analysis, we will focus on implied volatility in particular.

Table 4 contains price volatility (P-Vol) for individual issues (standard deviation of the weekly rate of change for market prices observed for the period January 7, 1994 through December 1, 1995). We have also included the degree of contribution of individual risk categories (share prices, implied volatility, and interest rates) on price volatility (noted as S-Vol, IV-Vol, and R-Vol, respectively).

Table 4 lists issues in order of average parity for the observation period, with the highest parities at the top. Note that the higher the convertible bond's parity (and therefore its delta), the higher its price volatility (P-Vol). Turning to price fluctuation factors, we can see that below an average parity of 80, there is an increase in the

Table 4 Factor Analysis of Price Fluctuation: Observation Period January 7, 1994–December 1, 1995

Issuer	No.	P-Vol (percent)	S-Vol (percent)	IV-Vol (percent)	R-Vol (percent)	Average parity	Average delta
Ricoh	6	2.774	2.933	1.642	0.303	107.293	0.720
Nissan Motor	5	2.576	2.673	2.387	0.382	102.769	0.644
Fujitsu	10	2.300	2.469	1.343	0.332	101.106	0.728
Fujitsu	8	2.208	2.361	1.079	0.344	101.106	0.767
Fujitsu	9	2.100	2.376	1.007	0.346	101.106	0.618
Sumitomo Bakelite	6	2.036	2.457	1.426	0.313	100.571	0.857
Matsushita Electric Industrial	6	2.012	2.183	0.882	0.325	98.442	0.840
Matsushita Electric Industrial	5	1.844	1.959	0.896	0.345	98.442	0.774
Toshiba	6	1.901	1.921	1.996	0.426	96.562	0.599
Asahi Breweries	10	1.751	1.764	1.369	0.237	95.581	0.750
Asahi Breweries	9	1.596	1.666	1.300	0.269	95.581	0.574
Asahi Breweries	8	1.540	1.642	1.314	0.255	95.581	0.700
Hitachi Metals	12	1.410	2.171	1.351	0.363	94.994	0.711
Aisin Seiki	7	1.677	1.879	1.393	0.420	94.961	0.781
Hitachi	5	1.857	1.804	1.816	0.425	94.236	0.614
Mitsui & Co.	6	1.702	2.151	1.312	0.419	93.714	0.856
Ebara	2	1.713	1.961	0.405	0.405	93.462	0.748
Nippon Express	4	1.716	1.896	1.596	0.395	91.643	0.775
Hokkaido Electric Power	1	1.229	0.960	1.664	0.495	91.062	0.468
Hokuriku Electric Power	1	1.540	0.936	1.622	0.480	89.620	0.518
NGK Spark Plug	3	1.709	2.021	2.727	0.400	88.057	0.721
NGK Spark Plug	4	1.570	1.833	1.600	0.405	88.057	0.646
Shimizu	1	1.824	1.842	2.323	0.514	87.978	0.538
Kubota	7	1.536	1.567	1.571	0.412	86.740	0.609
Kubota	9	1.529	1.692	1.573	0.383	86.740	0.540
Kubota	8	1.481	1.625	1.499	0.407	86.740	0.525
Sanyo Electric	6	1.697	1.902	2.145	0.566	86.665	0.551
Yasuda Fire & Marine Insurance	3	1.407	1.216	1.529	0.475	84.011	0.385
Koa Fire & Marine Insurance	3	1.203	0.978	1.113	0.367	82.911	0.285
Chugai Pharmaceutical	5	1.800	1.741	1.757	0.420	82.069	0.753
Tohoku Electric Power	1	1.180	0.886	1.590	0.575	81.727	0.419
Chugoku Electric Power	1	1.270	0.603	1.363	0.600	80.470	0.391
Fukuyama Transporting	2	2.250	2.223	1.727	0.471	79.858	0.720
Hanshin Electric Railway	9	1.727	1.649	1.801	0.511	79.489	0.516
Sekisui House	14	1.795	1.325	1.934	0.538	79.280	0.509
Sekisui House	15	1.697	1.124	1.699	0.517	79.280	0.563
Toray Industries	7	1.534	0.963	1.709	0.706	72.195	0.430
Sekisui House	5	2.020	0.810	2.158	0.676	69.345	0.387
Sekisui House	6	1.028	0.537	1.010	0.559	69.345	0.227
Maeda Corp.	2	1.412	1.046	1.692	0.681	68.377	0.420
Teijin	7	1.172	0.836	1.349	0.849	57.085	0.282
Sekisui House	3	1.409	0.466	1.464	0.811	56.463	0.266
Asahi Chemical Industry	7	1.185	0.582	1.458	0.836	53.666	0.282
NEC	6	1.109	0.835	1.047	0.790	53.631	0.267
All Nippon Airways	4	1.254	0.731	1.488	0.796	50.943	0.323
Nippon Oil	4	1.278	0.390	1.304	0.868	48.417	0.229
Nippon Oil	5	0.862	0.179	1.043	0.683	48.417	0.114
Nikko Securities	4	0.973	0.596	1.155	0.756	46.769	0.229
Daiwa Securities	7	1.459	1.004	1.471	0.837	44.523	0.314
Sapporo Breweries	1	1.357	0.349	1.356	0.842	44.292	0.230
Mitsubishi Chemical	6	1.179	0.388	1.281	0.932	43.568	0.144
Mitsubishi Estate	16	1.323	0.437	1.284	0.898	41.895	0.223

Notes: P-Vol is share price volatility.
S-Vol is the contribution of share price fluctuation to P-Vol.
IV-Vol is the contribution of implied volatility fluctuation to P-Vol.
R-Vol is the contribution of interest rate fluctuation to P-Vol.
For each issue, the risk category which has the largest contribution is shaded.

degree of contribution to risk of implied volatility (IV-Vol[30]), which indicates that implied volatility fluctuation becomes the main factor in convertible bond price fluctuation. While the degree of contribution of share price fluctuation (S-Vol) tends to decline the lower the average delta, the degree of contribution of implied volatility fluctuation (IV-Vol) is generally high and stable for issues with low average deltas and average parities.

Table 5 contains the results of a similar analysis performed for the 1996–97 period. This period saw further declines in share prices, which made issues even more strongly linked to interest rates. But even under these conditions, implied volatility fluctuation continued to be the main factor in convertible bond price fluctuation.

Table 5 Factor Analysis of Price Fluctuation: Observation Period May 1, 1996–November 21, 1997

Issuer	No.	P-Vol (percent)	S-Vol (percent)	IV-Vol (percent)	R-Vol (percent)	Average parity	Average delta
Hokkaido Electric Power	1	0.898	0.285	1.009	0.376	81.922	0.176
Hokuriku Electric Power	1	1.080	0.449	1.167	0.365	81.653	0.250
Toray Industries	7	0.543	0.824	0.927	0.354	79.553	0.300
Chugoku Electric Power	1	0.422	0.266	0.588	0.358	73.200	0.151
Tohoku Electric Power	1	0.450	0.270	0.599	0.369	70.117	0.143
Sekisui House	5	0.930	0.377	0.904	0.449	67.563	0.108
Sekisui House	6	0.472	0.161	0.445	0.261	67.563	0.049
NEC	6	0.881	0.573	0.728	0.390	66.873	0.156
Teijin	7	0.622	0.282	0.627	0.443	57.573	0.085
Mitsubishi Estate	16	0.664	0.368	0.579	0.488	57.212	0.098
Sekisui House	3	0.471	0.157	0.487	0.444	55.012	0.052
Asahi Chemical Industry	7	0.628	0.219	0.705	0.481	51.477	0.097
Sapporo Breweries	1	0.462	0.179	0.560	0.422	45.722	0.100
Nippon Oil	4	0.547	0.230	0.630	0.481	44.860	0.104
Nippon Oil	5	0.276	0.109	0.333	0.277	44.860	0.048
All Nippon Airways	4	0.635	0.235	0.700	0.476	42.441	0.106
Nikko Securities	4	0.663	0.239	0.517	0.371	37.401	0.085
Mitsubishi Chemical	6	0.502	0.199	0.495	0.442	35.384	0.087
Daiwa Securities	7	0.685	0.225	0.655	0.450	33.891	0.121

Note: For each issue, the risk category which has the largest contribution is shaded.

At present, the convertible bond market contains a high percentage of issues with conversion prices below share prices, and in situations like this it is particularly important to manage implied volatility, which is one of the risk parameters peculiar to convertible bonds.

Our Monte Carlo simulation (VaR calculation) did not explicitly consider the influence of time on convertible bond prices. Most convertible bonds are low-coupon bonds, and because of this the price of their bond component tends to be under par. The value of the bond component rises over time[31] (all else being equal)

30. IV-Vol is the price volatility of the convertible bond when only implied volatility fluctuation is taken into account. In other words, a binomial tree model of the theoretical price of the convertible bond is created using the current value only for implied volatility and previous values for other price fluctuation factors (underlying asset prices, interest rates). The rate of return from the theoretical price is then used to calculate a weekly price volatility. Similarly, S-Vol and R-Vol express price volatility for theoretical prices calculated when only share prices and interest rates (respectively) are allowed to change and all other price fluctuation factors are kept the same.
31. It is conceivable that there would be convertible bonds over par when interest rates are low, and in this case the value would decline over time.

and gradually moves closer to par, but as this is happening, the time value of the conversion option wanes because the term to maturity declines. Therefore, the value of the convertible bond will decline over time when the bond is highly linked to share prices, but will tend to rise over time when it is highly linked to interest rates. We considered these effects to be predictable and therefore excluded them from our definition of risk in this simulation, though it would be possible to include them. Suffice it to underscore here the need to pay particularly close attention to declines in time value for highly share price-driven portfolios.

III. Empirical Analysis of Japanese Convertible Bond Market

In this chapter, we use the binomial tree pricing model discussed in Chapter II to transform market price data for convertible bonds into implied volatility data and then perform a number of regression analyses and analyze market characteristics.

During the late 1980s, Japanese companies reduced the weight of bank borrowings in their fund-raising in favor of issues of equity-linked bonds, primarily convertible bonds and bonds with warrants. The traditional explanation for this behavior has been that "equity-linked bonds were a cheaper means of fund-raising than either bank borrowings or straight bonds." Cheaper in this context means that coupons were lower than they would have been for bank borrowings or straight bonds. However, the cost to issuers from convertible bond fund-raising is not just the coupon but the value of the options sold in order to reduce that coupon, since the issuer receives a premium from investors for the options it sells, which effectively helps it to reduce costs. In other words, the higher the issuing conditions with respect to the implied volatility of the conversion option, the more advantageous this method is to the issuer.

As this example illustrates, an analysis of implied volatility is essential to understanding the nature of the convertible bond market. Our analysis in the preceding chapter indicated that implied volatility was strong for individual convertible bond issues (but with very little correlation among issues). Nonetheless, it has been fairly rare in traditional analyses of the convertible bond market to delve into detailed analysis of implied volatility data at the individual issue level. In this chapter, we use the time-series implied volatility data calculated from the binomial tree model to observe the workings of the convertible bond market.

Our analysis covers weekly data on convertible bonds issued in 1987 and 1994 with a rating of at least BBB and an issue amount of at least ¥20 billion. We will refer to Appendix Figure 2 and Appendix Figure 3 in discussing implied volatility for some of the issues covered in this analysis.

A. Linkage between the Convertible Bond Market and the Stock Market

In Section II.C, we observed that for most issues there was a negative correlation between share price and implied volatility, the risk parameters of convertible bonds. In this section, we see statistical verification of the significance of this correlation.

We use a regression model to accomplish this.[32]

$$IV_{i,t+1} - IV_{i,t} = a_i + b_i(SP_{i,t+1} - SP_{i,t}) + \varepsilon_{i,t}, \tag{1}$$

where
i is the issue,
t is the weeks elapsed, $t = 0, 1, 2, \ldots,$
SP is the share price.

When coefficient b is negative and the t-value (absolute) is large, there will be a strong negative correlation between share price fluctuation and implied volatility fluctuation. Appendix Table 2 contains regression results for individual issues, with the overall trends summarized in Table 6.

