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Bankruptcy prediction: the case of Japanese listed companies

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Abstract This paper investigates if bankruptcy of Japanese listed companies can be predicted using data from 1992 to 2005. We find that the traditional measures, such as Altman's (J Finance 23:589–609, 1968) Z-score, Ohlson's (J Accounting Res 18:109–131, 1980) O-score and the option pricing theory-based distance-to-default, previously developed for the U.S. market, are also individually useful for the Japanese market. Moreover, the predictive power is substantially enhanced when these measures are combined. Based on the unique Japanese institutional features of main banks and business groups (known as Keiretsu), we construct a new measure that incorporates bank dependence and Keiretsu dependence. The new measure further improves the ability to predict bankruptcy of Japanese listed companies.

Keywords Bankruptcy risk measure · Accounting information · Option pricing theory · Japanese listed companies · Bank dependence · Keiretsu

JEL Classifications G15 · G33

1 Introduction

When a company falls into bankruptcy, its stakeholders lose some or all the value they invested in the company. From an investor's point of view, it is important to

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assess a firm's likelihood of bankruptcy so that the bankruptcy risk can be appropriately compensated in expected returns. Academic researchers and practitioners have developed various models to estimate bankruptcy risk. These models have been applied mostly to U.S. companies. The current debate in the literature about the performance of the models centers on two issues. The first issue is related to the usefulness of accounting variables versus market variables in predicting bankruptcy. The second issue is about ad hoc statistical models versus option pricing theory-based models.

The early bankruptcy prediction models are based on accounting variables. Examples include Beaver (1966, 1968); Altman (1968);[1] Altman et al. (1977); Ohlson (1980); and Zmijewski (1984). The variables used to give an early warning of bankruptcy are mostly traditional accounting ratios from financial statements. Shumway (2001), however, finds that half of the accounting variables used by Altman (1968) and Zmijewski (1984) are statistically unrelated to bankruptcy probability. Instead, he argues, some market variables such as firm size, past stock returns, and idiosyncratic returns variability are all strongly related to bankruptcy risk. By combining two accounting ratios and three market variables together, Shumway's hazard model outperforms the previous models. Chava and Jarrow (2004) support Shumway's (2001) model by showing that accounting variables add little predictive power when market variables are already included in the bankruptcy model. On the other hand, a study by Beaver et al. (2005) using a similar model with a longer time period finds that the ability of accounting ratios to predict bankruptcy remains. Their findings indicate that the market variables complement accounting variables and that the use of market variables causes only a slight reduction of predictive power of the accounting variables in certain subperiods. While statistical models have been widely used in practice, option pricing theory-based models have gained in popularity. With the option pricing theory-based models, both the predictive variables and the functional form of the predictive relationship are rigorously derived, unlike the statistical models in which both are based on intuition only. Several recent papers have used the standard Black–Scholes model to estimate bankruptcy risk. Examples include Crosbie and Bohn (2002); Vassalou and Xing (2004); and Hillegeist et al. (2004). As reported by Vassalou and Xing (2004) and Hillegeist et al. (2004), the option pricing theory-based bankruptcy risk measures outperform those based on traditional statistical models.

In this paper, we examine the possibility of predicting the bankruptcy of Japanese listed companies using accounting variables, option pricing theory-based variables, and other variables unique to the Japanese economy. The Japanese market merits this analysis for two reasons. First, most academic research on predicting bankruptcy has been conducted on U.S. companies. Whether or not models developed for U.S. companies also work outside the U.S. is a question that has not been previously answered. Japan is a natural choice because the Japanese economy is comparable with that of the United States in many aspects. The Japanese stock market in terms of market capitalization was the second largest in the world during

[1] Altman's (1968) model includes one market-based measure: the ratio of the market value of equity to the book value of total liabilities.

the sample period we study, next to that of the United States. By using a previously untested data set, we gain understanding of how bankruptcy prediction models might work outside the U.S. market. Since the time period of the Japanese data set is shorter than that of the U.S. data set and the sample size of the Japanese data set is smaller than that of the United States, we do not expect to resolve the debates in the literature about what kind of variables are more useful in predicting bankruptcy and what type of model is more accurate. Nevertheless, evidence from the Japanese data should illuminate unresolved issues arising from the U.S. studies. Second, while Japan's financial market is well developed, like the one in the United States, it does have its own unique characteristics. One of the important features of the corporate structure in Japan is the so-called main bank system, in which each company is associated with a main commercial bank. There are several large business groups centered on large banks known as horizontal Keiretsu. Whether a company belongs to one of the Keiretsu groups and how close it is to its main bank should have important bearing on how likely the company is to go bankrupt in the short run. Companies having close ties with their banks and other companies within a Keiretsu tend to get help when they face financial difficulties. Therefore these companies tend to have lower bankruptcy risk, other things being equal. The Japanese setting is ideal for examining the role that institutional arrangements may play in predicting bankruptcy beyond variables from accounting statements and financial markets.

We address two questions. First, do models developed for predicting the bankruptcy of U.S. companies remain valid in principle for predicting the bankruptcy of Japanese companies? Second, do corporate structure variables affect the probability of bankruptcy? For the first question, we simply borrow the original models from the existing literature with slight modification. We estimate a version of Altman's Z-score, Ohlson's O-score and the option pricing theory-based measure of the bankruptcy risk for Japanese listed companies. For the second question, we construct two variables that measure how closely a company is related to its main bank and the extent to which it belongs to a Keiretsu. One variable is the proportion of the company's stock held by its banks, which is a proxy for the dependence of the company on its banks. The other variable is a rating of the company's inclination to be in a Keiretsu, which is based on various criteria explained in the main text. We add these two variables to the accounting and market based variables and test how they contribute to bankruptcy prediction.

Our results show that the models based on accounting information and stock market information remain valid for Japanese listed companies. While not all the variables in these models are significant and the estimated parameters differ from those estimated from the data for U.S. companies, these models capture the fact that bankruptcy is a lengthy process and that the deterioration of a company's financial status is reflected in its financial statements and stock prices. We also find that these models are non-exhaustive and non-exclusive. Combining some of the variables in all three models generates a model that has more predictive power than each of the three models does alone. The two new variables, bank dependence and Keiretsu dependence, which capture the main feature of the corporate structure in Japan, are found to be useful in predicting bankruptcy of Japanese listed companies. They contribute to the prediction model to a certain extent.

The remainder of this paper is organized as follows. Section 2 reviews the existing literature on bankruptcy prediction models and provides the details of the methodology used to estimate the models. Section 3 describes the institutional background of Japanese firms and the two new variables that indicate bank dependence and Keiretsu dependence. Section 4 presents data sources and simple statistics of the variables used in various models. Section 5 reports the results of the estimated bankruptcy prediction models and compares the performance of these models. The last section summarizes the paper.

2 Existing models of bankruptcy prediction

Statistical models using accounting data to predict bankruptcy abound. A popular method used to estimate the likelihood of bankruptcy is multiple discriminant analysis. Altman (1968) uses the method to examine a sample of 66 manufacturing companies, half of which filed bankruptcy petitions under Chapter X of the U.S. National Bankruptcy Act during the period from 1946 to 1965. Altman considers 22 financial ratios, of which five are found to be useful for predicting bankruptcy. The estimated model takes the form:

$$Z_{it} = 1.2V_{1it} + 1.4V_{2it} + 3.3V_{3it} + 0.6V_{4it} + 0.999V_{5it}, \tag{1}$$

where t is a year, i is a company, and Z_{it} is a score to indicate the probability for company i to survive in year $t + 1$, and $V_1 =$ Working capital/Total assets; $V_2 =$ Retained earnings/Total assets; $V_3 =$ Earnings before interest and taxes/Total assets; $V_4 =$ Market value of equity/Book value of total liabilities; $V_5 =$ Sales/Total assets.

The fitted value of Z_{it} is known as the Z-score for company i in year t. The higher the Z-score, the higher the chance of survival. Overall, these five accounting ratios capture the company's characteristics such as liquidity, profitability, productivity, solvency and sales-generating ability.

