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The determinants of credit spread changes in Japan

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Abstract

In this paper, we examine the relationship between credit spread changes in Japan and financial and macroeconomic variables such as the risk-free interest rate and stock price indices. We use a model that belongs to the class of so-called structural models for corporate bond pricing originally developed by Merton (1974) and extended by Longstaff and Schwartz (1995) among others. Our empirical results indicate that credit spreads in Japan are negatively correlated with the risk-free interest rate and with corporate financial conditions (which stand proxy for the market valuations of firms). The magnitude of such correlations increases as the credit ratings of the bond issuers decline. These results are consistent with the implications of structural models and with the related literatures in the U.S. and Europe. We also find that credit spreads in Japan are positively correlated with the implied volatility of interest rates. In other words, an increase in uncertainty about future interest-rate contributes to the widening in credit spreads.

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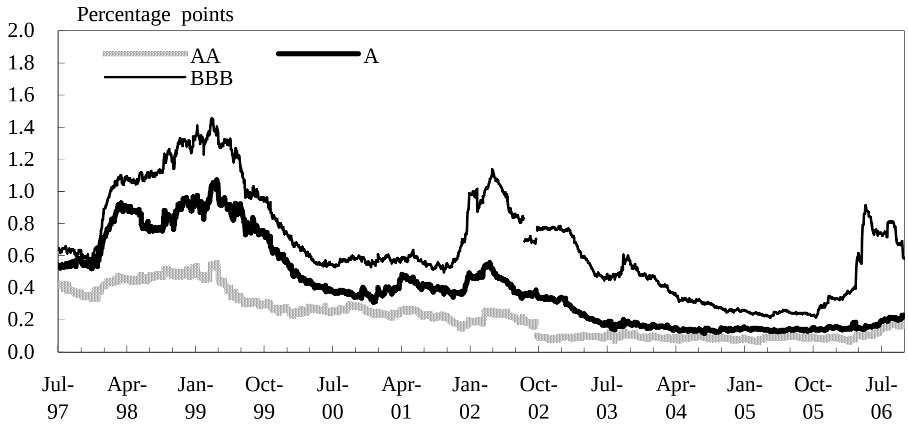
1. Introduction

1.1. Motivation

The primary market for corporate bonds in Japan grew rapidly in the late 1990s. Two causal factors can be identified. One is the abolition of regulatory constraints on corporate bonds, including 'Issue Standards'. The other is the decline in the lending capacity of the Japanese banks caused by a major disturbance to the financial system. Along with the growth in the issue of corporate bonds, a secondary market for bonds has developed since then. Price quotations in the market have been publicly observable since the middle of 1997 (see Figure 1).

Figure 1: Credit spreads in Japan



Notes: Yields on bonds with 5-year maturity. Ratings are those of Moody's, but we express them in the more widely-used forms (for example AAA) rather than those of Moody's (for example Aaa) in this paper.

Source: Japan Securities Dealers Association, 'Over-the-Counter Standard Bond Quotations.'

The differences between the yields on corporate bonds and those on government bonds (hereafter the 'credit spreads') peaked at the end of the 1990s, at around the first half of 2002, and in early 2006. The first peak corresponds to the emergence of anxiety about the stability of the financial system. The second corresponds to a series of major domestic and foreign bankruptcies. Credit spreads remained stable and low from 2003 to 2005. In early 2006, the spread of BBB-rated (Baa-rated) bonds widened. The triggers were the major Leverage-Buy-Out (LBO) shock and the regulatory actions taken against the consumer finance industry. Credit spreads for AA- (Aa-) and A-rated bonds also widened to some extent around the time of the termination of the 'quantitative easing' and 'zero interest rate' policies of the Bank of Japan.[1]

The determinants of credit spreads, in general, consist not only of firms' values (credit risks), but also of other factors, such as coupons, covenants, embedded call options, taxation issues, and liquidity conditions in the market. Although there are many empirical studies of the relationship between credit spreads and such factors in the U.S. and Europe, not enough empirical studies of credit spreads in Japan have been undertaken for a consensus to emerge.[2] Therefore, we empirically investigate the role of financial and macroeconomic variables in determining the dynamics of credit spreads in Japan and contribute to understanding recent developments in credit spreads.

1.2. Related literature

There are two major classes of models used to describe credit spread dynamics: structural models and reduced-form models. The so-called structural models are based on option pricing theory. Merton (1974), Longstaff and Schwartz (1995) and others have developed major structural models. In a standard structural model, it is assumed that a firm's value follows a stochastic process and the default situation is one in which the firm's value falls below a certain threshold, such as the nominal value of debt. On the other hand, in a standard reduced-form model, it is assumed that the mechanism that governs a default process is unobservable, and that a latent factor known as 'default intensity' determines the probability of default. In this paper, we apply the structural model, because it explicitly describes the default mechanism and enables us to analyze the relationship between credit spreads and financial and macroeconomic variables.