Table 6 Summary of Results for Coefficient *b* on Regression Model (1)
—Ratio of issues with negative coefficient b and significant t-value to all sample issues
Percent

Issued in 1987		Issued in 1994	
$b < 0$	t-value < –2	$b < 0$	t-value < –2
100.0	85.7	100.0	96.3

These results find a negative value for coefficient b for all issues and a t-value (absolute) in excess of two for most issues, which confirms that there is a significant negative correlation between share price fluctuation and implied volatility fluctuation.[33]

Let us now examine two hypotheses regarding this negative correlation.

(1) This is a phenomenon that is commonly seen between share prices and the implied volatility of options with shares as underlying assets, and is not something peculiar to the convertible bond market.

(2) This is a phenomenon that is peculiar to the convertible bond market, and it happens because convertible bond prices respond sluggishly to changes in the price of their underlying shares. For example, when the share price rises (or falls), convertible bond prices do not incorporate the move, which causes a decline (rise) in nominal implied volatility.

We tested the first hypothesis with a similar analysis of options on the Nikkei 225 index, as shown in Table 7. We did not find significance for either coefficient b or the t-value for any observation period and indeed could find no negative correlation like that seen for the convertible bond.

These findings make it difficult to conclude that it is common to have a negative correlation between underlying asset price fluctuation and implied volatility fluctuation. We have therefore rejected hypothesis (1).

32. All of the models in this paper, including this one, are time-series data analysis models for individual issues. As an alternative to these models, panel data models could be used. When performing the analysis for this paper, we began by testing panel data analysis, but F-tests forced us to reject panel data handling and select analysis of individual issues. Because of this, all of the analysis that follows is time-series data analysis for individual issues.

33. It is conceivable that a positive correlation could similarly be demonstrated for implied volatility fluctuation and interest rate fluctuation.

Table 7 Results for Regression Model (1) Applied to the Nikkei 225 Index

Period	*a*	*t*-value	*b*	*t*-value	$\bar{R}^2$
1994–95	–0.0768	–0.2608	0.0007	1.2249	0.0049
1995–96	–0.0677	–0.1814	0.0007	0.8942	–0.0020
1996–97	0.0765	0.2125	–0.0001	–0.1581	–0.0097

We do not directly test hypothesis (2) in this paper, though this also means that we cannot reject the possibility that there are other factors in the convertible bond market that would cause a negative correlation besides those in hypothesis (2). We would, however, draw the reader's attention to prior research[34] that points to a time lag between changes in share prices and changes in convertible bond prices. Compared to the Nikkei 225 index market, the convertible bond market lacks liquidity and effective hedge functions (futures, lending market). It may be, therefore, that price formation in this market is unable to fully reflect price movements in the stock market that underlies it. Nonetheless, the fact that implied volatility is influenced by sluggish price response is one of the characteristics of the convertible bond market.

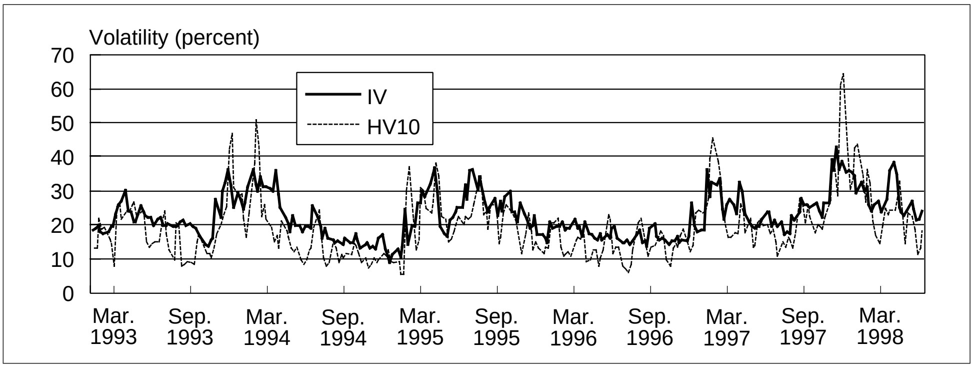
B. Weak Arbitrage in the Convertible Bond Market

In this section, we use historical volatility to investigate the fluctuation characteristics of implied volatility in the secondary market for convertible bonds.

Implied volatility evaluation is essential to investment studies of option-style instruments, as we have already demonstrated. One benchmark to be used in determining whether implied volatility is relatively high or relatively low is the historical volatility of the underlying assets.[35] We will therefore consider the relationship between the implied volatility of options on the Nikkei 225 index and the historical volatility of the Nikkei 225 index.

Figure 3 plots implied volatility for the nearest contract month for options on the Nikkei 225 index and 10-day historical volatility (HV10) for the Nikkei 225 index.

Figure 3 Movement of Implied Volatility for Options on the Nikkei 225 Index and 10-Day Historical Volatility (HV10)



34. See Nakamura and Suzuki (1997).
35. We must emphasize that historical volatility is data on the historical fluctuation of the underlying assets and does not directly predict future fluctuation.

It would appear that, on the whole, there is a close relationship between implied volatility and historical volatility trends.

We used the following regression to examine implied volatility and historical volatility, with historical volatility measured in 10-day, 20-day, and 30-day units:

$$IV_t = bHV_t. \qquad (2)$$

Table 8 contains the results from the regression analysis. The results show the value of coefficient b to be close to one for all historical volatility units. The "t (b = 1)" column in the table represents t-values for the null hypothesis b = 1. The results for HV10 in particular make it impossible to reject the hypothesis "b = 1," which gives an indication of the strength of the link between implied volatility and historical volatility. Note also that the adjusted coefficient of determination ($\bar{R}^2$) is generally at about 50 percent.

Table 8 Results for Regression Model (2)

	b	t-value (b = 0)	t-value (b = 1)	$\bar{R}^2$
HV10	1.0331	54.9245	**1.7597**	0.5386
HV20	1.0549	67.3274	3.5050	0.5918
HV30	1.0570	69.1783	3.7300	0.5670

We analyzed the relationship between implied volatility as calculated from convertible bond prices and the historical volatility of the underlying assets. Appendix Table 3 (1987 issues) and Appendix Table 4 (1994 issues) contain the results for a regression analysis performed using the same method as that for the Nikkei 225 index. Given the long terms of the option components of convertible bonds, we extended the historical volatility observation period to a maximum of 200 days.

The results rejected the null hypothesis "b = 1" for 23 of the 28 1987 issues (82.1 percent) and 25 of the 27 1994 issues (92.6 percent). In other words, we did not observe the kind of strong links that were seen for the options on the Nikkei 225 index. The reason for this is probably that arbitrage does not function as well in this market as it does in the market for options on the Nikkei 225 index because the terms of convertible bond options are so long, there is no effective hedge in the market, and liquidity is inadequate. Therefore, although share price historical volatility and convertible bond implied volatility do not have the kind of strong linkage that was observed for the Nikkei 225 index and options on the Nikkei 225 index, we predict that there will be a weak relationship, and we test that prediction with the following hypothesis.

HYPOTHESIS. *There is no significant gap between implied volatility and historical volatility.*

The market for convertible bonds is not like that for options on the Nikkei 225 index (where there was a relatively strong correlation between implied volatility and historical volatility levels). Rather, it is a market in which implied volatility will move so as to *reduce the gap with historical volatility over a set period of time (for this analysis, we posited one week hence). (For the purposes of this paper, we refer to this mechanism as "weak arbitrage.")*

If this hypothesis is correct, then there should be some form of benchmark for convertible bond implied volatility, and this can be interpreted as a volatility that stably reflects the company's potential and uncertainty.

To test this hypothesis, we posited the following regression model:

$$IV_{i,t+1} - IV_{i,t} = a_i + b_i(HV_{i,t} - IV_{i,t}) + \varepsilon_{i,t}. \tag{3}$$

If coefficient b is positive and the t-value high, then we will be able to confirm a statistically significant "weak arbitrage." For the test, we used historical volatility calculated in periods of 20, 60, 100, and 200 days. Appendix Table 5 (1987 issues) and Appendix Table 6 (1994 issues) contain the regression results for individual issues. We have summarized the overall trends observed in Table 9.

Table 9 Summary of Results for Coefficient *b* on Regression Model (3)

—Ratio of issues with positive coefficient *b* and significant *t*-value to all sample issues

Percent

	Issued in 1987		Issued in 1994	
	$b > 0$	t-value > 2	$b > 0$	t-value > 2
HV20	100.0	75.0	100.0	59.3
HV60	100.0	82.1	100.0	85.2
HV100	100.0	85.7	100.0	88.9
HV200	100.0	100.0	100.0	92.6

Table 9 indicates that the coefficient b value that would demonstrate the existence of weak arbitrage was positive on an all-issue basis. The statistical significance of coefficient b tends to rise the longer the historical volatility observation period. These results allow us to revise model (3) as follows:

$$IV_{i,t+1} - IV_{i,t} = c_i(x_i - IV_{i,t}) + \varepsilon_{i,t}. \tag{4}$$

This is a mean reversion model that assumes the existence of an implied volatility convergence value (x) for each issue at the extremes of historical volatility. Appendix Table 7 contains the results of an analysis using the same data as in model (3). Table 10 summarizes the overall trends.

Table 10 Summary of Results for Coefficient *c* on Regression Model (4)

—Ratio of issues with positive coefficient *c* and significant *t*-value to all sample issues

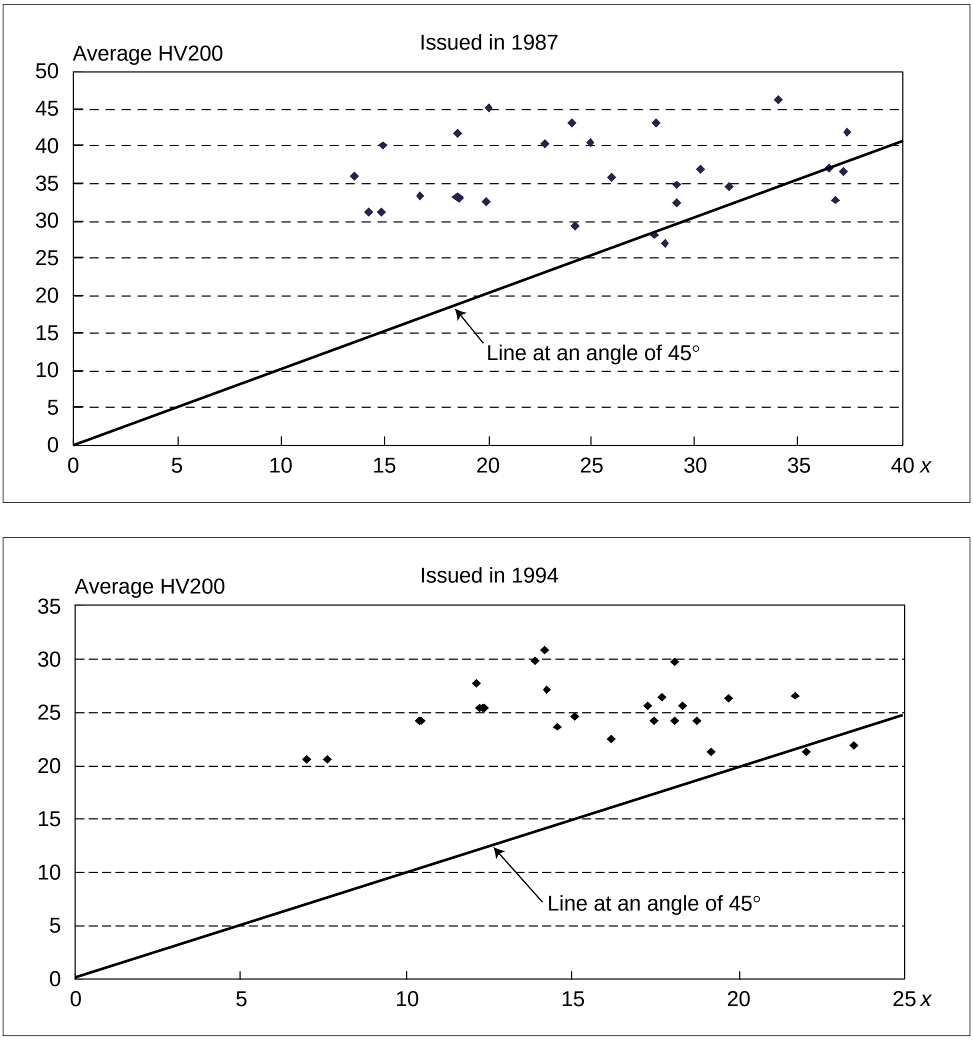
Percent

	Issued in 1987		Issued in 1994	
	$c > 0$	t-value > 2	$c > 0$	t-value > 2
Convergence value (x)	100.0	100.0	100.0	92.6

We confirm here that coefficient *c* is positive on an all-issue basis. The results were statistically significant for all of the 1987 issues and for most (25 out of 27) of the 1994 issues.