Ohlson (1980) uses conditional logit models to predict bankruptcy. The best known model is his Model 1, which identifies four basic factors that affect the probability of bankruptcy within 1 year: (1) company size; (2) financial structure; (3) performance; and (4) current liquidity. These four factors are represented by nine accounting variables. Using data from the period of 1970–1976 with 105 bankrupt companies and 2058 non-bankrupt companies, his Model 1 is estimated as:

$$\begin{aligned} O_{it} = &- 1.32 - 0.407W_{1it} + 6.03W_{2it} - 1.43W_{3it} + 0.076W_{4it} \\ &- 1.72W_{5it} - 2.37W_{6it} - 1.83W_{7it} + 0.285W_{8it} - 0.521W_{9it}, \end{aligned} \tag{2}$$

where the observation on O_{it} is one if company i goes bankrupt during the next year and zero otherwise, and $W_1 =$ log(Total assets/GNP price-level index); $W_2 =$ Total liabilities/Total assets; $W_3 =$ Working capital/Total assets; $W_4 =$ Current liabilities/Current assets; $W_5 =$ One if total liabilities exceeds total assets, zero otherwise; $W_6 =$ Net income/Total assets; $W_7 =$ Funds from operations/Total liabilities; $W_8 =$ One if net income was negative for the last 2 years, zero otherwise; $W_9 =$ (Net income$_t$ − Net income$_{t-1}$)/(|Net income$_t$| + |Net income$_{t-1}$|).

The fitted value of O_{it} is known as the O-score for company i in year t. The greater the O-score, the higher its bankruptcy risk.

Both Altman's model and Ohlson's model continued to work well in the 1980s and the 1990s, as shown by Altman (1993), Begley et al. (1996) and Dichev (1998). In the current paper, we adopt the same sets of variables to determine the bankruptcy risk for Japanese listed companies, by using a hazard model to estimate the coefficients:

$$\tilde{Z}_{it} = \Phi(a_0 + a_1 V_{1it} + a_2 V_{2it} + a_3 V_{3it} + a_4 V_{4it} + a_5 V_{5it}), \tag{3}$$

$$\begin{aligned} O_{it} =& \Phi(b_0 + b_1 W_{1it} + b_2 W_{2it} + b_3 W_{3it} + b_4 W_{4it} + b_5 W_{5it} + b_6 W_{6it} \\ & + b_7 W_{7it} + b_8 W_{8it} + b_9 W_{9it}), \end{aligned} \tag{4}$$

where the observations of $\tilde{Z}_{it}$ and O_{it} are one if company i goes bankrupt within a year and zero if not, Φ is the cumulative standard normal distribution function, and the fitted values of $\tilde{Z}_{it}$ and O_{it} are the models' predictions of the probability of bankruptcy within a year. The independent variables are the same as those in Altman (1968) and Ohlson (1980). Note that what we call the Z-score and O-score refer to the accounting variables used in the original work. The method we use to estimate the model follows Shumway (2001). As shown by Shumway (2001), the hazard model is theoretically preferable to the static models used previously because it uses all available information to produce bankruptcy probability estimates for all firms at each point in time and avoids the selection biases inherent in static models. To compare Altman's model with Ohlson's model and other models to be discussed later, we define the fitted value of $\tilde{Z}_{it}$ as the probability of bankruptcy, instead of a measure of survival.

While accounting information is useful, it tends to look backwards. There is information that may not be contained in accounting statements but reflected in the price of stocks if the companies are listed and frequently traded. The information in stock prices tends to be more forward looking. In the recent literature, a new methodology for bankruptcy prediction has emerged that is based on the option pricing theory. As have been well articulated, the equity of a company with a simple capital structure can be viewed as a call option written on its assets with its debt as the strike price. Therefore, bankruptcy can be interpreted as the call finishing out of money at the maturity of the debt, whose probability can be calculated using standard option pricing models developed by Black and Scholes (1973) and Merton (1973, 1974). Vassalou and Xing (2004) compute the default likelihood indicator (*DLI*) to measure bankruptcy probability in such a framework. Hillegeist et al. (2004) use a similar approach to compute bankruptcy probability. The difference between Vassalou and Xing (2004) and Hillegeist et al. (2004) is a technical one about adjustments for dividends. Since the difference is small, we follow Vassalou and Xing (2004) in the rest of the discussion. In the Black–Scholes–Merton setting, the market value of a company's underlying assets follows a geometric Brownian motion of the form:

$$dV_{it} = \mu_i V_{it} dt + \sigma_i V_{it} dW_{it}, \tag{5}$$

where V is the value of company i's total assets, μ is its instantaneous drift, σ is its instantaneous volatility, and W is a standard Wiener process whose change represents unpredictable shocks to the asset value. Suppose that the firm has a single debt, X, to be paid at $t + T$. Then, the bankruptcy probability, defined as the probability for the company's assets to be less than the book value of the company's liabilities at $t + T$, is

$$\begin{aligned} DLI_{it} &= \Pr(V_{i,t+T} \leq X_{it} | V_{it}) = \Pr(\ln(V_{i,t+T}) \leq \ln(X_t) | V_{it}) \\ &= \Phi\left(-\frac{\ln(V_{it}/X_{it}) + (\mu_i - \frac{1}{2}\sigma_i^2)T}{\sigma_i \sqrt{T}} \right) \equiv \Phi(-DD_{it}), \end{aligned} \tag{6}$$

where Φ is the cumulative density function of the standard normal distribution. The quantity *DD* is known as the distance-to-default measure. It measures the distance between the current value of assets and the debt amount in terms of the volatility, that is, the standard deviation of the growth rate, of the assets.[2] Apart from the stock price, asset value volatility also enters the calculation of the default probability. This is an additional advantage of using the option pricing theory-based model to estimate bankruptcy probability. Note that (6) follows from (5) without dependence on the option pricing theory. However, since the market value of assets and its drift and volatility are not directly observed, the option pricing theory is conducive to estimating the asset process from the observed stock price and its volatility. Vassalou and Xing (2004) use an iterative procedure to estimate V and σ first and then to calculate *DLI*. Since typically a company will have a more complicated capital structure than the model assumes, for convenience, T is chosen to be 1 year and X_t is chosen to be all the short-term debt (with maturities less than 1 year) plus half of the long-term debt (with maturities greater than 1 year). For companies that have no debt, *DD* is set at five which corresponds to a *DLI* of virtually zero.[3]

We use a hazard model to estimate the following bankruptcy measure, named the *D*-score:[4]

$$D_{it} = \Phi(c_0 + c_1 DD_{it}). \tag{7}$$

The *DLI* is a special case when $c_0 = 0$ and $c_1 = -1$. The added flexibility given by the free parameters can improve the predictive power of the option pricing theory-based measures.

The accounting variable-based models and option pricing theory-based models have strengths and weaknesses. Accounting variable-based models have the advantage of the abundance of information regarding all aspects of a company's

[2] Despite its name, *DD* can take negative values. It is possible for the asset value to be less than the amount of debt before the debt is due.

[3] There are further developments along the line. Brockman and Turtle (2003), Leland (2004), and Charitou and Trigeorgis (2004) deviate from the standard option pricing model by incorporating some more realistic assumptions about default and bankruptcy. Bharath and Shumway (2005) examine the accuracy and the contribution of the theory-based models, and they conclude that the theory-based models have slightly better out-of-sample performance than statistical models have. Campbell et al. (2007) present evidence that bankruptcy risk cannot be adequately summarized by a theory-based measure, while Duffie et al. (2007) confirm that theory-based measures can predict bankruptcy.

[4] Our choice of the default boundaries follows those in Crosbie and Bohn (2002); Vassalou and Xing (2004); and Hillegeist et al. (2004). The results remain qualitatively the same with different default boundaries.

past activities, such as the amount of debt, earnings, and sales. But they tend to look backwards, and the models are mostly empirically determined. The option pricing theory-based models are theoretically rigorous and forward looking, but they are weak in their reliance on perhaps oversimplified assumptions about the capital structure of the companies and the restrictive assumptions about the stochastic processes governing the asset values. We, therefore, consider a combined model that comprises various ingredients of both types of models. Obviously, some of the variables used in the Z-score and the O-score are highly correlated and may proxy for similar company characteristics. We use the stepwise approach to remove insignificant variables from the regression model. Specifically, the variables are entered into and removed from the model in such a way that each forward selection step is followed by one or more backward elimination steps. The selection process terminates if no further variable can be added to the model, or if the variable just entered into the model is the only variable removed in the subsequent backward elimination. Eventually, we arrive at the following model:

$$C_{it} = \Phi(d_0 + d_1 V_{5it} + d_2 W_{4it} + d_3 W_{8it} + d_4 DD_{it}), \tag{8}$$

where the definitions of variables are the same as before. This C-score contains accounting information on current sales, liabilities, liquidity, earnings, and the market information about future profitability and asset value volatility. It synthesizes the accounting variable-based models and the option pricing theory-based models.

3 Japanese corporate structure and bankruptcy prediction

The Japanese economy has its own unique structure that necessitates fine-tuning of the bankruptcy risk measures. To explain how we include corporate structure variables in a new bankruptcy predicting model, we first briefly review the evolution over time of the relationship of Japanese companies with their banks.