The standard framework for a structural model treats a corporate bond as a synthetic asset that consists of a long position on a risk-free bond and a short position on a put option whose underlying asset is the issuer's asset. In this framework, changes in credit spreads correspond to those in the premium value of put options. Therefore, the determinants of the put option value are those of the changes in credit spreads. That is, increases in the firm's value and increases in the risk-free interest rate

[1] Appendix 1 summarizes the history of credit spread changes in Japan.
[2] For example, Ichiue, Ohoka, and Ueno (2006) and Ohashi and Makita (2006) present a different interpretation on the role of interest rates in affecting Japanese credit spreads from 2003 to 2006.

lower the value of the put option and, in turn, cause a narrowing of credit spreads. An increase in the volatility of the firm's value raises the probability of default and thus causes a widening of credit spreads.

There are many empirical studies of structural models on credit spreads for the U.S. and European markets. For example, Longstaff and Schwartz (1995) find that credit spread changes in the U.S. are negatively correlated with changes in the yields of 30-year government bonds and with changes in the returns of the corresponding stock prices. They also find that the lower the credit rating of the bond, the more sensitive the credit spread is to changes in stock returns. These results are consistent with the implications of the structural models.

Duffee (1998) and Collin-Dufresne, Goldstein, and Martin (2001) point out that there is a negative correlation between credit spread changes in the U.S. and changes in the level and slope of the U.S. government bond yield curve. Collin-Dufresne, Goldstein, and Martin (2001) also find that both the leverage ratios of firms and the implied volatility of the options for the S&P100 index are positively correlated with credit spreads. The positive correlation with stock option volatility increases as the credit ratings of bonds decline. These results are also consistent with the predictions of the structural model.

Van Landschoot (2004) studies credit spreads in the European market to confirm the validity of the structural model. He reports that the short-term interest rate, the slope of the government bond yield curve, and stock returns are negatively correlated with credit spreads, while the implied volatility of stock options is positively correlated with credit spreads.

These studies generally support the validity of the structural models of credit spreads in the U.S. and European markets. However, they also reveal the shortcomings of the structural model in the empirical study. They point out that the explanatory power of the structural models is limited and, therefore, it is likely that factors other than those included in the structural model influence the dynamics of credit spreads. Collin-Dufresne, Goldstein, and Martin (2001) indicate that the single common factor driving the residuals of their models might represent some kind of imperfection of the corporate bond market.

Pynnönen, Hogan, and Batten (2006) conduct an empirical study of a structural model of the Japanese market.[3] They examine the responses of the credit spreads of AAA- and AA-rated euro-yen corporate bonds to the yield on the 20-year Japanese government bond (JGB), the slope of the JGB yield curve, and the returns of the NIKKEI 225 index. They obtain significantly negative coefficients on the JGB yields, as predicted by the structural model. However, the coefficients on the slope of the JGB yield curve and on the stock index returns are positive, contrary to the predictions of the structural model. They suggest that their choice of sample period (January 1995 to October 1998, which was "an exceptional period in the Japanese economy") may explain this perverse result.

1.3. The features and structure of this paper

In comparison with related studies, our paper has the following features.

First, this paper comprehensively examines the validity of the structural model for credit spread changes in Japan. Our data set includes virtually all the available time series data from the late 1990s. Despite the so-called 'uniqueness' of the corporate bond market in Japan, we find that credit spread changes in Japan share the same characteristics as those in the U.S. and Europe.

Second, our model incorporates factors other than those included in the standard structural model in order to overcome the shortcomings of standard structural models identified in previous studies. These factors are the implied volatility of the interest rate and other variables related to the conditions of corporate bond market. The empirical results reveal that these additional factors have statistically significant influences on the changes in credit spreads.

Third, whereas standard studies of structural models utilize stock prices in order to proxy firms' values, we use alternative proxy variables. This is because the stock price index in Japan may bear 'noises' unrelated to firms' values. The alternative proxies we use are indicators of the firms' financial standings. We find that the estimated coefficients on these variables have signs that are consistent with model

[3] Although they do not explicitly use the structural model, Hattori, Koyama, and Yonetani (2001) and Ichiue, Ohoka, and Ueno (2006) analyze the time series characteristics of credit spreads in Japan.

predictions.