Figure 4 is a dispersion graph that plots HV200 averages (Average HV200) and implied volatility convergence values (*x*) for individual issues.

Figure 4 Implied Volatility Convergence Values (*x*) versus Average of HV200



Observe the broader range for the implied volatility convergence values than for the HV200 averages, and also the fact that the implied volatility convergence values for most issues are lower than the HV200 average (distributed above a line at an angle of 45°). The reason why the implied volatility convergence value tends to be lower than the historical volatility average is probably a reflection of the fact that the costs inherent in the convertible bond market (stock borrowing costs, liquidity costs) make it difficult to engage in arbitrage.

To sum up the findings from these analyses, convertible bond implied volatility does not have as strong an arbitrage function as options on the Nikkei 225 index, but it does have a "weak arbitrage" mechanism that converges on some value with a lag of about a week.

C. Convertible Bond Issuing Conditions as Seen in Terms of Implied Volatility

One of the things that set the convertible bond market of the "bubble" period apart was that prices immediately after listing were well above issuing prices. This phenomenon was broadly known in the markets, and there are two main schools of thought as to why.

(1) The price of the underlying shares shot higher between the time issuing conditions were set and the time the bond was listed, so convertible bond prices rose to the levels rationally implied by the share price gains.

(2) Issuing conditions were set at a discount to prevailing market conditions, or conversely, speculation after listing created a premium in prevailing prices.

The effect of the first of these explanations is to say that convertible bond prices merely provided a rational reflection of trends on the stock market, so this was not a phenomenon peculiar to convertible bonds (and should not therefore be delved into any further in this paper). The effect of the second is to say that this is a reaction that is peculiar to the convertible bond market and that can therefore be examined using implied volatility trends (specifically, if this is true, implied volatility as calculated from market prices immediately after listing will be higher than implied volatility as calculated from issuing conditions). If, as stated in the first hypothesis, we are able to explain all convertible bond price gains from skyrocketing share prices, then there should be no unusual movement detected in implied volatility. Because of this, few researchers have bothered to analyze the second hypothesis. In the pages that follow, we provide a statistical analysis of implied volatility trends in the convertible bond market just after issuing.

We begin by comparing and graphing implied volatility as calculated from issuing prices and implied volatility as calculated from market prices for convertible bonds issued in 1987 (during the "bubble") and in 1994 (after the "bubble"). (As one example, see Appendix Figure 2[36] and Appendix Figure 3.) At both points in time, large numbers of issues experienced sharp rises in implied volatility just after listing.

We posit the following hypothesis in order to statistically analyze this trend.

HYPOTHESIS. *There are odd movements in implied volatility as calculated from convertible bond prices just after listing.*

There are many cases in which the price of a convertible bond rose sharply just after listing (for example, from ¥100 to ¥120). Inherent in this were factors that cannot be explained in terms of share price and interest rate changes and therefore indicate odd implied volatility movements.

36. Notice in Appendix Figure 2 that NEC No. 6 sees two sharp drops in implied volatility. These were cases in which there was a conversion discount (the convertible bond price was lower than the price of converted shares) that made it impossible to rationally value the implied volatility of the conversion option. One task for the future will be to improve the pricing model so that it can appropriately handle this sort of data.

We use the following regression model to test this hypothesis.

$$IV_{i,t+1} - IV_{i,t} = a_i(x_i - IV_{i,t}) + b_i DUM0_t + \varepsilon_{i,t}. \quad (5)$$

where
- i is the issue,
- t is the weeks elapsed, $t = 0, 1, 2 \ldots,$
- x is the implied volatility convergence value as explained in the preceding section,
- $DUM0_t$ is the dummy variable that is one only at the time of issue ($t = 0$) and zero at other times.

If coefficient b of the dummy variable is positive and the t-value is high, then implied volatility as valued from prevailing prices just after listing ($t = 1$) is rising in an odd manner not observed at other times. Appendix Table 8[37] contains findings from the analysis of individual issues. We have summarized the results for the sample as a whole in Table 11.

Table 11 Summary of Results for Coefficient *b* on Regression Model (5)
—Ratio of issues with positive coefficient b and significant t-value to all sample issues
Percent

Issued in 1987		Issued in 1994	
$b > 0$	t-value > 2	$b > 0$	t-value > 2
96.3	63.0	82.6	43.5

Coefficient b is positive for almost all issues. Of particular note is the larger number of statistically significant issues in 1987 (during the "bubble") compared to 1994 (after the "bubble"). This analysis therefore demonstrates that there is a statistically significant rise in implied volatility just after the listing of the convertible bond.

The reason for the sharp rise in implied volatility just after listing could be either (1) because issuing conditions were at a discount to prevailing market conditions; or (2) because there was an influx of speculation just after listing that resulted in prices rising to a premium *vis-à-vis* prevailing market conditions. To decide which of these is correct, we must compare implied volatility as calculated from issuing conditions and implied volatility just after listing against the implied volatility convergence value measured in Section III.B.

Table 12[38] covers shares that experienced a statistically significant rise in implied volatility just after listing (see Appendix Table 8) and summarizes their implied volatility before and after listing (respectively, IV(t = 0) and IV(t = 1)) and their implied volatility convergence value (x).

37. We have excluded from this analysis issues that experienced a conversion discount just after listing.
38. We have excluded from this analysis shares that experienced several conversion discounts (conversion price below the price of converted shares) during the observation period. Our criterion for exclusion was a conversion discount for 25 percent or more of the observation period.

Table 12 Relations among Implied Volatility at Issuance, Implied Volatility Just after Listing, and Implied Volatility Convergence Value

Issued in 1987

Issuer	No.	IV(t = 0)	x	IV(t = 1)	Deviation from x (percent)	
					IV(t = 0)	IV(t = 1)
NEC	6	4.461	28.193	36.408	–84.2	29.1
Nikko Securities	4	6.648	34.087	45.484	–80.5	33.4
Sapporo Breweries	1	8.041	36.743	38.363	–78.1	4.4
Teijin	7	7.205	28.579	35.093	–74.8	22.8
Toray Industries	7	8.567	28.101	30.263	–69.5	7.7
Mitsubishi Estate	16	13.481	30.299	40.425	–55.5	33.4
Asahi Chemical Industry	7	9.707	29.136	35.464	–66.7	21.7
Hitachi	5	11.009	24.063	52.389	–54.2	117.7
Mitsubishi Chemical	6	4.006	29.207	39.409	–86.3	34.9
Sony	2	18.086	18.661	40.792	–3.1	118.6
Sekisui House	3	7.926	31.718	40.058	–75.0	26.3
Daiwa Securities	7	17.336	37.365	48.626	–53.6	30.1
Chugoku Electric Power	1	17.234	37.153	45.961	–53.6	23.7
Tohoku Electric Power	1	16.042	36.447	58.433	–56.0	60.3
Murata Mfg.	4	5.121	20.009	32.275	–74.4	61.3
All Nippon Airways	4	6.139	24.309	19.921	–74.7	–18.1

Issued in 1994

Issuer	No.	IV(t = 0)	x	IV(t = 1)	Deviation from x (percent)	
					IV(t = 0)	IV(t = 1)
Nippon Express	4	10.117	17.695	18.972	–42.8	7.2
Sekisui House	14	15.654	22.016	26.135	–28.9	18.7
Sekisui House	15	13.992	19.185	24.014	–27.1	25.2
Ebara	2	12.940	21.694	26.738	–40.4	23.3
Yasuda Fire & Marine Insurance	3	12.614	14.207	19.482	–11.2	37.1
Chugai Pharmaceutical	5	15.719	23.474	22.945	–33.0	–2.3
Koa Fire & Marine Insurance	3	11.458	12.071	16.107	–5.1	33.4

Notes: IV(t = 0) is the implied volatility calculated based on issuing conditions.
X is the implied volatility convergence value measured in the preceding section.
IV(t = 1) is the implied volatility just after listing.
Shaded cells indicate that the absolute value of deviation from convergence value (x) is over 40 percent.
The calculation formula for the deviation between convergence value (x) and implied volatility is deviation = $(IV - x)/x$.

We would draw the reader's attention to two specific points regarding Table 12:

(1) For 1987 issues, the implied volatility just after listing (t = 1) was not that different from the implied volatility convergence value (x) (about 75 percent of all issues had an absolute spread value of less than 40 percent), but for most issues, implied volatility at the time of issue (t = 0) was substantially below the convergence value (93.8 percent of all issues had an absolute spread value of

more than 40 percent). It would seem that implied volatility was undervalued at the time of issue for these bonds (examples would include NEC No. 6 and Nikko Securities No. 4).

(2) For 1994 issues, there was not as much difference between implied volatility just after listing and implied volatility versus the convergence value as there was for 1987 issues (there are few shaded cells for 1994 issues in Table 12).

Therefore, when implied volatility is used as a yardstick for measuring the profitability of financing, a not inconsiderable number of the convertible bonds issued during the "bubble" period (1987) had issuing conditions that undervalued implied volatility *vis-à-vis* prevailing market volatility (the convergence value of implied volatility). In other words, in many cases this financing was disadvantageous to issuers (and therefore advantageous to purchasing investors) because they could have sold the conversion options for higher premiums. We also confirmed that this phenomenon has faded since the collapse of the "bubble" (1994). It is conceivable that this is because the methods used to determine issuing conditions are now more in line with prevailing market conditions.

IV. Conclusions

This paper reached the following conclusions from its empirical analysis of the implied volatility of individual convertible bond issues:

(1) At the individual issue level, the convertible bond market is slow to respond to movements in share prices and other factors. Remedying this point will require greater market efficiency, perhaps by establishing a market for borrowed stock.

(2) The implied volatility of convertible bonds moves as a mean reversion that does not depart widely from the actual fluctuation of share prices (historical volatility). We interpret this mechanism as "weak arbitrage."

(3) Valuation of the implied volatility of issues indicates that equity financing was not necessarily advantageous for issuers during the "bubble" period.

(4) Implied volatility management is an important component of market risk management for convertible bonds. It is often the case, with convertible bonds that have a low degree of linkage to share prices in particular, that implied volatility will have more of an influence on the bond's price fluctuation than either share prices or interest rates.