Unlike their U.S. counterparts, Japanese companies rely more on banks, instead of financial markets, for financing. It has been documented extensively that equity holdings in companies by their main banks and other financial institutions are substantial in Japan. This is not seen in United States for regulatory reasons. Until the late 1980s, a Japanese company's access to credit was mostly dictated by its affiliation to an economic group built around its main bank. Under the main bank system, main banks had privileged knowledge of companies' prospects and strengths, so they were in a good position to monitor the companies' performance. This was especially so when bank officers served on the companies' boards. Even if some companies fell into distress, the main banks would try to rescue them. Typically, the company's main bank would ease its own credit terms to the distressed company, pay off other bank creditors, and put pressure on the suppliers of the company to continue to do business with the distressed company. This practice resulted in relatively few exchange-listed companies going bankrupt before the end of the 1980s.

The financial liberalization in the 1980s in Japan allowed large companies to reduce their dependence on bank loans and to obtain cheaper financing through financial markets. This prompted the banks to look for new customers, mainly among smaller companies and nonmanufacturing companies. In particular, much credit was extended to the construction and real estate sectors through banks' nonbank subsidiaries. The banks usually relied on pledges of collateral rather than on careful monitoring of these new clients. Thus, when a bubble in the stock market and the property market burst in 1990, banks had less incentive to provide significant support to those clients that were difficult to monitor or control. Nevertheless, bankruptcies among large companies were still contained during most of the 1990s. Although banks were no longer so willing to rescue distressed companies, they were still reluctant to force companies into bankruptcy. Loan syndication made every bank vulnerable to other banks' actions, so banks preferred to roll over their loans to distressed companies without forcing them into bankruptcy. Therefore, the balance sheets of banks were weakened by many nonperforming loans. In late 1997, three large financial institutions failed. According to Nakamura (2006), in 1998, the Japanese government tightened its regulatory standards and ordered banks to reduce the holdings in their client companies and improve their financial performance. Only then did banks start to reassess their strategies and curtail credit. Gradually, banks came to prefer solving financial problems via transparent legal procedures to save time, costs and expenses. As a result, the number of bankruptcies started to increase.

An illustration of the changing landscape of the Japanese main bank system is Sogo, a well-known department store chain. The Industrial Bank of Japan (IBJ) was its largest lender, providing 21.7% of Sogo's loans and holding 4.99% of its shares in 1996. One of the vice presidents of Sogo was an ex-IBJ banker. In the late 1990s, Sogo fell into financial trouble and faced pressure from many of its creditors. At that time, IBJ intervened and prevented Sogo from going bankrupt. By early 2000, IBJ realized that it could not support Sogo by itself any more. A rescue attempt was made by IBJ when it asked all the other major lenders to Sogo to ease their terms. The attempt failed, however, and Sogo was forced to apply for a court-supervised restructuring. The story of Sogo's bankruptcy is documented by Hoshi and Kashyap (2001), among others.

In addition to the main bank system, the Keiretsu system is also unique to the corporate structure in Japan. A Keiretsu is a large business group surrounding a few large financial institutions and manufacturing companies collectively known as the nucleus. According to Flath (2001), there were eight Keiretsu groups in the 1990: Mitsubishi, Mitsui, Sumitomo, Fuyo, DKB, Sanwa, IBJ and Tokai. The members of a Keiretsu are connected through crossholding of shares, mutual appointment of directors, and intra-group financing. Obviously, such a group structure gives its members an advantage in acquiring loans with favorable terms from financial institutions within the group, especially from the main bank. In addition, long-term relationships from cross-shareholding help maintain greater commitments among Keiretsu members and help cement Keiretsu ties. For this reason, a company's bankruptcy risk is reduced if it is affiliated with a specific Keiretsu. Hoshi et al. (1990) find that Keiretsu members invest and sell more after the onset of distress than do nonmember companies. Suzuki and Wright (1985) provide statistical evidence on the role of Keiretsu financing in reducing the costs of financial distress. With a model that predicts whether a troubled company would file for bankruptcy or would be given concessions by its creditors, they find that Keiretsu members are more likely to be given concessions on interest or principal payments. It should be noted that Keiretsu dependence and bank dependence are two different concepts, although the nucleus of a Keiretsu is a bank. For one thing, most listed companies are not Keiretsu members. Sogo, for example, is not a Keiretsu member.

Like the main bank system, Keiretsu also experienced serious challenges after the bubbles in the stock market and the property market burst in the early 1990s. The group system continued to weaken as cross-shareholding gradually decreased. In 2001, there were significant changes in the Keiretsu. The original eight Keiretsu were replaced by four new Megabank Groups (Mitsubishi Tokyo Financial Group Inc., Sumitomo Mitsui Banking Corp., UFJ Holdings Inc., and Mizuho Holdings Inc.). In the new Keiretsu system, cross-shareholding and intra- and inter-group consolidation are no longer characteristics, and the nucleus is not strong enough to exert controlling power over its members. The weakening of both the main-bank system and the Keiretsu system resulted in more bankruptcy cases in Japan in the 2000s.

The potential effect of the main bank/Keiretsu systems on bankruptcy risk has been discussed in literature. Shread (1989, 1994) uses 42 cases of main bank rescues in Japan from the mid-1960s to the late 1980s and finds that the main bank system efficiently reduces the problems of firms in distress. Miwa and Mark Ramseyer (2005) investigate troubled firms in two particular years (1978 and 1984) and find no strong evidence that the firms with main bank affiliations are more likely to receive assistance from their main bank than are firms without such an affiliation. Both studies examine the period before the burst of stock market bubble in 1990–1992 when bankruptcy was rare.

In this paper, we test whether the implicit rescuing contracts between companies and their main banks/Keiretsu exist in a more recent period from 1992 to 2005. We use two variables that proxy for bank dependence and Keiretsu dependence. For the former, we use the fraction of a listed company's stock directly owned by financial institutions including banks, insurance companies, securities companies, and other financial companies. This variable speaks for itself and needs no further explanation. For the latter, we adopt the rating given by Brown & Company Ltd. in its biannual publication *Industrial Groupings in Japan*. The dependence on the Keiretsu varies widely across the different companies. The following factors are taken into account in arriving at the degree of inclination towards membership in a specific group: the characteristics and historical background of the group or the company; sources and amounts of bank loans; board directors sent by or sent to the nucleus or other group companies; the company's attitude towards the group; and the company's connections with other group or nongroup companies. As such, a company's inclination to be a member of a Keiretsu group is rated on a scale of zero to four asterisks. Companies rated with four asterisks are nucleus group companies. The companies with strong inclinations towards membership in a Keiretsu are rated with three asterisks. Companies rated with two asterisks are inclined towards and connected with a Keiretsu, but the links are not particularly strong. The companies with weak inclination to be members in a Keiretsu are rated with one asterisk. Companies unrelated to any Keiretsu group receive a rating of zero asterisks. The model for the new bankruptcy risk measure, the X-score, is as follows:

$$X_{it} = \Phi(e_0 + e_1 V_{5it} + e_2 W_{4it} + e_3 W_{8it} + e_4 DD_{it} + e_5 U_{1it} + e_6 U_{2it}), \qquad (9)$$

where U_1 is the ownership by financial institutions in year t, U_2 is the inclination towards a membership in a Keiretsu (0–4) in year t, and the other explanatory variables are defined as above.

4 Data

The data used in this study are taken from the PACAP Japanese database and Datastream Inc. We include all the Japanese listed companies from 1992 to 2005, except for financial service companies (banks, insurance and securities companies). Companies in these financial industries are structurally different and have a different bankruptcy environment. While Japan has nine stock exchanges (the Tokyo, Osaka, Nagoya, Kyoto, Hiroshima, Fukuoka, Niigata, Sapporo and JASDAQ exchanges), the market is dominated by the Tokyo Stock Exchange (TSE) with around 90% of the country's total market capitalization. Most Japanese capital market studies focus on the TSE. The TSE is divided into a main section and a secondary section, referred to as sections 1 and 2, respectively. Typically, smaller companies are listed on the second section, and they may move to the first section when they satisfy the standards set by the exchange. Data on the companies listed on the TSE are retrieved from the PACAP Japanese database. Most of the companies listed on the TSE are large companies that conform to the listing requirements. Generally, small companies tend to have higher bankruptcy risk. To avoid distorting the analysis, we include the companies listed on the other stock exchanges as well, as long as the required accounting variables are available. Data on those companies come from Datastream Inc. As shown in Table 1, there are 3,510 listed companies in the final sample, with 2,055 companies listed on the TSE. Most of the sample companies are in the manufacturing industry.