The rest of this paper is organized as follows. In Section 2, we describe our model, which is a linear representation of the structural model, as well as the data set. In Section 3, we report the empirical results, which are based on daily data. In Section 4, we develop and explain further analysis based on the alternative proxies for firms' values. Section 5 concludes the paper.

2. Model and data

In the framework of the standard structural model, the credit spread is determined by the firm's value, its volatility, and the risk-free interest rate. Because credit spreads are uniquely determined given the current values of these state variables, it follows that changes in credit spreads are determined by changes in these state variables. We follow the literature, including the study of Longstaff and Schwartz (1995), by adopting a linear representation of the structural model. Because the empirical studies for the U.S. and Europe have identified potential shortcomings of the structural models, we extend the standard model to incorporate variables that are relevant in the context of corporate bond markets, in addition to those included in the structural models. The specification of our linear model is as follows:

$$\begin{aligned} \Delta CS_{i,j,t} &= c_{i,j} + \beta_{1,i,j}\Delta r_{j,t} + \beta_{2,i,j}\Delta\sigma_t^r + \beta_{3,i,j}\Delta\log(TPX_t) \\ &\quad + \beta_{4,i,j}\Delta\sigma_t^{NKY} + \beta_{5,i,j}\Delta TL_t + \beta_{6,i,j}\Delta onoff_t + \varepsilon_{i,j,t} \\ \varepsilon_{i,j,t} &\sim N(0,\sigma_{i,j,t}^2) \end{aligned} \tag{1}$$

where CS, c, r, σ^r, TPX, σ^{NKY}, TL, $onoff$, and ε denote the credit spread, the constant, the yield of the JGB, the implied volatility of interest rates, the stock price index (TOPIX), the implied volatility of options on the stock price index (NIKKEI 225), the LIBOR spread, the premium on the 'on-the-run' JGB, and the residuals, respectively. The subscripts i, j, and t denote credit ratings, maturities, and time, respectively, while Δ and $\Delta\log$ represent the first difference and the log difference, respectively.

$CS_{i,j,t}$ is the average of the credit spreads whose credit ratings are i and whose maturity is from j to $j+1$ years. We obtain each $CS_{i,j,t}$ by subtracting the JGB yield with maturity j from the corresponding yields of corporate bonds. The data on corporate bond yields are published by the Japan Securities Dealers Association.[4] Our data set consists of the series without any missing data in the sample period.[5] Note that because $CS_{i,j,t}$ is an aggregate based on credit rating and maturity, changes in $CS_{i,j,t}$ may reflect changes in credit ratings and maturities, issues of new bonds, and changes in credit rating policy.

$r_{j,t}$ is the yield on the JGB with a j-year maturity, which is interpolated from JGB prices in the secondary market. The structural model suggests that an increase in the risk-free interest rate narrows credit spreads. Therefore, the expected sign of $r_{j,t}$ is negative.[6]

We assume that there is no strong negative correlation between the risk-free rate and the firm's value. Typically, an increase in the risk-free rate is accompanied by an increase in the real growth and the inflation rate; under such circumstances, firms' values also increase. This casual observation suggests a positive correlation between the risk-free interest rate and firms' values. However, if an increase in the risk-free rate lowered the firm's value and, in turn, widened the credit spread, then the coefficients of $r_{j,t}$ could be positive. Even if this correlation were negative, whether the coefficients of $r_{j,t}$ are negative depends on the size of the correlation or on the volatility of the firm's value.[7] We evaluate the appropriateness of our assumption by interpreting the estimation results.

The implied volatility of interest rates, σ_t^r, is measured by the implied volatility of the swaption on 10-year swap rate with one-month option period. We interpret σ_t^r as a proxy for uncertainty about future interest rate. We assume that investors in corporate bonds are risk averse and have unmatched duration of assets and liabilities in their balance sheets. Then, an increase in uncertainty about future interest rate makes

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4 The credit ratings are those of Moody's, which are categorized into Aaa (corresponding to AAA in this paper), Aa (AA), A (A), Baa (BBB), and Ba (BB).

5 We selected one-year, two-year, three-year, five-year, seven-year, and nine-year yields for AA- and A-rated bonds, and one-year, two-year, three-year, and five-year yields for BBB-rated bonds.

6 We assume that $r_{j,t}$ proxies the spot rate of the risk-free rate. It is likely, however, that $r_{j,t}$ contains information about the slope of the JGB yield curve as well as information about the level of risk-free interest rate. This is because $r_{j,t}$ is the JGB yield with a maturity of more than one year.