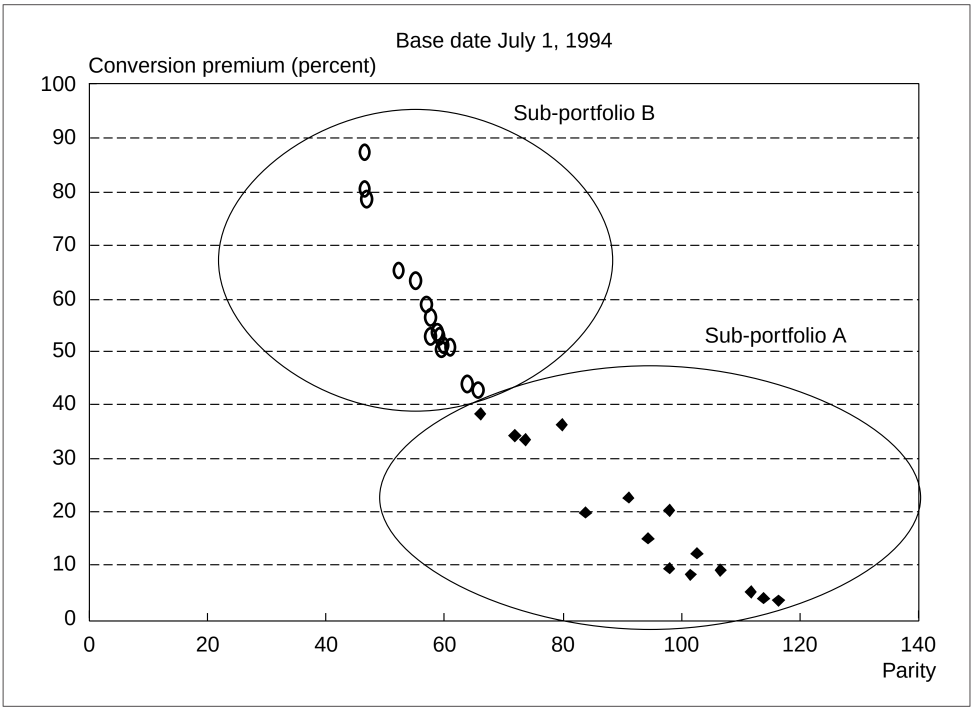
Among topics that this paper did not explore, we would point out the following two points as important subjects.

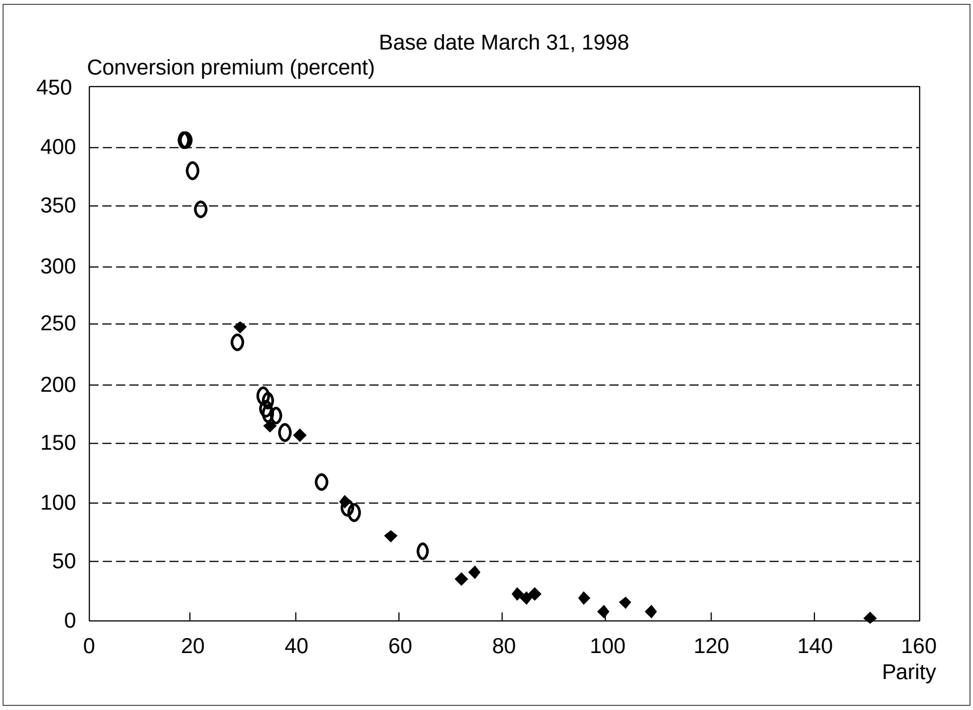
(1) Methods for convertible bond pricing and risk management that take account of default potential (credit risk).

(2) Pricing method and empirical analysis for convertible bonds with exotic features.

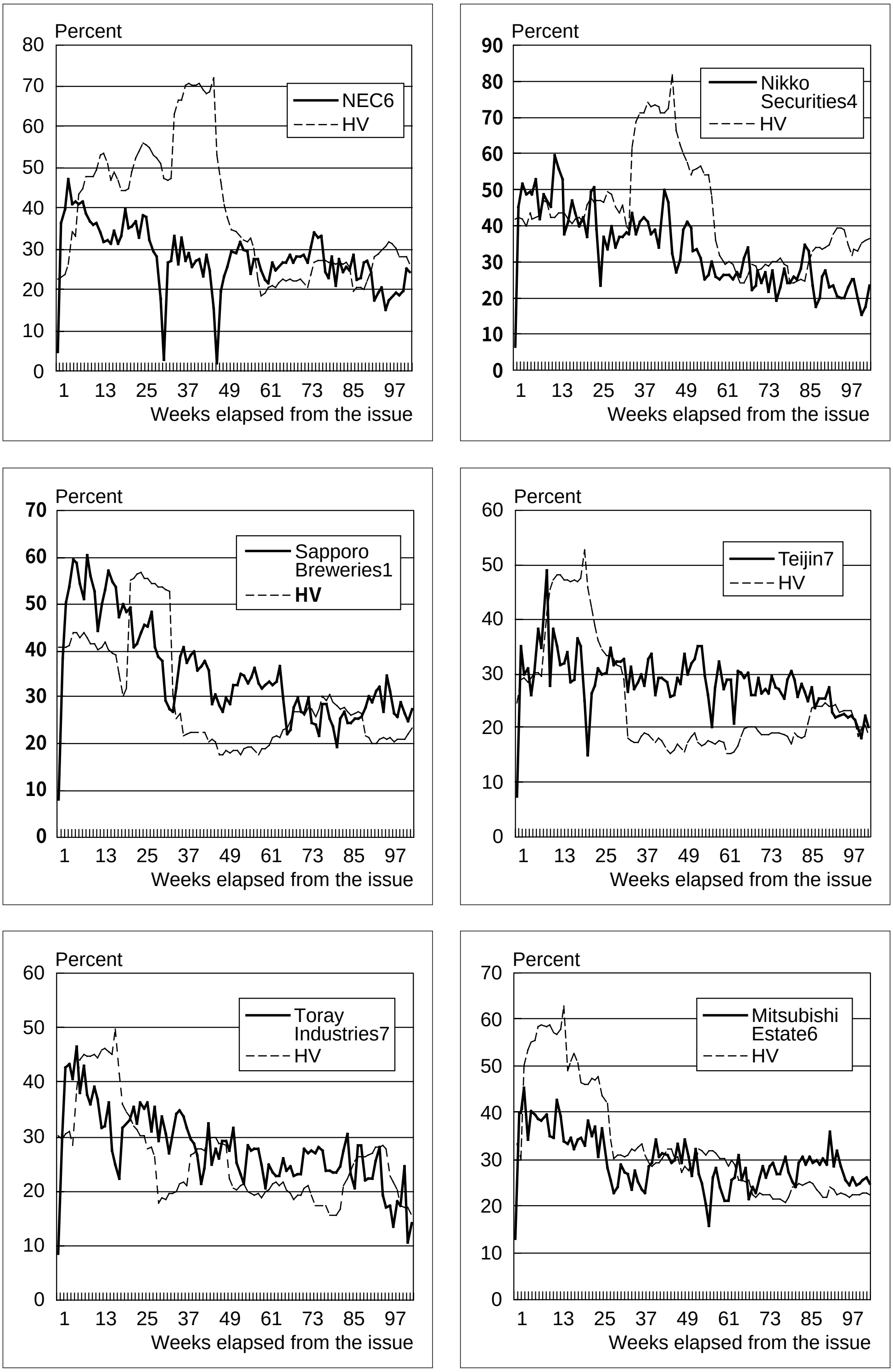
The crash that was seen in the convertible bond market on November 1997 was caused by manifestation of credit risk, and it is related to the first topic. Hence it is all the more necessary to develop a means of pricing that accounts for default potential when there is a wide spread between share prices and conversion prices and the bond is driven by interest rates. The second topic will be an important part of research into the influence on financial institution share prices of convertible bonds issued with forced conversion provisions for the purposes of meeting capital adequacy standards.

Appendix Figure 1 Distribution of Parity and Conversion Premium

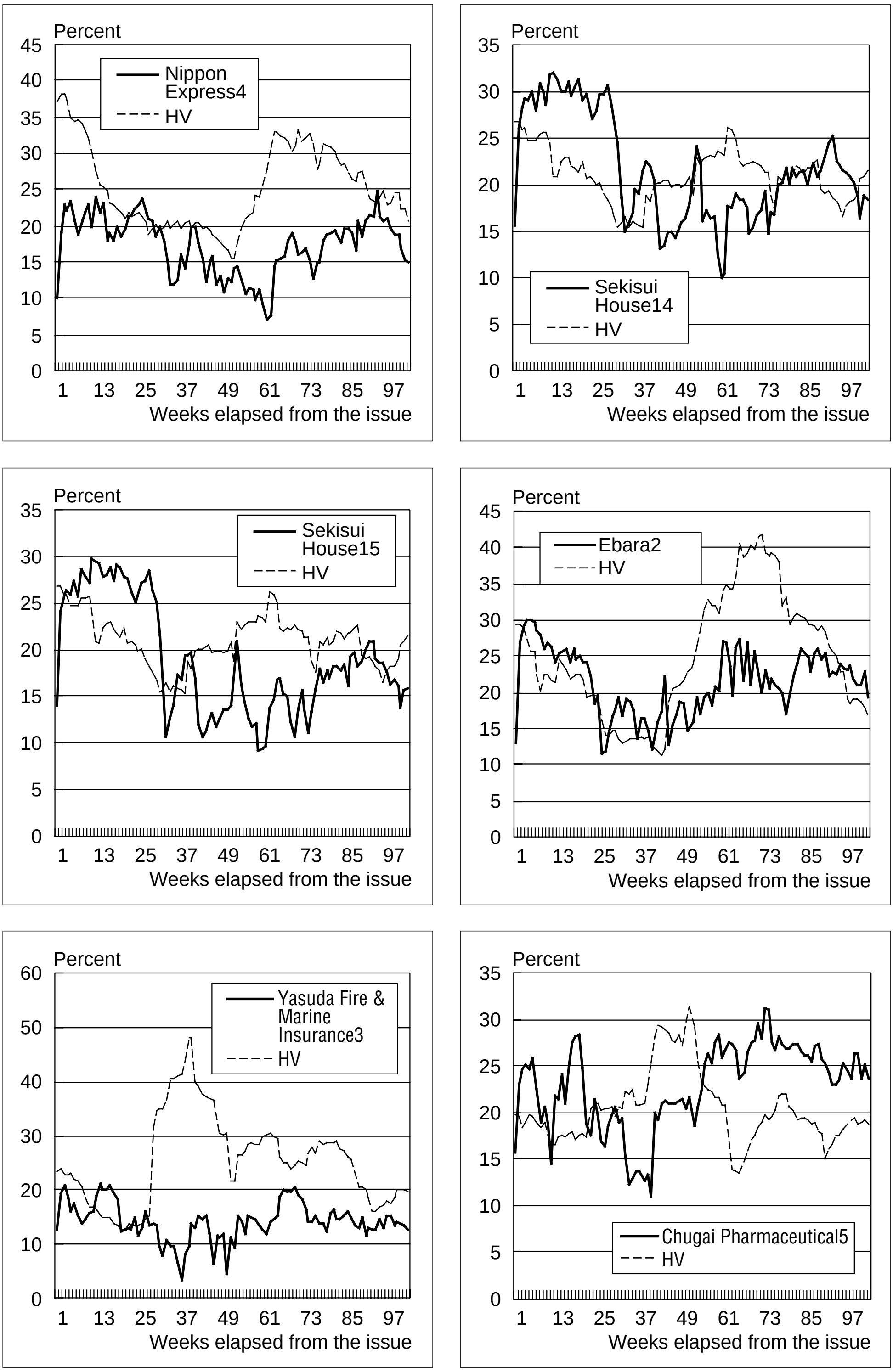




Appendix Figure 2 Implied Volatility (Solid Line) and 60-Day Historical Volatility (Dotted Line) for Convertible Bonds Issued in 1987