We examine performance-related delistings. The reasons given for this kind of delisting are formally classified as liquidation, rehabilitation, reorganization and failure to meet the listing conditions.[5] We regard all these cases as bankruptcy. Although the data start from 1975, no listed nonfinancial companies went bankrupt before 1993. Since standard models in the literature predict bankruptcy within 1 year, we confine our analysis to the period from 1992 to 2005. During the sample period, the number of exchange-listed companies going bankrupt is relatively small,

[5] There were mainly three types of bankruptcy filings available to large companies in Japan: the Civil Rehabilitation Law, the Corporate Reorganization Law and the Liquidation Law. The Liquidation Law is equivalent to Chapter 7 of the U.S. Bankruptcy Code, whereas the Civil Rehabilitation Law and the Corporate Reorganization Law are roughly equivalent to Chapter 11 of the U.S. Bankruptcy Code. Xu (2004) found that bankrupt Japanese companies preferred rehabilitation or reorganization to liquidation, which is similar to the U.S. evidence in Bris et al. (2006).

Table 1 Characteristics of the sample. This table presents the composition of the sample by stock exchange and industry respectively. #N is the number of companies in the sample. #B is the number of performance-related delistings

	#N	#B	#B/#N(%)
A. Stock exchange			
Tokyo	2,055	60	2.92
JASDAQ	872	8	0.92
Osaka	389	4	1.03
Nagoya	109	1	0.92
Fukuoka	26	0	0.00
Sapporo	12	1	8.33
Others	47	2	4.26
Total	3,510	76	2.17
B. Industry			
Agriculture, forestry, fisheries and mining	29	0	0.00
Construction	263	18	6.84
Manufacturing	2,022	33	1.63
Wholesale and retail	496	13	2.62
Real estate	44	1	2.27
Transportation and communication	187	5	2.67
Electric power and gas	37	0	0.00
Services	432	6	1.39
Total	3,510	76	2.17

especially in the early part of the sample period. We identify 76 bankrupt companies in the sample. Of these, 60 companies are delisted from the TSE, and the other 16 companies are delisted from the other stock exchanges. In the sample, the percentage of companies delisted from the TSE is 2.92, and the percentage delisting from the other exchanges varies. Many nonTSE-listed bankrupt companies do not have available accounting variables and are not included in the sample.

Table 2 reports a profile of the performance-related delistings over time. Notably, most bankruptcy cases occur in the second half of the sample period. In the same table, we also present the time-series of the cross-sectional averages of the two variables, U_1 and U_2, that are proxies for bank dependence and Keiretsu dependence. Three samples are considered when the cross-sectional averages are taken. In the first sample, all the companies are included. As we see from the table, both variables decrease over time. In the first half of the sample period, more than 30% of the sample companies' shares are owned by financial institutions. However, the ownership by financial institutions decreases to 3% after 2001. As mentioned in the last section, this reduction in the holding of client companies by banks resulted from the regulatory changes in Japan. The average Keiretsu dependence variable also decreases from 0.9835 in 1992 to 0.3408 in 2005. These patterns provide *time-series* evidence that, as bank dependence becomes weaker and Keiretsu membership inclination reduces, more delisting cases emerge. In the case of Sogo, for example,

Table 2 Summary report of Japanese performance-related delistings. This table reports the profile of performance-related delistings over time. #N is the number of companies in the sample. #B is the number of performance-related delistings. The cross-sectional averages of bank dependence and Keiretsu dependence are also reported. U_1 = Ownership by financial companies; U_2 = Inclination towards the membership in a Keiretsu (taking values from 0 to 4). $\overline{U}_1$ and $\overline{U}_2$ are the cross-sectional averages of U_1 and U_2 for all the companies in the sample; U_1^* and U_2^* are the cross-sectional averages of U_1 and U_2 for the companies that existed in 1992 with a sample size of 1273 in 1992 and 970 in 2005; U_1^{**} and U_2^{**} are the cross-sectional averages of U_1 and U_2 for the 970 companies that existed during the entire sample period from 1992 to 2005

Year	#B	Full-sample			1992-Sample		1992–2005-Sample	
		#N	$\overline{U}_1$	$\overline{U}_2$	U_1^*	U_2^*	U_1^{**}	U_2^{**}
1992	0	1,273	0.3776	0.9835	0.3776	0.9835	0.3819	1.0220
1993	1	1,434	0.3691	0.9766	0.3724	0.9834	0.3744	1.0166
1994	0	1,473	0.3658	0.9697	0.3704	0.9904	0.3725	1.0134
1995	1	1,499	0.3606	0.9652	0.3646	0.9910	0.3677	1.0131
1996	0	1,539	0.3513	0.9529	0.3564	0.9989	0.3595	1.0069
1997	6	1,577	0.3373	0.9370	0.3440	0.9842	0.3454	1.0048
1998	5	1,617	0.2997	0.8603	0.3270	0.9765	0.3271	0.9971
1999	6	1,810	0.2689	0.7979	0.3078	0.9523	0.3080	0.9958
2000	8	2,018	0.2207	0.6627	0.2882	0.9424	0.2914	0.9618
2001	7	2,678	0.1071	0.5463	0.1534	0.8711	0.1551	0.9114
2002	11	2,746	0.0357	0.4632	0.0504	0.8455	0.0507	0.8504
2003	10	2,880	0.0373	0.4230	0.0573	0.8222	0.0583	0.8477
2004	10	3,078	0.0348	0.3937	0.0535	0.8146	0.0543	0.8293
2005	11	3,230	0.0333	0.3408	0.0516	0.7749	0.0516	0.7749

the weakening tie to the main bank and other financial institutions is reflected in its U_1. The value of its U_1 was 52.44% in 1992. It gradually decreased to 11.43% in 1999 and finally became zero before the company went bankrupt in 2000. Note that the number of companies in the full sample increases over time. The new companies tend to be smaller ones with weaker ties with main banks and Keiretsu. One might wonder if the decline in the average bank dependence and the average Keiretsu dependence is caused by the inclusion of these new companies in the sample. To answer that question, we examine cross-sectional averages over two more samples. One sample, the 1992-sample, includes only companies that existed in 1992. The number of companies in the sample decreases as some companies are delisted for either performance-related reasons or other reasons. The other sample, the 1992–2005-sample, includes only companies that existed during the entire 1992–2005 period. While the numbers in the table show that all the averages follow a decreasing pattern over time, two observations are worth noting. First, the patterns for bank dependence are very similar in all three samples. This means that the declining pattern in bank dependence we see in the full sample is not due to the inclusion of new companies. Second, Keiretsu dependence declines faster in the full sample than in the 1992-sample, which in turn is faster than in the 1992–2005-sample. This means that the decreasing pattern of Keiretsu dependence that we see in the full-sample is indeed partially due to the inclusion of new companies, although Keiretsu dependence of existing companies also exhibits significant decline. The difference in Keiretsu dependence between the 1992-sample and the 1992–2005-sample is also worth noting. The average Keiretsu dependence is higher for the 1992–2005-sample than for the 1992-sample, indicating that the companies exiting from the 1992-sample (either because of performance-related reasons or because of merger and acquisitions) are those with weaker Keiretsu ties. This is *cross-sectional* evidence showing that Keiretsu dependence reduces bankruptcy risk.

Table 3 presents descriptive statistics for the explanatory variables that are used to estimate the bankruptcy risk measures. We first calculate the time-series average of the explanatory variables for each Japanese company in the sample. We then report descriptive statistics for the cross-sectional distribution of the sample companies, including the mean, standard deviation (Std), and quartiles of the distributions (minimum, lower quartile, median, upper quartile, and maximum) of the time-series averages. Since the sample size increases over time, the descriptive statistics calculated this way are more indicative of the situation in the later sample years.

Table 3 Descriptive statistics of the predictive variables. This table presents the descriptive statistics (mean, standard deviation [Std], minimum, lower quartile [Q1], median, upper quartile [Q3] and maximum) for the cross-sectional distribution of the time-series averages of all the predictive variables used in the prediction models for the sample period from 1992 to 2005. The variables are defined as follows: V_1 = Working capital/Total assets; V_2 = Retained earnings/Total assets; V_3 = Earnings before interest and taxes/Total assets; V_4 = Market value of equity/Book value of total liabilities; V_5 = Sales/Total assets; W_1 = log(Total assets/GNP price-level index); W_2 = Total liabilities/Total assets; W_3 = Working capital/Total assets; W_4 = Current liabilities/Current assets; W_5 = One if total liabilities exceeds total assets, zero otherwise; W_6 = Net income/Total assets; W_7 = Funds from operations/Total liabilities; W_8 = One if net income was negative for the last 2 years, zero otherwise; W_9 = (Net income$_t$ − Net income$_{t-1}$)/(|Net income$_t$| + |Net income$_{t-1}$|); *DD* = Distance to default; U_1 = Ownership by financial companies; U_2 = Inclination to the membership in a Keiretsu