7 Longstaff and Schwartz (1995) present an illustrative example in which the coefficient on $r_{j,t}$ is negative, even though the correlation between the interest rate and firms' asset values is negative.

investment in corporate bonds less attractive and thereby widens credit spreads. In other words, the coefficient on σ_t^r is expected to be positive.

The stock index (TOPIX), TPX_t, and the implied volatility of stock returns (the NIKKEI 225 index), σ_t^{NKY}, proxy firms' values and their volatility, respectively.[8] The former is predicted by the structural models to have a negative coefficient; the coefficient of the latter is expected to be positive.

TL_t is the 10-year LIBOR spread over the yield of the 10-year JGB. Collin-Dufresne, Goldstein, and Martin (2001) consider the LIBOR spread as a proxy for liquidity in the corporate bond market, because "if liquidity in the swap market 'dries up', it seems plausible that liquidity in the corporate bond market will dry up as well." Note that interpreting the role of TL_t in credit spread changes is not straightforward. One of the reasons is that the LIBOR spread reflects not only liquidity in the financial market, but also reflects the risk premium for the banking sector. Because corporate finance in Japan has relied heavily on the banking sector, the financial health and strength of the banking sector may affect credit spreads in nonfinancial sectors. Another reason relates to the pricing of corporate bonds. Historically, in Japan, the prices of BBB-rated bonds, and some A-rated bonds, have been based on the yield quoted over the LIBOR. Therefore, the credit spreads on these bonds, measured in terms of differences from the JGB yield, incorporate changes in the difference between the LIBOR and the JGB yield. However, whatever mechanism is involved, the coefficient on TL_t is expected to be positive.

The variable $onoff_t$ is calculated as the yield on the newly issued (on-the-run) 20-year JGB minus the yields on previously issued (off-the-run) bonds. Following Collin-Dufresne, Goldstein, and Martin (2001), we interpret $onoff_t$ as an indicator of the liquidity conditions in bond markets overall. Normally, the on-the-run bonds are traded more frequently than the off-the-run bonds; hence, $onoff_t$ reflects a premium for liquidity. In other words, a decrease in $onoff_t$ corresponds to an increased preference for bond liquidity, which widens credit spreads. Thus, the coefficient of $onoff_t$ is expected to be negative.

[8] σ_t^{NKY} is the average of the implied volatilities of the at-the-money call and put options in the NIKKEI 225 index. We used the options on the NIKKEI 225 rather than those on TOPIX because of data availability.

As equation (1) indicates, we estimate the model in first differences.[9] We use daily data from December 1st, 1998 to August 25th, 2006. The estimation method is the Ordinary Least Squares.

3. Estimation results based on daily data[10]

3.1. JGB yields

In this section, we report and interpret the estimation results of equation (1) on daily data. We start with the responses of changes in credit spreads to changes in JGB yields. Most of the estimated coefficients on the JGB yields ($\Delta r_{j,t}$) in equation (1), $\beta_{1,i,j}$, are statistically significant and negative, which is consistent with the predictions of the structural model (see Table 1).[11] These results imply that a strong negative correlation between the risk-free interest rate and firms' values is unlikely.

Table 1: Coefficients on JGB yields: $\beta_{1,i,j}$

	j					
i	1	2	3	5	7	9
AA	–0.1949 (–12.18)	0.0749 (7.30)	0.0215 (2.76)	–0.0228 (–4.24)	–0.0836 (–17.54)	–0.0782 (–15.88)
A	–0.2628 (–13.90)	–0.0226 (–1.68)	–0.0505 (–4.46)	–0.0921 (–11.98)	–0.1310 (–16.19)	–0.0975 (–13.71)
BBB	–0.3049 (–15.04)	–0.0347 (–2.35)	–0.0743 (–5.58)	–0.0959 (–8.79)		

Notes: Numbers in parentheses are t-values. Shaded cells contain estimated coefficients that are statistically significant and of the expected signs.

[9] We estimate in first differences because we cannot reject the hypotheses that $CS_{i,j,t}$, $r_{j,t}$, and TPX_t have unit roots.

[10] Detailed estimation results are presented in Appendix 2.

[11] There may be other interpretations of these results. One is that the negative coefficients merely reflect the difference in efficiency between the corporate bond and JGB markets. If the corporate bond market does not absorb a shock as quickly as the JGB market, the estimated coefficient on $r_{j,t}$ could be negative. However, we interpret the results not only in terms of coefficient signs, but also in terms of the relative magnitude of the responses. The relative magnitudes of the estimated coefficients across maturities and credit ratings also support the validity of the structural model.