Appendix Figure 3 Implied Volatility (Solid Line) and 60-Day Historical Volatility (Dotted Line) for Convertible Bonds Issued in 1994



Appendix Table 1 List of Issues in the Test Portfolio Used for VaR Measurements

Issuer	No.	Parity	Years to maturity	Conversion premium (percent)	Sub-portfolio	Price (1) (yen)	Price (2) (yen)	Difference (yen)
Sharp	11	116.474	4.249	3.378	A	118.5	99.9	–18.6
Shin-Etsu Chemical	5	114.040	4.748	3.468	A	118.0	153.0	35.0
Toshiba	6	111.602	7.742	5.016	A	117.2	104.1	–13.1
Ebara	2	106.502	8.748	8.919	A	116.0	105.3	–10.7
Hitachi	5	102.726	7.742	11.948	A	115.0	113.5	–1.5
Nippon Express	4	101.463	9.748	8.118	A	109.7	101.2	–8.5
Mitsui & Co.	3	97.919	8.748	9.171	A	106.9	107.5	0.6
Kyushu Matsushita Electric	3	97.863	6.247	20.066	A	117.5	105.4	–12.1
Dai Nippon Printing	5	94.228	7.915	14.828	A	108.2	116.6	8.4
Matsushita Electric Works	7	91.111	6.416	22.379	A	111.5	118.0	6.5
Sekisui House	15	83.610	7.082	19.603	A	100.0	97.0	–3.0
Japan Energy	4	79.787	6.247	35.987	A	108.5	102.1	–6.4
Sumitomo Bakelite	5	73.511	4.249	33.410	A	98.3	100.0	1.7
Daimaru	12	71.840	9.660	34.326	A	96.5	93.0	–3.5
Chubu Electric Power	1	65.839	4.748	38.208	A	91.0	100.2	9.2
Mitsubishi Electric	4	65.625	9.249	42.629	B	93.6	98.6	5.0
Nikko Securities	8	63.810	5.748	43.866	B	91.8	98.0	6.2
Teijin	7	61.009	8.249	50.797	B	92.0	97.7	5.7
NEC	6	59.996	7.742	51.010	B	90.6	102.1	11.5
Sekisui House	3	59.316	8.082	50.211	B	89.1	98.0	8.9
Nikko Securities	4	59.031	7.244	52.632	B	90.1	95.5	5.4
Asahi Chemical Industry	7	58.738	8.748	53.223	B	88.9	98.4	9.5
Nippon Oil	4	57.537	8.748	52.424	B	87.7	96.2	8.5
Nippon Oil	5	57.537	5.748	56.422	B	90.0	100.0	10.0
Daiwa Securities	7	56.985	8.249	58.814	B	90.5	93.0	2.5
Nomura Securities	7	55.238	5.748	63.111	B	90.1	99.0	8.9
All Nippon Airways	4	52.129	8.748	65.167	B	86.1	96.0	9.9
Mitsubishi Chemical	6	46.858	8.082	78.197	B	83.5	97.6	14.1
Mitsubishi Estate	16	46.538	8.748	80.496	B	84.0	97.2	13.2
Sapporo Breweries	1	46.460	7.992	87.257	B	87.0	97.1	10.1
Sum						2,967.8	3,081.2	113.4
Sum of Sub-portfolio A						1,632.8	1,616.8	–16.0
Sum of Sub-portfolio B						1,335.0	1,464.4	129.4

Notes: In Sub-portfolio A, the parity is above 65.8 and the conversion premium is below 40 percent.
In Sub-portfolio B, the parity is below 65.8 and the conversion premium is above 40 percent.
The base date for parity, year to maturity, conversion premium, and price (1) is July 1, 1994.
The base date for price (2) is March 31, 1998.

Appendix Table 2 Results of Regressions for Model (1)

Issued in 1987

IV(+1) – IV = *a* + *b*(SP(+1) – SP)

Issuer	No.	*a*	*t*-value	*b*	*t*-value	R^2
NEC	6	0.199	0.352	–0.020	–4.181	0.144
Nikko Securities	4	0.025	0.043	–0.029	–6.376	0.288
Toshiba	6	0.114	0.181	–0.038	–2.505	0.051
Sapporo Breweries	1	0.036	0.079	–0.037	–4.315	0.152
Teijin	7	0.130	0.274	–0.089	–5.877	0.255
Toray Industries	7	0.069	0.144	–0.010	–0.672	–0.006
Shimizu	1	0.008	0.006	–0.021	–1.269	0.006
Mitsubishi Estate	16	0.080	0.190	–0.017	–4.603	0.171
Nippon Oil	4	0.169	0.305	–0.044	–4.461	0.162
Nippon Oil	5	0.116	0.206	–0.049	–4.977	0.195
Asahi Chemical Industry	7	0.163	0.451	–0.032	–3.982	0.132
Sanyo Electric	6	0.116	0.121	–0.088	–2.567	0.054
Nissan Motor	5	0.492	0.217	–0.102	–2.129	0.035
Hitachi	5	0.125	0.123	–0.040	–3.091	0.080
Mitsubishi Chemical	6	0.084	0.174	–0.062	–6.075	0.268
Hokkaido Electric Power	1	0.229	0.210	–0.022	–3.294	0.091
Sony	2	0.014	0.016	–0.007	–2.018	0.030
Sekisui House	3	–0.055	–0.109	–0.031	–4.216	0.146
Sekisui House	5	0.082	0.184	–0.033	–4.627	0.172
Sekisui House	6	0.004	0.010	–0.020	–3.132	0.082
Daiwa Securities	7	–0.265	–0.485	–0.036	–9.863	0.496
Chugoku Electric Power	1	0.079	0.104	–0.007	–1.515	0.013
Tohoku Electric Power	1	–0.092	–0.132	–0.007	–1.462	0.011
Hokuriku Electric Power	1	–0.169	–0.161	–0.017	–2.419	0.047
Ricoh	6	0.351	0.229	–0.081	–3.010	0.076
Murata Mfg.	4	0.193	0.282	–0.029	–6.351	0.286
Maeda Corp.	2	0.354	0.604	–0.051	–5.811	0.251
All Nippon Airways	4	–0.005	–0.018	–0.022	–4.071	0.137

Issued in 1994

IV(+1) – IV = *a* + *b*(SP(+1) – SP)

Issuer	No.	*a*	*t*-value	*b*	*t*-value	R^2
Nippon Express	4	0.014	0.081	–0.051	–7.528	0.362
Sekisui House	14	0.011	0.051	–0.022	–3.038	0.077
Sekisui House	15	0.009	0.040	–0.014	–2.005	0.030
Ebara	2	0.072	0.276	–0.034	–6.004	0.263
Asahi Breweries	8	–0.044	–0.146	–0.051	–4.110	0.140
Asahi Breweries	9	–0.059	–0.165	–0.044	–3.030	0.077
Asahi Breweries	10	–0.063	–0.184	–0.047	–3.398	0.097
Yasuda Fire & Marine Insurance	3	0.014	0.063	–0.043	–3.963	0.130
Mitsui & Co.	6	0.008	0.037	–0.054	–5.909	0.257
Kubota	7	0.015	0.090	–0.047	–5.324	0.218
Kubota	8	0.012	0.075	–0.047	–5.649	0.240
Kubota	9	0.014	0.086	–0.054	–6.259	0.280
Sumitomo Bakelite	6	–0.029	–0.081	–0.053	–3.546	0.106
Hanshin Electric Railway	9	–0.027	–0.144	–0.084	–5.305	0.217
Matsushita Electric Industrial	5	0.025	0.164	–0.010	–3.384	0.096
Matsushita Electric Industrial	6	0.016	0.100	–0.013	–4.106	0.139
Hitachi Metals	12	–0.014	–0.101	–0.031	–10.112	0.508
Aisin Seiki	7	0.095	0.400	–0.034	–5.907	0.257
Fujitsu	8	0.065	0.388	–0.015	–3.260	0.089
Fujitsu	9	0.093	0.695	–0.019	–5.166	0.208
Fujitsu	10	0.114	0.614	–0.023	–4.502	0.164
Chugai Pharmaceutical	5	–0.006	–0.029	–0.042	–5.203	0.210
Koa Fire & Marine Insurance	3	–0.001	–0.007	–0.038	–3.665	0.113
Kawasaki Heavy Industries	5	0.106	0.258	–0.152	–5.449	0.226
Fukuyama Transporting	2	–0.032	–0.089	–0.020	–1.814	0.023
NGK Spark Plug	3	–0.027	–0.111	–0.060	–10.911	0.546
NGK Spark Plug	4	0.020	0.110	–0.026	–6.301	0.283

Note: Shaded cells represent a *t*-value (absolute value) in excess of two.

Appendix Table 3 Results of Regressions for Model (2) (Issued in 1987)

IV = *b*HV

Issuer	No.	HV20 *b*	HV20 *t*-value (*b* = 0)	HV20 *t*-value (*b* = 1)	HV20 R^2	HV60 *b*	HV60 *t*-value (*b* = 0)	HV60 *t*-value (*b* = 1)	HV60 R^2
NEC	6	0.590	20.840	–14.455	0.105	0.602	23.433	–15.474	0.018
Nikko Securities	4	0.705	21.517	–9.000	0.100	0.730	29.290	–10.827	0.191
Toshiba	6	0.564	15.637	–12.083	0.004	0.592	19.148	–13.181	0.053
Sapporo Breweries	1	1.063	21.911	1.295	0.189	1.078	30.008	2.170	0.296
Teijin	7	0.967	20.085	–0.691	0.048	0.991	24.981	–0.222	0.074
Toray Industries	7	0.973	24.274	–0.679	0.182	0.995	33.308	–0.176	0.230
Shimizu	1	0.576	12.604	–9.271	0.004	0.587	13.739	–9.647	0.016
Mitsubishi Estate	16	0.800	23.431	–5.846	0.192	0.830	37.626	–7.733	0.408
Nippon Oil	4	0.489	15.568	–16.238	0.023	0.520	20.148	–18.565	0.051
Nippon Oil	5	0.492	16.185	–16.732	0.040	0.523	21.403	–19.523	0.090
Asahi Chemical Industry	7	0.802	18.160	–4.494	0.007	0.832	25.129	–5.068	0.008
Sanyo Electric	6	0.449	9.948	–12.208	0.066	0.479	13.414	–14.580	0.313
Nissan Motor	5	0.519	8.263	–7.666	0.003	0.514	8.530	–8.081	0.004
Hitachi	5	0.538	15.183	–13.058	0.004	0.545	16.126	–13.473	0.001
Mitsubishi Chemical	6	0.767	22.487	–6.816	0.158	0.790	29.266	–7.758	0.202
Hokkaido Electric Power	1	0.652	13.276	–7.088	0.000	0.649	13.206	–7.134	0.126
Sony	2	0.687	15.102	–6.876	0.190	0.658	15.591	–8.115	0.199
Sekisui House	3	0.798	17.506	–4.439	0.136	0.827	22.824	–4.779	0.131
Sekisui House	5	0.586	16.050	–11.356	0.001	0.494	16.448	–16.873	0.046
Sekisui House	6	0.565	16.708	–12.864	0.001	0.472	16.548	–18.521	0.035
Daiwa Securities	7	0.916	24.382	–2.229	0.306	0.933	39.480	–2.816	0.520
Chugoku Electric Power	1	0.977	17.925	–0.421	0.021	1.037	22.151	0.790	0.017
Tohoku Electric Power	1	1.062	24.136	1.415	0.028	1.105	31.151	2.957	0.046
Hokuriku Electric Power	1	0.450	10.831	–13.232	0.006	0.481	12.948	–13.956	0.028
Ricoh	6	0.373	10.996	–18.497	0.073	0.369	10.804	–18.499	0.047
Murata Mfg.	4	0.455	17.864	–21.364	0.179	0.438	16.663	–21.368	0.074
Maeda Corp.	2	0.547	15.872	–13.149	0.043	0.567	19.020	–14.511	0.066
All Nippon Airways	4	0.688	13.465	–6.106	0.048	0.725	18.163	–6.899	0.011