Variable	Mean	Std	Min	Q1	Med	Q3	Max
V_1 (W_3)	0.16	0.22	−1.68	0.02	0.16	0.30	0.97
V_2	0.21	0.27	−5.18	0.05	0.20	0.35	0.95
V_3	0.04	0.09	−1.28	0.01	0.03	0.06	1.79
V_4	2.51	5.72	0.00	0.44	0.91	2.09	92.76
V_5	1.13	0.65	0.02	0.72	0.98	1.38	8.63
W_1	5.82	1.49	0.75	4.81	5.69	6.65	12.23
W_2	0.56	0.22	0.02	0.40	0.56	0.72	2.35
W_4	0.82	0.61	0.02	0.49	0.72	0.98	13.72
W_5	0.01	0.04	0.00	0.00	0.00	0.00	1.00
W_6	0.01	0.16	−8.30	0.00	0.01	0.03	1.59
W_7	0.10	0.65	−11.84	0.03	0.08	0.15	32.91
W_8	0.10	0.20	0.00	0.00	0.00	0.10	1.00
W_9	0.00	0.24	−1.00	−0.08	0.00	0.08	1.00
DD	3.99	1.32	−2.79	3.28	4.59	5.00	5.00
U_1	0.13	0.15	0.00	0.00	0.06	0.23	0.79
U_2	0.42	0.99	0.00	0.00	0.00	0.00	4.00

The descriptive statistics for the accounting variables do not differ much from the same statistics reported for U.S. companies. We therefore focus our discussion on the non-accounting variables. More than a quarter of the Japanese companies have a distance-to-default variable equal to five, which implies virtually zero bankruptcy probability. Less than a quarter of the Japanese companies have a distance-to-default variable that is less than three, indicating that the majority of Japanese companies are not close to bankruptcy most of the time. During the sample period, an average of 13% of the total shares in Japanese companies is owned by financial institutions. The distributions, however, are very skewed; the extreme case has a bank dependence of 79%. The distribution of the Keiretsu dependence is also skewed. It takes a value between zero and four, but has a cross-sectional average of only 0.42. More than three-quarters of the companies in the sample are not affiliated with a Keiretsu.

Table 4 reports the unconditional correlations between the variables used in the bankruptcy prediction. As mentioned above, some accounting variables in Altman's and Ohlson's models are highly correlated and tend to reflect similar information about a company's financial status. For example, the correlation between Working capital/Total assets (V_1) and Current liabilities/Current assets (W_4) is quite high: the Pearson product moment correlation coefficient is -0.79, and the Spearman rank correlation coefficient is -0.97. Both variables measure the liquidity of the company. For this reason, we opt for selecting predictive variables following the stepwise approach mentioned earlier. As a result, three accounting variables, Sales/Total assets (V_4), Current liabilities/Current assets (W_4), and the Dummy variable on the net income for the last 2 years (W_8) remain in the combined prediction model for the C-score. These variables cover different aspects of business conditions, including liquidity, profitability, solvency, and sales-generating ability.

In the X-score model, which incorporates the unique Japanese institutional features of main banks and business groups, we use the same three accounting variables chosen from the accounting variable-based models, the computed distance-to-default variable from the option pricing theory-based model, bank dependence and Keiretsu dependence. The calculated correlations of these six variables show that they are not highly correlated. The largest absolute value of the correlation occurs between *DD* and W_4. Both are based on the asset liability ratio, with one using current liabilities and the market value of assets and the other using a mixture of the book value of current liabilities and current assets. As anticipated, *DD* is negatively correlated with the negative net income indicator, W_8, and is positively correlated with sales level indicator, V_5. U_1 and U_2 are positively related, which indicates that the Keiretsu group companies tend to be more highly controlled by financial institutions. *DD* is negatively correlated with U_1 and U_2, and the correlation coefficients are economically small though statistically significant. This indicates that U_1 and U_2 might capture different characteristics of Japanese companies from what *DD* captures. Actually, U_1 and U_2 are basically unrelated to the other variables except for $W_{1,}$ which represents firm size. Overall, the low correlations among these variables facilitate the interpretation of the regression results presented in the next section.

Table 4 Correlation analysis. This table presents the unconditional correlations between the variables used in the bankruptcy prediction. The lower diagonal refers to Pearson product moment correlations, while the upper diagonal refers to Spearman rank correlations. The correlations between the variables used in the prediction for the X-score are shown in bold. The *p*-values are reported in parentheses, where *, **, *** represent significance at the 0.10, 0.05 and 0.01 levels, respectively

	V_1 (W_3)	V_2	V_3	V_4	V_5	W_1	W_2	W_4	W_5	W_6	W_7	W_8	W_9	DD	U_1	U_2
V_1 (W_3)	1	0.52	0.25	0.56	−0.12	−0.11	−0.70	−0.97	−0.11	0.33	0.37	−0.14	0.00	0.39	0.04	−0.10
		(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.76)	(0.00)***	(0.00)***	(0.00)***
V_2	0.46	1	0.36	0.60	−0.11	0.13	−0.72	−0.57	−0.11	0.41	0.61	−0.25	−0.04	0.36	0.28	−0.04
	(0.00)***		(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***
V_3	0.06	0.15	1	0.46	0.11	0.03	−0.32	−0.24	−0.09	0.86	0.73	−0.41	0.29	0.38	0.04	−0.09
	(0.00)***	(0.00)***		(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***
V_4	0.32	0.16	0.07	1	−0.12	−0.06	−0.74	−0.61	−0.08	0.52	0.64	−0.19	0.04	0.57	0.19	−0.08
	(0.00)***	(0.00)***	(0.00)***		(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***
V_5	−0.09	−0.09	0.03	−0.08	1	−0.15	0.16	**0.19**	0.00	0.12	−0.03	**−0.08**	0.04	**0.05**	**−0.14**	**−0.03**
	(0.00)***	(0.00)***	(0.00)***	(0.00)***		(0.00)***	(0.00)***	**(0.00)*** **	(0.84)	(0.00)***	(0.00)***	**(0.00)*** **	(0.00)***	**(0.00)*** **	**(0.00)*** **	**(0.00)*** **
W_1	−0.11	0.14	0.01	−0.10	−0.12	1	0.16	0.10	−0.04	−0.02	0.03	−0.11	−0.01	0.00	0.49	0.29
	(0.00)***	(0.00)***	(0.15)	(0.00)***	(0.00)***		(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.04)**	(0.65)	(0.00)***	(0.00)***
W_2	−0.75	−0.61	−0.09	−0.39	0.15	0.15	1	0.76	0.12	−0.42	−0.63	0.15	−0.01	−0.48	0.05	0.19
	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***		(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.02)**	(0.00)***	(0.00)***	(0.00)***
W_4	−0.79	−0.39	−0.01	−0.21	**0.03**	0.11	0.60	1	0.10	−0.33	−0.43	**0.13**	0.00	**−0.40**	**−0.04**	**0.11**
	(0.00)***	(0.00)***	(0.13)	(0.00)***	**(0.00)*** **	(0.00)***	(0.00)***		(0.00)***	(0.00)***	(0.00)***	**(0.00)*** **	(0.79)	**(0.00)*** **	**(0.00)*** **	**(0.00)*** **
W_5	−0.25	−0.27	−0.02	−0.02	0.01	−0.04	0.27	0.23	1	−0.10	−0.09	0.15	−0.03	−0.07	−0.05	−0.01
	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.37)	(0.00)***	(0.00)***	(0.00)***		(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.03)**
W_6	0.07	0.12	0.91	0.03	0.01	0.01	−0.08	−0.04	−0.05	1	0.72	−0.46	0.40	0.45	0.00	−0.11
	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.02)**	(0.10)*	(0.00)***	(0.00)***	(0.00)***		(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.79)	(0.00)***
W_7	0.09	0.22	0.45	0.13	−0.01	0.02	−0.16	−0.06	−0.02	0.76	1	−0.36	0.17	0.42	0.11	−0.09
	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.14)	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***		(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***
W_8	−0.16	−0.25	−0.13	−0.05	**−0.07**	−0.12	0.16	**0.13**	0.15	−0.09	−0.15	1	−0.02	**−0.23**	**−0.10**	**−0.01**
	(0.00)***	(0.00)***	(0.00)***	(0.00)***	**(0.00)*** **	(0.00)***	(0.00)***	**(0.00)*** **	(0.00)***	(0.00)***	(0.00)***		(0.01)***	**(0.00)*** **	**(0.00)*** **	**(0.13)**
W_9	0.01	−0.03	0.08	0.03	0.03	−0.01	−0.01	0.00	−0.04	0.07	0.07	−0.01	1	0.13	−0.09	−0.02
	(0.28)	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.39)	(0.06)*	(0.57)	(0.00)***	(0.00)***	(0.00)***	(0.00)***		(0.00)***	(0.00)***	(0.00)***

Table 4 continued

	V_1 (W_3)	V_2	V_3	V_4	V_5	W_1	W_2	W_4	W_5	W_6	W_7	W_8	W_9	DD	U_1	U_2
DD	0.37	0.28	0.09	0.21	**0.05**	−0.02	−0.45	**−0.27**	−0.09	0.05	0.10	**−0.25**	0.12	1	**−0.06**	**−0.12**
	(0.00)***	(0.00)***	(0.00)***	(0.00)***	**(0.00)*****	(0.01)***	(0.00)***	**(0.00)*****	(0.00)***	(0.00)***	(0.00)***	**(0.00)*****	(0.00)***		**(0.00)*****	**(0.00)*****
U_1	0.05	0.19	0.01	0.00	**−0.13**	0.46	0.05	**−0.05**	−0.05	0.01	0.02	**−0.10**	−0.08	**−0.02**	1	**0.27**
	(0.00)***	(0.00)***	(0.36)	(0.74)	**(0.00)*****	(0.00)***	(0.00)***	**(0.00)*****	(0.00)***	(0.10)*	(0.00)***	**(0.00)*****	(0.00)***	**(0.00)*****		**(0.00)*****
U_2	−0.08	−0.03	−0.02	−0.09	**−0.04**	0.32	0.17	**0.01**	−0.02	0.00	−0.02	**−0.01**	−0.01	**−0.11**	**0.28**	1
	(0.00)***	(0.00)***	(0.00)***	(0.00)***	**(0.00)*****	(0.00)***	(0.00)***	**(0.00)*****	(0.00)***	(0.91)	(0.00)***	**(0.06)***	(0.04)**	**(0.00)*****	**(0.00)*****	

5 Empirical Results

The estimated coefficients of the $\tilde{Z}$, O and D-scores are shown in Table 5. In Panel A on the $\tilde{Z}$-score, three of the five slope coefficients are significant in terms of the Wald chi-square statistic. All the signs of the parameter estimates are in line with our anticipations. The measure of goodness-of-fit is indicated by the likelihood ratio index, 0.0652. The regression results for Ohlson's model are reported in Panel B. Only three of the variables are statistically significant. Except for the coefficients of W_2 and W_7, which are insignificant, the signs of the other coefficients are consistent with intuition. The likelihood ratio index is slightly higher than that in Panel A, probably due to the inclusion of more explanatory variables. The estimated coefficients of the explanatory variables in Panels A and B are quite different from the original models. This comes as no surprise because even in the U.S. data in the 1980s, Begley et al. (1996) find that the re-estimated coefficients of these two models change substantially from the original ones. The regression results presented here are qualitatively in agreement with those of Altman (1968) and Ohlson (1980).

Panel C of Table 5 presents the parameter estimates for the option pricing theory-based model (7). The estimated slope coefficient on *DD* is significantly negative. The likelihood ratio index of this model is much higher than the likelihood ratios of the accounting variable-based models. This shows that the market data do contain information about a company's future prospects. However, the estimated parameters (c_0, c_1) differ from the theoretical value of (0, -1), indicating that the distributional assumption implied by the geometric Brownian motion for the market value of assets is too restrictive, the way liabilities are measured is inappropriate, or both. More specifically, an estimate of c_1 with an absolute value of less than one means that the distance-to-default measure is too extreme, that is, some values are too large and some values are too small, while a negative c_0 means that the distance-to-default measure is biased upwards. Perhaps converting only half of the long-term liabilities as 1-year debt is too optimistic. While there are plenty of ways to refine the distance-to-default measure, we leave this for future research. The flexibility offered by the free parameters (c_0, c_1) serves our purpose.

Panel D of Table 5 reports the results of the C-score regression. The coefficients of all the variables are significant at the 0.05 level by construction because the insignificant accounting variables are left out of the model. In comparison with the original models, the coefficients of V_5, W_4, W_8 and *DD* do not change much and their p-values are almost the same as before. The significance level does not show a great improvement. However, there is one point worthy of attention. While the three accounting variables are taken from financial statements only, they remain significant when *DD* is added. This means that market data and financial statements have separate information about a company's future prospects. These variables are complementary in predicting bankruptcy. The likelihood ratio index increases to 0.1483, much greater than either of the accounting variable-based models or the option pricing theory-based model alone.

In Panel E of Table 5, the estimates of the model with the two Japanese institutional variables are reported. The coefficients of U_1 and U_2 are significantly negative, indicating that bank dependence and Keiretsu dependence are significantly

Table 5 Model estimation for the full sample period (1992–2005) . This table presents the estimates of five hazard models

$\tilde{Z}_{it} = \Phi(a_0 + a_1 V_{1it} + a_2 V_{2it} + a_3 V_{3it} + a_4 V_{4it} + a_5 V_{5it}),$
$O_{it} = \Phi(b_0 + b_1 W_{1it} + b_2 W_{2it} + b_3 W_{3it} + b_4 W_{4it} + b_5 W_{5it} + b_6 W_{6it} + b_7 W_{7it} + b_8 W_{8it} + b_9 W_{9it}),$
$D_{it} = \Phi(c_0 + c_1 DD_{it}),$
$C_{it} = \Phi(d_0 + d_1 V_{5it} + d_2 W_{4it} + d_3 W_{8it} + d_4 DD_{it}),$
$X_{it} = \Phi(e_0 + e_1 V_{5it} + e_2 W_{4it} + e_3 W_{8it} + e_4 DD_{it} + e_5 U_{1it} + e_6 U_{2it}),$

where $\tilde{Z}$,O, D, C, and X are the bankruptcy probabilities and Φ is the cumulative standard normal distribution. ** and *** represent significance at the 0.05 and 0.01 levels, respectively. The *p*-values that are less than 0.0001 are marked as 0.0001. LRI is the likelihood ratio index. The number of observations included in the regression analysis is reported as #OBS

Variable	Estimate	*p*-Value	LRI	#OBS
A. Altman's model: $\tilde{Z}$-score				
Intercept	−4.1776	0.0001***	0.0652	28,712
V_1	−0.5294	0.0206**		
V_2	−0.2139	0.1035		
V_3	−1.0411	0.1219		
V_4	−0.4303	0.0032***		
V_5	−1.3183	0.0001***		
B. Ohlson's model: O-score				
Intercept	−5.9422	0.0001***	0.0748	27,123
W_1	−0.0813	0.3151		
W_2	−0.0944	0.8743		
W_3	−0.2189	0.7593		
W_4	0.2751	0.0004***		
W_5	−0.8617	0.4162		
W_6	−0.0745	0.2526		
W_7	0.0374	0.4479		
W_8	1.5211	0.0001***		
W_9	−0.6270	0.0039***		
C. Option pricing theory based D-score				
Intercept	−4.5118	0.0001***	0.1251	27,702
DD	−0.5405	0.0001***		
D. The combined model: C-score				
Intercept	−4.3803	0.0001***	0.1483	26,086
V_5	−0.6674	0.0117**		
W_4	0.1683	0.0009***		
W_8	0.7019	0.0079***		
DD	−0.4470	0.0001***		
E. The most comprehensive model: X-score				
Intercept	−3.7458	0.0001***	0.1645	26,086
V_5	−0.7030	0.0086***		
W_4	0.1407	0.0056***		
W_8	0.5591	0.0367**		

Table 5 continued

Variable	Estimate	*p*-Value	LRI	#OBS
DD	−0.4548	0.0001***		
U_1	−2.2099	0.0048***		
U_2	−0.2512	0.0391**		

and negatively associated with the probability of bankruptcy. The original variables from the existing accounting variable-based and option pricing theory-based models remain useful. The likelihood ratio index of the new model increases further.

To interpret the negative association between bank/Keiretsu dependences and bankruptcy probability as a causal relationship, we need to entertain an alternative explanation. Financial institutions, which have private information about the business of the client company, may reduce their capital participation as these companies approach bankruptcy. This endogeneity interpretation obviously differs from our intended interpretation that troubled companies may get help from their main banks and other affiliated companies. To differentiate between the two interpretations, we do an independence test of the bank/Keiretsu dependences and the bankruptcy probability based on the C-score. The idea is that if the main banks and Keiretsu members decide to distance themselves from their client or cohort companies because these companies are in financial trouble, we should see a negative association between the bank/Keiretsu dependences and the bankruptcy measures without bank/Keiretsu dependences. Panel A of Table 6 provides the test of independence between U_1 and the C-score. All the sample firm-years are equally divided into three U_1-sorted and three C-score-sorted portfolios independently. Nine portfolios are created from the intersections. The matrix on the left side of Panel A shows the observed percentages of firm-years in the nine portfolios, while the matrix on the right side shows the expected percentages of the firm-years under the null hypothesis of independence between U_1 and the C-score. The χ^2 test for the independence between U_1 and the C-score takes the value of 1.62, which is not significant at the conventional 5% significance level. Therefore, the null hypothesis of independence cannot be rejected. This indicates that the main banks do not deliberately choose their client companies according to their bankruptcy probability. Panel B of Table 6 presents the test results based on 15 U_2- and the C-score-sorted portfolios. The portfolios are constructed similarly to that of the portfolios of Panel A, except that five U_2-sorted portfolios are constructed according to the discrete value of U_2 (0–4). The χ^2 value for the independence between U_2 and C-score is 1.41, which is not significant at the conventional 5% significance level. Therefore, the results in Table 6 indicate that the endogeneity interpretation is less likely.