Issuer	No.	HV100 *b*	HV100 *t*-value (*b* = 0)	HV100 *t*-value (*b* = 1)	HV100 R^2	HV200 *b*	HV200 *t*-value (*b* = 0)	HV200 *t*-value (*b* = 1)	HV200 R^2
NEC	6	0.608	23.720	–15.266	0.005	0.609	28.106	–18.023	0.004
Nikko Securities	4	0.729	29.518	–10.963	0.142	0.709	32.919	–13.524	0.135
Toshiba	6	0.592	19.886	–13.714	0.076	0.592	21.982	–15.168	0.593
Sapporo Breweries	1	1.072	35.824	2.406	0.373	1.053	39.978	2.020	0.351
Teijin	7	1.002	27.091	0.048	0.063	0.982	34.684	–0.620	0.132
Toray Industries	7	1.001	39.605	0.027	0.281	0.974	50.492	–1.344	0.417
Shimizu	1	0.597	14.396	–9.734	0.013	0.618	15.835	–9.798	0.024
Mitsubishi Estate	16	0.811	37.636	–8.772	0.300	0.780	42.252	–11.922	0.228
Nippon Oil	4	0.536	23.033	–19.945	0.008	0.550	27.482	–22.460	0.041
Nippon Oil	5	0.538	24.846	–21.296	0.026	0.552	30.072	–24.403	0.009
Asahi Chemical Industry	7	0.841	27.951	–5.293	0.007	0.841	34.893	–6.619	0.005
Sanyo Electric	6	0.482	14.382	–15.437	0.456	0.455	13.989	–16.769	0.634
Nissan Motor	5	0.522	9.052	–8.277	0.022	0.516	9.267	–8.681	0.054
Hitachi	5	0.550	17.119	–14.011	0.003	0.555	19.258	–15.433	0.048
Mitsubishi Chemical	6	0.795	32.269	–8.322	0.233	0.786	31.787	–8.652	0.077
Hokkaido Electric Power	1	0.652	13.264	–7.088	0.334	0.680	13.813	–6.507	0.557
Sony	2	0.663	17.834	–9.082	0.366	0.643	19.805	–11.013	0.663
Sekisui House	3	0.836	25.369	–4.987	0.112	0.835	28.244	–5.575	0.030
Sekisui House	5	0.482	17.102	–18.391	0.057	0.479	20.652	–22.440	0.162
Sekisui House	6	0.460	17.186	–20.140	0.043	0.460	21.225	–24.947	0.155
Daiwa Securities	7	0.915	36.801	–3.423	0.394	0.885	38.019	–4.964	0.372
Chugoku Electric Power	1	1.052	24.742	1.217	0.012	1.003	27.776	0.071	0.024
Tohoku Electric Power	1	1.079	32.896	2.399	0.097	1.000	40.586	0.008	0.373
Hokuriku Electric Power	1	0.488	13.879	–14.540	0.107	0.480	13.524	–14.644	0.134
Ricoh	6	0.365	10.522	–18.307	0.024	0.361	10.290	–18.250	0.004
Murata Mfg.	4	0.429	15.633	–20.832	0.015	0.413	15.800	–22.446	0.001
Maeda Corp.	2	0.579	21.429	–15.568	0.030	0.574	25.098	–18.641	0.000
All Nippon Airways	4	0.740	22.323	–7.852	0.100	0.727	25.798	–9.678	0.041

Appendix Table 4 Results of Regressions for Model (2) (Issued in 1994)

IV = *b*HV

Issuer	No.	HV20 *b*	HV20 *t*-value (*b* = 0)	HV20 *t*-value (*b* = 1)	HV20 R^2	HV60 *b*	HV60 *t*-value (*b* = 0)	HV60 *t*-value (*b* = 1)	HV60 R^2
Nippon Express	4	0.652	24.823	–13.254	0.013	0.660	34.311	–17.691	0.038
Sekisui House	14	1.003	29.401	0.097	0.009	1.020	36.093	0.691	0.023
Sekisui House	15	0.875	26.175	–3.739	0.008	0.890	30.969	–3.833	0.026
Ebara	2	0.784	24.372	–6.699	0.074	0.795	32.130	–8.307	0.174
Asahi Breweries	8	0.420	18.706	–25.825	0.368	0.411	17.519	–25.093	0.363
Asahi Breweries	9	0.416	17.829	–24.990	0.349	0.408	16.879	–24.471	0.366
Asahi Breweries	10	0.466	17.787	–20.359	0.373	0.456	16.746	–19.943	0.389
Yasuda Fire & Marine Insurance	3	0.463	15.958	–18.486	0.135	0.485	19.239	–20.398	0.209
Mitsui & Co.	6	0.741	27.209	–9.486	0.180	0.754	38.530	–12.584	0.323
Kubota	7	0.683	22.303	–10.332	0.005	0.715	32.398	–12.911	0.104
Kubota	8	0.709	22.441	–9.215	0.005	0.741	32.302	–11.304	0.097
Kubota	9	0.738	23.208	–8.222	0.017	0.770	33.780	–10.071	0.134
Sumitomo Bakelite	6	0.626	26.088	–15.559	0.138	0.637	32.872	–18.757	0.211
Hanshin Electric Railway	9	0.635	29.060	–16.688	0.245	0.651	35.663	–19.095	0.407
Matsushita Electric Industrial	5	0.435	26.282	–34.105	0.005	0.437	33.176	–42.760	0.028
Matsushita Electric Industrial	6	0.440	27.630	–35.137	0.069	0.441	34.869	–44.206	0.137
Hitachi Metals	12	0.423	27.872	–38.026	0.004	0.444	39.970	–50.022	0.069
Aisin Seiki	7	0.448	24.391	–29.993	0.197	0.476	38.126	–42.001	0.466
Fujitsu	8	0.462	30.674	–35.781	0.006	0.471	38.937	–43.702	0.022
Fujitsu	9	0.460	30.402	–35.675	0.002	0.470	38.954	–43.916	0.042
Fujitsu	10	0.461	29.736	–34.725	0.000	0.472	37.943	–42.520	0.055
Chugai Pharmaceutical	5	1.042	23.980	0.960	0.153	1.075	31.234	2.191	0.113
Koa Fire & Marine Insurance	3	0.414	20.165	–28.499	0.136	0.434	29.072	–37.870	0.013
Kawasaki Heavy Industries	5	0.615	24.049	–15.045	0.101	0.633	30.272	–17.572	0.212
Fukuyama Transporting	2	0.674	17.921	–8.664	0.278	0.712	21.443	–8.657	0.205
NGK Spark Plug	3	0.690	25.588	–11.470	0.028	0.706	31.762	–13.226	0.006
NGK Spark Plug	4	0.644	26.604	–14.693	0.038	0.661	35.033	–17.992	0.000

Issuer	No.	HV100 *b*	HV100 *t*-value (*b* = 0)	HV100 *t*-value (*b* = 1)	HV100 R^2	HV200 *b*	HV200 *t*-value (*b* = 0)	HV200 *t*-value (*b* = 1)	HV200 R^2
Nippon Express	4	0.655	42.098	–22.199	0.168	0.660	65.700	–33.843	0.588
Sekisui House	14	1.022	42.637	0.905	0.200	1.027	42.993	1.126	0.484
Sekisui House	15	0.893	35.374	–4.258	0.197	0.896	35.215	–4.068	0.484
Ebara	2	0.786	40.197	–10.931	0.298	0.794	52.489	–13.634	0.305
Asahi Breweries	8	0.406	17.575	–25.715	0.458	0.378	15.800	–25.992	0.258
Asahi Breweries	9	0.402	16.743	–24.915	0.423	0.374	15.168	–25.347	0.241
Asahi Breweries	10	0.449	16.576	–20.327	0.444	0.417	14.909	–20.818	0.230
Yasuda Fire & Marine Insurance	3	0.498	23.290	–23.457	0.127	0.514	35.497	–33.617	0.000
Mitsui & Co.	6	0.758	47.677	–15.195	0.400	0.725	54.644	–20.758	0.335
Kubota	7	0.731	43.774	–16.077	0.328	0.706	72.734	–30.279	0.547
Kubota	8	0.758	44.091	–14.064	0.333	0.732	74.260	–27.197	0.554
Kubota	9	0.787	46.460	–12.545	0.390	0.758	72.630	–23.186	0.522
Sumitomo Bakelite	6	0.636	33.617	–19.254	0.161	0.604	31.576	–20.715	0.003
Hanshin Electric Railway	9	0.657	39.038	–20.425	0.596	0.626	29.781	–17.784	0.197
Matsushita Electric Industrial	5	0.436	40.183	–52.026	0.081	0.430	55.335	–73.321	0.229
Matsushita Electric Industrial	6	0.439	42.066	–53.709	0.237	0.431	51.647	–68.070	0.415
Hitachi Metals	12	0.450	45.164	–55.136	0.090	0.451	43.998	–53.565	0.011
Aisin Seiki	7	0.481	44.654	–48.266	0.571	0.466	37.124	–42.622	0.492
Fujitsu	8	0.473	44.387	–49.466	0.074	0.470	46.553	–52.449	0.076
Fujitsu	9	0.471	43.403	–48.687	0.092	0.468	43.944	–49.981	0.061
Fujitsu	10	0.472	41.310	–46.142	0.095	0.468	40.493	–46.012	0.034
Chugai Pharmaceutical	5	1.088	36.490	2.960	0.049	1.032	46.616	1.465	0.027
Koa Fire & Marine Insurance	3	0.441	35.092	–44.495	0.001	0.434	48.509	–63.164	0.148
Kawasaki Heavy Industries	5	0.630	30.111	–17.683	0.164	0.590	26.149	–18.197	0.001
Fukuyama Transporting	2	0.735	24.175	–8.697	0.099	0.737	29.037	–10.368	0.016
NGK Spark Plug	3	0.711	38.493	–15.620	0.014	0.703	43.713	–18.498	0.029
NGK Spark Plug	4	0.666	44.355	–22.290	0.049	0.658	55.413	–28.741	0.152

Appendix Table 5 Results of Regressions for Model (3) (Issued in 1987)

$$IV(+1) - IV = a + b(HV - IV)$$

		HV20					HV60				
Issuer	No.	*a*	*t*-value	*b*	*t*-value	R^2	*a*	*t*-value	*b*	*t*-value	R^2
NEC	6	–0.281	–0.389	0.040	1.220	0.005	–0.222	–0.273	0.031	0.781	–0.004
Nikko Securities	4	–0.545	–0.758	0.095	2.607	0.056	–0.957	–1.162	0.117	2.352	0.044
Toshiba	6	–1.310	–1.644	0.090	2.521	0.052	–1.908	–1.999	0.121	2.552	0.053
Sapporo Breweries	1	0.833	1.528	0.088	2.501	0.051	0.863	1.638	0.131	2.961	0.073
Teijin	7	0.575	0.993	0.097	2.163	0.036	0.568	1.003	0.130	2.462	0.049
Toray Industries	7	0.385	0.789	0.107	2.405	0.047	0.339	0.722	0.173	3.028	0.077
Shimizu	1	–2.617	–1.885	0.229	3.339	0.094	–3.775	–2.564	0.298	3.948	0.130
Mitsubishi Estate	16	0.035	0.077	0.050	1.484	0.012	–0.257	–0.526	0.104	2.102	0.034
Nippon Oil	4	–0.862	–1.116	0.077	2.002	0.030	–2.187	–2.279	0.158	3.023	0.077
Nippon Oil	5	–1.162	–1.480	0.097	2.461	0.049	–2.453	–2.484	0.174	3.192	0.086
Asahi Chemical Industry	7	0.181	0.508	0.100	4.332	0.153	–0.015	–0.040	0.080	2.536	0.053
Sanyo Electric	6	–2.742	–2.358	0.178	3.537	0.105	–5.171	–3.456	0.282	4.135	0.141
Nissan Motor	5	–7.467	–3.374	0.581	6.479	0.295	–8.636	–3.748	0.602	6.506	0.297
Hitachi	5	–2.492	–1.895	0.153	2.882	0.069	–2.992	–2.109	0.172	2.928	0.072
Mitsubishi Chemical	6	–0.124	–0.218	0.082	2.113	0.034	–0.395	–0.667	0.118	2.395	0.046
Hokkaido Electric Power	1	–1.014	–0.828	0.113	2.063	0.032	–1.564	–1.253	0.149	2.687	0.060
Sony	2	–1.100	–1.148	0.128	2.174	0.037	–2.000	–1.962	0.190	3.142	0.083
Sekisui House	3	0.272	0.507	0.044	1.434	0.011	0.145	0.270	0.057	1.501	0.013
Sekisui House	5	–1.039	–1.730	0.104	2.407	0.047	–0.884	–1.331	0.059	1.592	0.015
Sekisui House	6	–0.892	–1.639	0.083	2.110	0.034	–0.751	–1.278	0.047	1.469	0.012
Daiwa Securities	7	0.246	0.326	0.124	2.504	0.051	–0.256	–0.346	0.243	3.283	0.091
Chugoku Electric Power	1	0.318	0.410	0.078	1.908	0.026	0.410	0.536	0.119	2.487	0.050
Tohoku Electric Power	1	0.317	0.421	0.090	1.697	0.019	0.438	0.589	0.138	2.193	0.037
Hokuriku Electric Power	1	–2.117	–1.585	0.104	2.189	0.037	–4.062	–2.517	0.186	3.015	0.076
Ricoh	6	–7.874	–3.339	0.345	4.276	0.150	–9.261	–3.715	0.387	4.579	0.169
Murata Mfg.	4	–1.654	–1.312	0.090	1.858	0.024	–1.724	–1.248	0.084	1.671	0.018
Maeda Corp.	2	–0.404	–0.511	0.053	1.510	0.013	–1.075	–1.234	0.095	2.298	0.042
All Nippon Airways	4	0.062	0.209	0.077	4.455	0.161	–0.091	–0.295	0.071	3.258	0.089

		HV100					HV200				
Issuer	No.	*a*	*t*-value	*b*	*t*-value	R^2	*a*	*t*-value	*b*	*t*-value	R^2
NEC	6	–0.732	–0.894	0.068	1.682	0.018	–1.842	–1.913	0.130	2.683	0.059
Nikko Securities	4	–1.294	–1.539	0.143	2.820	0.066	–2.729	–2.760	0.223	3.850	0.124
Toshiba	6	–2.419	–2.344	0.147	2.853	0.068	–3.563	–2.943	0.205	3.346	0.094
Sapporo Breweries	1	0.983	1.974	0.201	4.094	0.139	0.700	1.463	0.209	3.984	0.132
Teijin	7	0.681	1.234	0.181	3.269	0.090	0.535	1.059	0.303	4.787	0.183
Toray Industries	7	0.362	0.803	0.266	4.092	0.138	–0.067	–0.168	0.478	6.661	0.307
Shimizu	1	–4.499	–2.998	0.350	4.414	0.159	–5.786	–3.771	0.456	5.243	0.213
Mitsubishi Estate	16	–0.554	–1.111	0.143	2.987	0.075	–0.970	–1.689	0.157	2.999	0.075
Nippon Oil	4	–3.111	–2.902	0.219	3.565	0.107	–6.001	–4.728	0.410	5.319	0.218
Nippon Oil	5	–3.660	–3.319	0.256	3.969	0.131	–6.935	–5.305	0.475	5.872	0.255
Asahi Chemical Industry	7	–0.116	–0.301	0.095	2.758	0.063	–0.436	–1.123	0.158	3.919	0.128
Sanyo Electric	6	–8.119	–4.749	0.419	5.336	0.219	–11.488	–5.503	0.522	5.887	0.256
Nissan Motor	5	–10.340	–4.394	0.674	7.021	0.330	–12.361	–5.098	0.740	7.541	0.363
Hitachi	5	–4.127	–2.783	0.230	3.665	0.113	–5.899	–3.426	0.306	4.096	0.139
Mitsubishi Chemical	6	–0.728	–1.221	0.175	3.320	0.093	–0.884	–1.405	0.168	3.138	0.083
Hokkaido Electric Power	1	–1.711	–1.361	0.158	2.820	0.066	–1.780	–1.437	0.179	3.060	0.079
Sony	2	–3.186	–2.848	0.274	3.936	0.129	–5.898	–4.321	0.428	5.109	0.204
Sekisui House	3	0.033	0.062	0.085	2.066	0.032	–0.206	–0.375	0.113	2.514	0.052
Sekisui House	5	–1.124	–1.610	0.072	1.906	0.026	–2.018	–2.409	0.120	2.687	0.060
Sekisui House	6	–0.870	–1.405	0.052	1.585	0.015	–1.715	–2.285	0.098	2.496	0.051
Daiwa Securities	7	–0.559	–0.747	0.239	3.455	0.100	–1.336	–1.689	0.287	4.027	0.134
Chugoku Electric Power	1	0.426	0.564	0.147	2.858	0.068	0.128	0.176	0.195	3.510	0.104
Tohoku Electric Power	1	0.627	0.905	0.236	3.786	0.120	–0.054	–0.085	0.348	4.690	0.176
Hokuriku Electric Power	1	–6.254	–3.535	0.280	4.062	0.137	–6.227	–3.409	0.271	3.871	0.125
Ricoh	6	–9.730	–3.841	0.400	4.686	0.176	–11.719	–4.499	0.466	5.352	0.220
Murata Mfg.	4	–2.095	–1.487	0.097	1.940	0.027	–3.456	–2.162	0.140	2.596	0.055
Maeda Corp.	2	–1.560	–1.679	0.125	2.713	0.061	–2.586	–2.425	0.175	3.312	0.092
All Nippon Airways	4	–0.228	–0.726	0.087	3.525	0.104	–0.418	–1.227	0.089	3.201	0.086

Note: Shaded cells represent a *t*-value in excess of two.

Appendix Table 6 Results of Regressions for Model (3) (Issued in 1994)

$$IV(+1) - IV = a + b(HV - IV)$$

		HV20					HV60				
Issuer	No.	*a*	*t*-value	*b*	*t*-value	R^2	*a*	*t*-value	*b*	*t*-value	R^2
Nippon Express	4	–0.551	–2.028	0.085	3.487	0.102	–1.044	–3.159	0.137	4.216	0.146
Sekisui House	14	0.114	0.497	0.075	2.336	0.044	0.106	0.475	0.113	3.014	0.076
Sekisui House	15	–0.082	–0.373	0.062	2.114	0.034	–0.185	–0.829	0.098	2.848	0.068
Ebara	2	–0.131	–0.425	0.077	2.498	0.051	–0.305	–0.929	0.103	2.658	0.058
Asahi Breweries	8	–2.896	–3.429	0.247	3.508	0.103	–3.550	–3.957	0.295	4.041	0.135
Asahi Breweries	9	–3.816	–4.221	0.327	4.386	0.157	–4.289	–4.360	0.357	4.490	0.164
Asahi Breweries	10	–2.654	–3.316	0.241	3.457	0.101	–3.005	–3.604	0.265	3.743	0.117
Yasuda Fire & Marine Insurance	3	–0.250	–0.810	0.024	1.296	0.007	–0.368	–1.045	0.033	1.428	0.011
Mitsui & Co.	6	–0.308	–1.120	0.077	2.239	0.039	–0.577	–1.842	0.126	2.726	0.062
Kubota	7	–0.126	–0.595	0.035	1.735	0.020	–0.327	–1.370	0.069	2.443	0.048
Kubota	8	–0.088	–0.446	0.031	1.566	0.015	–0.263	–1.213	0.064	2.392	0.046
Kubota	9	–0.067	–0.327	0.032	1.511	0.013	–0.251	–1.139	0.073	2.513	0.051
Sumitomo Bakelite	6	–0.851	–1.773	0.117	2.540	0.053	–1.407	–2.528	0.181	3.170	0.085
Hanshin Electric Railway	9	–0.361	–1.123	0.046	1.423	0.010	–0.889	–2.117	0.110	2.389	0.046
Matsushita Electric Industrial	5	–0.374	–1.287	0.034	1.572	0.015	–0.528	–1.433	0.044	1.614	0.016
Matsushita Electric Industrial	6	–0.449	–1.395	0.039	1.622	0.016	–0.720	–1.734	0.058	1.884	0.025
Hitachi Metals	12	0.013	0.033	0.004	0.167	–0.010	–0.748	–1.308	0.051	1.520	0.013
Aisin Seiki	7	–0.607	–1.343	0.042	1.666	0.018	–1.255	–1.951	0.084	2.137	0.035
Fujitsu	8	–0.820	–2.058	0.069	2.441	0.048	–1.170	–2.232	0.095	2.479	0.050
Fujitsu	9	–0.651	–1.887	0.057	2.358	0.044	–0.976	–2.120	0.082	2.432	0.048
Fujitsu	10	–0.945	–2.040	0.082	2.508	0.051	–1.575	–2.561	0.129	2.882	0.069
Chugai Pharmaceutical	5	0.268	1.118	0.065	2.424	0.047	0.273	1.125	0.076	2.285	0.041
Koa Fire & Marine Insurance	3	–0.821	–2.393	0.063	3.033	0.077	–0.878	–1.799	0.062	2.019	0.030
Kawasaki Heavy Industries	5	–1.108	–1.865	0.126	2.806	0.066	–1.555	–2.257	0.167	2.932	0.072
Fukuyama Transporting	2	–0.363	–0.898	0.061	2.015	0.030	–0.526	–1.261	0.089	2.463	0.049
NGK Spark Plug	3	–0.341	–0.769	0.070	1.632	0.017	–0.840	–1.711	0.142	2.690	0.060
NGK Spark Plug	4	–0.133	–0.466	0.028	1.044	0.001	–0.542	–1.610	0.079	2.296	0.042

		HV100					HV200				
Issuer	No.	*a*	*t*-value	*b*	*t*-value	R^2	*a*	*t*-value	*b*	*t*-value	R^2
Nippon Express	4	–1.444	–3.677	0.174	4.443	0.161	–4.040	–5.909	0.451	6.221	0.278
Sekisui House	14	0.082	0.363	0.118	2.696	0.060	0.070	0.308	0.092	2.054	0.032
Sekisui House	15	–0.204	–0.876	0.096	2.404	0.046	–0.149	–0.630	0.072	1.782	0.022
Ebara	2	–0.651	–1.836	0.158	3.497	0.103	–0.985	–2.236	0.205	3.189	0.086
Asahi Breweries	8	–3.741	–3.854	0.302	3.910	0.127	–3.021	–3.274	0.224	3.318	0.093
Asahi Breweries	9	–4.489	–4.347	0.363	4.457	0.161	–3.679	–3.665	0.273	3.757	0.118
Asahi Breweries	10	–3.010	–3.467	0.257	3.578	0.107	–2.481	–2.964	0.193	3.055	0.078
Yasuda Fire & Marine Insurance	3	–0.516	–1.256	0.043	1.547	0.014	–1.745	–2.751	0.135	2.956	0.073
Mitsui & Co.	6	–0.901	–2.547	0.186	3.303	0.092	–1.650	–3.382	0.264	3.761	0.118
Kubota	7	–0.454	–1.680	0.091	2.499	0.051	–1.284	–2.856	0.189	3.209	0.087
Kubota	8	–0.375	–1.544	0.086	2.463	0.049	–1.067	–2.662	0.173	3.046	0.078
Kubota	9	–0.366	–1.504	0.099	2.599	0.055	–0.968	–2.562	0.177	3.049	0.078
Sumitomo Bakelite	6	–1.550	–2.601	0.191	3.137	0.083	–1.942	–2.798	0.201	3.169	0.084
Hanshin Electric Railway	9	–1.016	–1.961	0.124	2.110	0.034	–0.491	–1.135	0.054	1.264	0.006
Matsushita Electric Industrial	5	–0.827	–1.814	0.065	1.954	0.028	–2.061	–2.716	0.150	2.787	0.065
Matsushita Electric Industrial	6	–1.193	–2.263	0.092	2.376	0.045	–3.071	–3.412	0.222	3.464	0.101
Hitachi Metals	12	–1.276	–1.775	0.083	1.943	0.028	–1.875	–2.300	0.119	2.453	0.049
Aisin Seiki	7	–1.829	–2.158	0.119	2.267	0.041	–3.944	–3.179	0.236	3.247	0.089
Fujitsu	8	–1.683	–2.595	0.132	2.782	0.064	–2.522	–3.163	0.192	3.310	0.092
Fujitsu	9	–1.283	–2.273	0.104	2.510	0.051	–1.848	–2.790	0.143	2.991	0.075
Fujitsu	10	–2.175	–2.968	0.173	3.227	0.088	–2.861	–3.541	0.220	3.778	0.119
Chugai Pharmaceutical	5	0.340	1.407	0.109	2.898	0.070	0.219	0.974	0.154	3.375	0.096
Koa Fire & Marine Insurance	3	–1.767	–3.009	0.123	3.229	0.088	–4.369	–4.242	0.280	4.332	0.153
Kawasaki Heavy Industries	5	–1.661	–2.309	0.172	2.916	0.071	–1.813	–2.293	0.154	2.758	0.063
Fukuyama Transporting	2	–0.575	–1.336	0.100	2.421	0.047	–0.961	–1.992	0.146	2.929	0.072
NGK Spark Plug	3	–1.368	–2.446	0.212	3.298	0.092	–2.348	–3.640	0.325	4.399	0.158
NGK Spark Plug	4	–0.830	–2.013	0.111	2.513	0.051	–1.787	–3.270	0.213	3.645	0.111