To compare the quality of the various models in predicting bankruptcy of Japanese listed companies, we take a look at the ex post bankruptcies. Following Dichev (1998) and Shumway (2001), we perform an informal examination of realized bankruptcy cases across different categories of bankruptcy risk measures. All the firm-years are sorted into ten equally populated categories according to one of the bankruptcy risk measures, the $\tilde{Z}$, O, D, C, and X-scores. Panel A of Table 7

Table 6 Test of independence between C-score and Japanese institutional variables. Panel A provides the results of nine U_1- and C-score-sorted portfolios. All the sample firm-years are equally classified into three U_1-sorted and three C-score-sorted portfolios independently. Nine portfolios are created from the intersections. The matrix on the left side shows the observed percentages of firm-years in different portfolios, while the matrix on the right side shows the percentages under the null hypothesis of independence between U_1 and the C-score. χ^2 is the Pearson chi-square statistics for the test of independence between U_1 and the C-score. Panel B provides the results based on 15 U_2- and C-score-sorted portfolios. The portfolios are constructed similarly to that of the portfolios of Panel A, except that five U_2-sorted portfolios are constructed according to the discrete value of U_2 (0−4)

Observed percentages						Percentages under the null					
		C-score						C-score			
		1 (Low)	2	3 (High)	Sum			1 (Low)	2	3 (High)	Sum
A.											
U_1	1 (Low)	13.29	10.50	9.55	33.34	U_1	1 (Low)	11.11	11.11	11.11	33.34
	2	10.97	9.96	12.41	33.33		2	11.11	11.11	11.11	33.33
	3 (High)	9.07	12.88	11.39	33.34		3 (High)	11.11	11.11	11.11	33.34
	Sum	33.33	33.33	33.34	100.00		Sum	33.33	33.33	33.34	100.00
χ^2 of independence test = 1.62; degrees of freedom = 4; p-value = 0.81											
B.											
U_2	0	24.39	22.90	20.84	68.13	U_2	0	22.71	22.71	22.71	68.13
	1	3.52	3.45	3.98	10.94		1	3.65	3.65	3.65	10.94
	2	1.92	2.23	2.43	6.59		2	2.20	2.20	2.20	6.59
	3	2.43	2.27	3.43	8.14		3	2.71	2.71	2.71	8.14
	4	1.07	2.48	2.65	6.19		4	2.06	2.06	2.07	6.19
	Sum	33.33	33.33	33.34	100.00		Sum	33.33	33.33	33.34	100.00
χ^2 of independence test = 1.41; degrees of freedom = 8; p-value = 0.99											

reports the estimated average bankruptcy probability for each category according to the $\tilde{Z}$, O, D, C, and X-scores. As bankruptcy is a rare event, the estimated probabilities, as measured by the $\tilde{Z}$, O, D, C, and X-scores, are all small. Panel B of Table 7 reports the number of observed performance-related delistings during the next year by the bankruptcy risk category. As we can see, all the measures are successful in predicting bankruptcy. The majority of delistings appear in the high-risk categories, that is, those with large $\tilde{Z}$, O, D, C, and X-scores. A more successful measure captures more delisted companies in its highest-risk category.

The option pricing theory-based D-score appears to be more successful than the $\tilde{Z}$-score and the O-score in terms of the likelihood ratio index. From Panel B of Table 7, we see that the D-score predicts more delisted companies in the highest-risk category than those predicted by the $\tilde{Z}$-score and the O-score. However, because accounting information and market information are complementary, the C-score successfully assigns more delisted companies into the highest-risk category than the D-score does. By incorporating U_1 and U_2 into the prediction model, the X-score further improves the prediction. As shown in Panel B of Table 7, only one company (1.3% of all the delistings) is allocated into three lowest-risk categories by the X-score, while 55 delisted companies (72.4% of all the delistings) are classified

Table 7 Comparison of the bankruptcy measures in predicting performance-related delistings. All the sample firm-years are equally sorted into ten categories according to their bankruptcy scores. Panel A reports the estimated average bankruptcy probability for each category. Panel B reports the number of actual performance-related delisting cases in each bankruptcy-risk-sorted category

Category	$\tilde{Z}$-score	O-score	D-score	C-score	X-score
A. Average bankruptcy scores					
1 (Low risk)	0.0001	0.0010	0.0007	0.0004	0.0002
2	0.0006	0.0013	0.0007	0.0006	0.0004
3	0.0010	0.0014	0.0007	0.0007	0.0006
4	0.0015	0.0016	0.0007	0.0008	0.0008
5	0.0019	0.0017	0.0007	0.0009	0.0010
6	0.0024	0.0019	0.0007	0.0011	0.0012
7	0.0029	0.0021	0.0016	0.0016	0.0016
8	0.0035	0.0026	0.0025	0.0025	0.0022
9	0.0046	0.0036	0.0046	0.0043	0.0041
10 (High risk)	0.0081	0.0109	0.0146	0.0161	0.0169
B. In-sample prediction test					
1 (Low risk)	2	6	3	2	1
2	4	4	3	3	0
3	1	2	3	3	0
4	5	1	2	2	4
5	3	4	3	2	3
6	4	1	3	0	5
7	4	8	4	5	2
8	5	5	7	9	6
9	16	10	7	6	9
10 (High risk)	32	35	41	44	46

into the two highest-risk categories. In sum, each of the five models appears to be fairly accurate, assigning between 59.2% and 72.4% of delistings to the two highest-risk categories. By incorporating the unique features of the Japanese institutions, the X-score is economically better.

An important aspect of the relationship between the bank/Keiretsu dependences and the bankruptcy probability is its cross-sectional implication: at any given point of time, companies with closer ties to their main banks and group members have less chance to go bankrupt. From Table 2, however, we see a strong time-series correlation between the number of bankruptcies per year and the average bank/Keiretsu dependences from that year. Basically, the number of bankruptcies increased over time while the average bank/Keiretsu dependences decreased. The decreasing pattern is particularly strong for average bank dependence. Is the result of the negative relationship between bankruptcy probability and bank/Keiretsu dependences reported in Panel E of Table 5 using panel data mainly driven by the time-series property? If it is and the cross-sectional effect is absent, the result might be spurious. In other words, the increase in the number of bankruptcies over time might just have happened when the average bank/Keiretsu dependences decreased over time, while there is no relationship between bank/Keiretsu dependences and bankruptcy probability at any given point of time.

An ideal way to determine whether the reported negative relationships exist only in time-series or in both time-series and cross-sections, if the data allow, is to run cross-sectional regressions every year. Unfortunately, because the number of bankruptcies per year is small, especially in the early years of the sample, the cross-sectional regressions lack the power to detect most of the relationships, not just the bank/Keiretsu dependences. An alternative approach, which is as effective as the cross-sectional regressions, is to run the following hazard regression model:

$$X_{it} = \Phi(e_1 T_{1t} + e_2 T_{2t} + e_3 T_{3t} + e_4 V_{5it} + e_5 W_{4it} + e_6 W_{8it} + e_7 DD_{it} + e_8 U_{1it} + e_9 U_{2it}), \tag{10}$$

where T_1 is the dummy variable for 1992–1997, T_2 is the dummy for 1998–2001, and T_3 is the dummy for 2002–2005. The division into the three subperiods follows the observed pattern of U_1 in Table 2. We expect the coefficients of these dummies to increase over the subperiods, capturing the increasing pattern of the number of bankruptcy cases over time. If the negative relationships between the bankruptcy probability and the bank/Keiretsu dependences are a time-series property only, we expect to see insignificant coefficients of U_1 and U_2. The result of the estimated regression model is reported in Table 8.