Note: Shaded cells represent a *t*-value in excess of two.

Appendix Table 7 Results of Regressions for Model (4)

Issued in 1987

IV(+1) – IV = $c(x - \text{IV})$

Issuer	No.	*c*	*t*-value	*x*	R^2	Average HV200
NEC	6	0.350	4.939	28.193	0.193	43.175
Nikko Securities	4	0.237	3.882	34.087	0.126	46.248
Toshiba	6	0.135	2.648	22.748	0.058	40.255
Sapporo Breweries	1	0.139	3.092	36.743	0.080	32.845
Teijin	7	0.625	7.277	28.579	0.346	26.972
Toray Industries	7	0.270	4.070	28.101	0.137	28.077
Shimizu	1	0.451	5.221	19.945	0.211	32.660
Mitsubishi Estate	16	0.379	5.120	30.299	0.205	36.770
Nippon Oil	4	0.400	4.981	18.565	0.195	33.148
Nippon Oil	5	0.546	6.103	18.581	0.270	33.148
Asahi Chemical Industry	7	0.448	6.037	29.136	0.266	32.368
Sanyo Electric	6	0.214	3.388	13.578	0.097	36.093
Nissan Motor	5	0.703	7.234	16.698	0.344	33.347
Hitachi	5	0.331	4.286	24.063	0.151	43.209
Mitsubishi Chemical	6	0.348	4.919	29.207	0.191	34.762
Hokkaido Electric Power	1	0.264	3.837	25.926	0.123	35.885
Sony	2	0.168	2.893	18.661	0.070	32.998
Sekisui House	3	0.294	4.537	31.718	0.167	34.530
Sekisui House	5	0.167	2.796	14.864	0.065	31.254
Sekisui House	6	0.143	2.531	14.233	0.052	31.254
Daiwa Securities	7	0.190	3.220	37.365	0.087	41.831
Chugoku Electric Power	1	0.169	2.972	37.153	0.074	36.547
Tohoku Electric Power	1	0.157	2.561	36.447	0.054	37.144
Hokuriku Electric Power	1	0.241	3.605	18.560	0.109	41.656
Ricoh	6	0.619	6.593	14.927	0.302	39.987
Murata Mfg.	4	0.252	3.807	20.009	0.121	45.108
Maeda Corp.	2	0.414	5.228	24.997	0.212	40.456
All Nippon Airways	4	0.313	4.628	24.309	0.172	29.340

Issued in 1994

IV(+1) – IV = $c(x - \text{IV})$

Issuer	No.	*c*	*t*-value	*x*	R^2	Average HV200
Nippon Express	4	0.165	3.108	17.695	0.081	26.473
Sekisui House	14	0.084	2.118	22.016	0.034	21.225
Sekisui House	15	0.068	1.878	19.185	0.025	21.225
Ebara	2	0.241	3.797	21.694	0.120	26.588
Asahi Breweries	8	0.189	3.140	6.961	0.083	20.547
Asahi Breweries	9	0.232	3.535	7.010	0.105	20.547
Asahi Breweries	10	0.169	2.956	7.602	0.073	20.547
Yasuda Fire & Marine Insurance	3	0.242	3.654	14.207	0.112	27.114
Mitsui & Co.	6	0.241	3.583	16.194	0.108	22.413
Kubota	7	0.169	2.999	17.421	0.075	24.180
Kubota	8	0.151	2.819	18.066	0.066	24.180
Kubota	9	0.174	3.058	18.740	0.079	24.180
Sumitomo Bakelite	6	0.392	4.833	15.064	0.186	24.532
Hanshin Electric Railway	9	0.071	1.868	14.545	0.025	23.602
Matsushita Electric Industrial	5	0.281	3.995	10.482	0.132	24.168
Matsushita Electric Industrial	6	0.202	3.299	10.382	0.092	24.168
Hitachi Metals	12	0.244	3.944	13.857	0.129	29.871
Aisin Seiki	7	0.149	2.779	14.162	0.064	30.801
Fujitsu	8	0.239	3.889	12.198	0.126	25.368
Fujitsu	9	0.197	3.900	12.331	0.127	25.368
Fujitsu	10	0.304	4.916	12.263	0.191	25.368
Chugai Pharmaceutical	5	0.142	2.862	23.474	0.068	21.972
Koa Fire & Marine Insurance	3	0.313	4.243	12.071	0.148	27.679
Kawasaki Heavy Industries	5	0.304	4.150	18.071	0.142	29.690
Fukuyama Transporting	2	0.182	3.119	19.719	0.082	26.283
NGK Spark Plug	3	0.423	5.203	18.331	0.210	25.587
NGK Spark Plug	4	0.223	3.628	17.225	0.110	25.587

Note: Shaded cells represent a *t*-value in excess of two.

Appendix Table 8 Results of Regressions for Model (5)

Issued in 1987

$$IV(+1) – IV = a(x – IV) + bDUM0$$

Issuer	No.	*a*	*t*-value	*x*	*b*	*t*-value	R^2
NEC	6	0.2471	3.7274	27.3556	26.2910	5.1429	0.3605
Nikko Securities	4	0.1511	2.8215	32.1548	34.9808	6.2187	0.3701
Toshiba	6	0.1363	2.6802	22.2787	6.4164	1.0286	0.0584
Sapporo Breweries	1	0.0684	1.8054	33.9860	28.5479	7.1499	0.3936
Teijin	7	0.4845	5.4989	28.2714	17.6817	3.8670	0.4287
Toray Industries	7	0.1913	2.9921	27.2278	18.1266	4.2201	0.2645
Shimizu	1	0.4512	5.2560	19.5766	16.4681	1.4975	0.2213
Mitsubishi Estate	16	0.2567	3.8935	29.5517	22.8187	6.2202	0.4272
Nippon Oil	4	0.3907	4.8208	18.4440	4.9501	0.9006	0.1939
Nippon Oil	5	0.5467	6.0193	18.5874	–0.3632	–0.0670	0.2625
Asahi Chemical Industry	7	0.2425	3.6110	28.4831	21.2038	7.0695	0.5120
Sanyo Electric	6	0.2232	3.5841	12.7379	19.5558	2.1393	0.1287
Hitachi	5	0.2990	4.1612	22.7478	37.8694	4.1642	0.2730
Mitsubishi Chemical	6	0.1989	3.1987	27.9136	30.6478	6.8624	0.4518
Hokkaido Electric Power	1	0.2637	3.8448	25.4530	12.3467	1.1557	0.1259
Sony	2	0.1657	2.9606	17.2570	22.8437	2.7957	0.1310
Sekisui House	3	0.1802	3.1508	30.5933	28.0470	6.4793	0.4141
Sekisui House	5	0.1671	2.7936	14.6203	4.0373	0.8534	0.0624
Sekisui House	6	0.1423	2.5186	13.9422	4.0271	0.9824	0.0519
Daiwa Securities	7	0.1531	2.7623	35.5149	28.5072	4.1365	0.2172
Chugoku Electric Power	1	0.1371	2.5440	35.1997	26.2632	3.7538	0.1841
Tohoku Electric Power	1	0.0858	1.6976	30.7414	41.1304	7.3069	0.3855
Hokuriku Electric Power	1	0.2484	3.7110	18.0623	13.1849	1.2991	0.1153
Ricoh	6	0.6183	6.6380	14.5844	21.0001	1.5899	0.3131
Murata Mfg.	4	0.2256	3.5506	19.0057	24.0208	3.2927	0.2020
Maeda Corp.	2	0.4085	5.0008	24.9626	1.6890	0.2721	0.2042
All Nippon Airways	4	0.2166	3.0397	23.9174	9.9312	3.2247	0.2455

Issued in 1994

$$IV(+1) – IV = a(x – IV) + bDUM0$$

Issuer	No.	*a*	*t*-value	*x*	*b*	*t*-value	R^2
Nippon Express	4	0.1285	2.5538	17.1534	7.9503	3.9380	0.2007
Sekisui House	14	0.0652	1.8174	20.5359	10.1625	4.9634	0.2235
Sekisui House	15	0.0543	1.6741	17.4232	9.8363	5.0866	0.2241
Ebara	2	0.1894	3.2259	21.1145	12.2499	4.6122	0.2725
Asahi Breweries	8	0.2072	3.5382	6.6170	8.3718	2.7673	0.1418
Asahi Breweries	9	0.2509	3.9150	6.6989	8.8721	2.6075	0.1555
Asahi Breweries	10	0.1852	3.3155	7.1836	9.0480	2.6942	0.1293
Yasuda Fire & Marine Insurance	3	0.2333	3.6566	13.9223	6.5634	2.9878	0.1790
Mitsui & Co.	6	0.2418	3.5776	16.1389	1.3343	0.5528	0.1013
Kubota	7	0.1649	2.9325	17.2717	2.5234	1.3671	0.0836
Kubota	8	0.1459	2.7552	17.8544	3.1433	1.7887	0.0869
Kubota	9	0.1687	2.9721	18.5756	2.8609	1.5417	0.0914
Sumitomo Bakelite	6	0.3896	4.7856	15.1253	–2.3897	–0.7028	0.1815
Hanshin Electric Railway	9	0.0708	1.8638	14.5961	–0.3529	–0.1700	0.0149
Matsushita Electric Industrial	5	0.2803	3.9563	10.4657	0.4688	0.3137	0.1243
Matsushita Electric Industrial	6	0.2010	3.2630	10.3291	1.0449	0.6439	0.0861
Hitachi Metals	12	0.2710	4.3034	13.9514	–3.3028	–1.7954	0.1489
Aisin Seiki	7	0.1614	2.9891	14.4190	–4.0595	–1.5217	0.0767
Chugai Pharmaceutical	5	0.1192	2.4658	23.0404	6.3536	2.8995	0.1345
Koa Fire & Marine Insurance	3	0.3093	4.2864	11.9247	4.5046	2.3198	0.1847
Kawasaki Heavy Industries	5	0.3032	4.1130	18.0405	0.9060	0.2087	0.1335
NGK Spark Plug	3	0.4222	5.0896	18.3254	0.2323	0.0712	0.2019
NGK Spark Plug	4	0.2153	3.4351	17.1663	1.4965	0.7390	0.1062

Note: Shaded cells represent a *t*-value (absolute value) in excess of two.

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