The results in Table 8 show that there is indeed a time-series effect: the coefficients of the subperiod dummies increase over the subperiods. Compared with Panel E of Table 5, the coefficients of U_1 and U_2 are slightly smaller, but they

Table 8 Test of a potentially spurious relationship. This table presents the estimates of the following hazard model:

$$X_{it} = \Phi(e_1 T_{1t} + e_2 T_{2t} + e_3 T_{3t} + e_4 V_{5it} + e_5 W_{4it} + e_6 W_{8it} + e_7 DD_{it} + e_8 U_{1it} + e_9 U_{2it}),$$

where X is the bankruptcy probability and Φ is the cumulative standard normal distribution. T_1 is the dummy variable for 1992–1997, T_2 is the dummy variable for 1998–2001, and T_3 is the dummy variable for 2002–2005. ** and *** represent significance at the 0.05 and 0.01 levels, respectively. The *p*-values that are less than 0.0001 are marked as 0.0001. LRI is the likelihood ratio index. The number of observations included in the regression analysis is reported as #OBS

Variable	Estimate	*p*-Value	LRI	#OBS
T_1	−3.8156	0.0001***	0.1656	26,086
T_2	−3.7409	0.0001***		
T_3	−3.5004	0.0001***		
V_5	−0.6943	0.0095***		
W_4	0.1420	0.0054***		
W_8	0.5555	0.0383**		
DD	−0.4455	0.0001***		
U_1	−2.6596	0.0082***		
U_2	−0.2495	0.0412**		

remain highly significant. The result shows that the relationship between the bank/Keiretsu dependences and bankruptcy probability is a cross-sectional property as well as a time-series one.

As is always the case when comparing bankruptcy prediction models, out-of-sample prediction should be the ultimate criterion, while in-sample performance may result from over-fitting of the data. To see how the models perform out of sample, we estimate all the bankruptcy scores with data from 1992–2003 and use the estimated coefficients to predict bankruptcy in the hold-out sample period of 2004–2005. The results of the model estimation for the period 1992–2003 are virtually the same as those reported in Table 5. The predictive power of the five models is robust. Most of the bankruptcy cases in 2004–2005 are classified in the two highest-risk deciles, while very few cases appear in the three lowest-risk deciles. As expected, the C-score model and the X-score model fare the best, and the other models are about equally good. These results are not reported to save the space.

6 Concluding remarks

In this paper, we investigate bankruptcy prediction of Japanese listed companies. Accounting variables used in Altman's Z-score, Ohlson's O-score and the option pricing theory-based distance-to-default measure, previously developed for the U.S. market, are useful in predicting bankruptcy of Japanese companies. Traditional accounting variables form the basis for predicting bankruptcy, while the stock market variables provide more forward-looking information about a company's future prospects. We find that, for Japanese listed companies, the option pricing theory-based bankruptcy measure is more successful than the accounting variable-based measures alone, but it does not subsume the accounting measures. These variables and models all have their own strengths and cover certain aspects of bankruptcy prediction. When the two sets of variables are combined together, the predictive power of the model improves substantially. Instead of picking a winner among them, a more meaningful question in future research is how we should better combine the models to produce better predictions.

The Japanese economy is unique because of its main bank system and Keiretsu structure. A new X-score is proposed to capture these special features. It incorporates a variable representing a company's bank dependence, a variable representing a company's Keiretsu dependence and some important ingredients from the existing bankruptcy prediction models. The negative relationships between bankruptcy probability and the bank/Keiretsu dependences are genuine cross-sectional relationships, which also exhibit a time-series pattern. The X-score further improves bankruptcy prediction of Japanese listed companies.

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References

Altman, E. (1968). Financial ratios, discriminant analysis and the prediction of corporate bankruptcy. *Journal of Finance,23*, 589–609.

Altman, E. (1993). *Corporate financial distress and bankruptcy: A complete guide to predicting and avoiding distress and profiting from bankruptcy*. NY: Wiley.

Altman, E., Haldeman, R. G., & Narayanan, P. (1977). Zeta analysis: a new model to identify bankruptcy risk of corporations. *Journal of Banking and Finance,10*, 29–54.

Beaver, W. (1966). Financial ratios as predictors of bankruptcy. *Journal of Accounting Research,6*, 71–102.

Beaver, W. (1968). Market prices, financial ratios, and the prediction of failure. *Journal of Accounting Research,8*, 179–192.

Beaver, W., McNichols, M., & Rhie, J. (2005). Have financial statements become less informative? Evidence from the ability of financial ratios to predict bankruptcy. *Review of Accounting Studies,10*, 93–122.

Begley, J., Ming, J., & Watts, S. (1996). Bankruptcy classification errors in the 1980s: An empirical analysis of Altman's and Ohlson's models. *Review of Accounting Studies,1*, 267–284.

Bharath, S., & Shumway, T. (2005). Forecasting default with the KMV-Merton model, Working paper, University of Michigan. http://w4.stern.nyu.edu/salomon/docs/Credit2006/shumway_kmvmerton1.pdf.

Black, F., & Scholes, M. (1973). The pricing of options and corporate liabilities. *Journal of Political Economy,81*, 637–659.

Bris, A., Welch, I., & Zhu, N. (2006). The costs of bankruptcy: Chapter 7 Liquidation versus Chapter 11 Reorganization. *Journal of Finance,61*, 1253–1303.

Brockman, P., & Turtle, H. (2003). A barrier option framework for corporate security valuation. *Journal of Financial Economics,67*, 511–530.

Brown & Company Ltd. *Industrial Groupings in Japan.* Various issues.

Campbell, J., Hilscher, J., & Szilagyi, J. (2007). In search of distress risk, Working paper, Harvard University. http://www.econ.nyu.edu/user/galed/fewpapers/FEW%20S07/Campbell-Hilscher-Szilagyi.pdf.

Charitou, A., & Trigeorgis, L., (2004). Explaining bankruptcy using option theory, Working paper, University of Cyprus. http://www.pba.ucy.ac.cy/courses/2004_11_TAR_Option_Bankr_2411_04.pdf.

Chava, S., & Jarrow, R. (2004). Bankruptcy prediction with industry effects. *Review of Finance,8*, 537–569.

Crosbie, P., & Bohn, J. (2002). *Modeling default risk*. KMV.

Dichev, I. (1998). Is the risk of bankruptcy a systematic risk? *Journal of Finance,53*, 1131–1147.

Duffie, D., Saita, L., & Wang, K. (2007). Multi-period corporate default prediction with stochastic covariates. *Journal of Financial Economics,83*, 635–665.

Flath, D. (2001). Japan's business groups, Chapter 11. In M. Nakamura (Ed.), *The Japanese business and economic system: History and prospects for the 21st century*. Palgrave Macmillan.

Hillegeist, S., Keating, E., Cram, D., & Lundstedt, K. (2004). Assessing the probability of bankruptcy. *Review of Accounting Studies,9*, 5–34.

Hoshi, T., & Kashyap, A. (2001). *Corporate financing and governance in Japan: The road to the future*. The MIT Press.

Hoshi, T., Kashyap, A., & Scharfstein, D. (1990). The role of banks in reducing the costs of financial distress in Japan. *Journal of Financial Economics,27*, 67–88.

Leland, H. (2004). Predictions of expected default probabilities in structural models of debt. *Journal of Investment Management,2*, 1–28.

Merton, R. C. (1973). Theory of rational option pricing. *Bell Journal of Economics and Management Science,4*, 141–183.

Merton, R. C. (1974). On the pricing of corporate debt: The risk structure of interest rates. *Journal of Finance,29*, 449–470.

Miwa, Y., & Mark Ramseyer, J. (2005). Conflicts of Interest in Japanese Insolvencies: The Problem of Bank Rescues. *Theoretical Inquiries in Law,6*, 301.
Nakamura, M. (2006). Japanese corporate governance practices in the post-bubble era: Implications of institutional and legal reforms in the 1990s and early 2000s. *International Journal of Disclosure and Governance,3*, 233–261.
Ohlson, J. (1980). Financial ratios and the probabilistic prediction of bankruptcy. *Journal of Accounting Research,18*, 109–131.
Shread, P. (1989). The main bank system and corporate monitoring and control in Japan. *Journal of Economic Behavior,11*, 399–422.
Shread, P. (1994). Main banks and the governance of financial distress. In M. Aoki & H. Patrick (Eds.), *The Japanese main bank system: Its relevancy for developing and transforming economies*. Oxford University Press.
Shumway, T. (2001). Forecasting bankruptcy more accurately: a simple hazard model. *Journal of Business,74*, 101–124.
Suzuki, S., & Wright, R. W. (1985). Financial structure and bankruptcy risk in Japanese companies. *Journal of International and Business Studies,16*, 97–110.
Vassalou, M., & Xing, Y. (2004). Default risk in equity returns. *Journal of Finance,59*, 831–868.
Xu, P. (2004). Bankruptcy Resolution in Japan: corporation Reorganization vs. Civil Rehabilitation, Working paper, Hosei University. http://www.rieti.go.jp/en/events/03010801/pdf/Xu_p.pdf.
Zmijewski, M. E. (1984). Methodological issues related to the estimation of financial distress prediction models. *Journal of Accounting Research,22*, 59–82.