A closer look at Table 1 shows that the absolute values of all the coefficients on one-year bonds are larger than those on the longer maturity bonds. This result may have arisen from the mismatch in maturities between $CS_{i,1,t}$ and $r_{1,t}$. While $CS_{i,1,t}$ measures the spread for corporate bonds with maturities of between one and two years, $r_{1,t}$ is the interpolated yield of the JGB with a exact one-year maturity. During the sample period, the short-term interest rates were approximately zero due to the Bank of Japan's policy. For this period, the slope of the JGB yield curve for one-year maturity is relatively steep. These unmatched maturities may have generated the high sensitivity of $CS_{i,1,t}$.[12]

Another interesting feature of Table 1 is the relative magnitudes of coefficients for bonds with maturities of two or more years. The longer the maturities, or the lower the credit ratings, the larger the relative magnitudes of the coefficients are. This result is consistent with the predictions of structural models, as pointed out by Longstaff and Schwartz (1995) and Duffee (1998).[13]

3.2. The implied volatility of the interest rate

Most of the coefficients, $\beta_{2,i,j}$, on the implied volatility of interest rates as measured by the swaptions ($\Delta\sigma_t^r$) are statistically significant and positive (see Table 2). This result clearly indicates that an increase in uncertainty about future interest rate widens credit spreads.

[12] An alternative interpretation relates to the limitations of the structural models. As pointed out in the literature, the structural models do not adequately explain the credit spreads of bonds with short maturities, because they assume a continuous process for firms' values and preclude sudden default. However, the reduced-form model and the structural model extended to incorporate a 'jump' process for the firm's value better explain the credit spreads of bonds with short maturities.

[13] They also pointed out that the negative relationship weakens when maturity lengthens beyond a certain period.

Table 2: Coefficients on the implied volatility of interest rates: $\beta_{2,i,j}$

i	j = 1	2	3	5	7	9
AA	0.00799 (11.13)	0.00539 (7.59)	0.00432 (5.88)	0.00217 (3.06)	0.00227 (3.04)	0.00104 (1.44)
A	0.00695 (8.19)	0.00542 (5.82)	0.00466 (4.36)	0.00412 (4.06)	0.00288 (2.28)	0.00163 (1.55)
BBB	0.00742 (8.15)	0.00683 (6.68)	0.00515 (4.10)	0.00334 (2.32)		

Notes: Numbers in parentheses are t-values. Shaded cells contain estimated coefficients that are statistically significant and of the expected signs.

In each row, shorter maturities are associated with larger estimated coefficients. One interpretation is that investors in corporate bonds prefer longer maturities in order to mitigate duration mismatches in their balance sheets. In theory, if the durations of assets and liabilities are perfectly matched, changes in the risk-free rate do not influence the net returns of investors. In practice, however, it is rarely feasible to match the durations of assets and liabilities perfectly. If investors in corporate bonds have liabilities with long durations, they tend to prefer corporate bonds with longer maturities. Increased holdings of assets with longer maturities help to reduce the degree of duration mismatch, and in turn reduce the influence of changes in the risk-free interest rate. The primary investors in corporate bonds in Japan are institutional investors, such as life insurance companies and pension funds. Because the durations of their liabilities are longer than those of their assets, it is consistent with the above interpretation to suggest that these investors prefer corporate bonds with longer maturities and thus ‘buy and hold’ primary issues.

There is another interpretation of the finding that the credit spreads with shorter maturities are associated with larger estimated coefficients. It is based on the idea that the implied volatilities of interest rate options diminish as maturities increase. One probable explanation of this is that the influences of realized and predicted shocks are less significant for long maturities than for short maturities. Hence, credit spreads of longer maturity corporate bonds may incorporate less uncertainty about future interest rate on an annualized basis.

3.3. Firms' values

The estimated coefficients on the returns of TOPIX ($\Delta \log(TPX_t)$), $\beta_{3,i,j}$, are statistically significant and positive in most cases (see Table 3). This result is inconsistent with the predictions of the structural models, but consistent with the findings of Pynnönen, Hogan, and Batten (2006) for euro-yen bonds.

Table 3: Coefficients on the returns of TOPIX: $\beta_{3,i,j}$

	j					
i	1	2	3	5	7	9
AA	0.0172 (1.25)	0.0335 (2.54)	0.0348 (2.60)	0.0276 (2.18)	0.0310 (2.36)	0.0112 (0.89)
A	0.0262 (1.61)	0.0473 (2.74)	0.0411 (2.11)	0.0439 (2.43)	0.0208 (0.93)	0.0224 (1.24)
BBB	0.0242 (1.39)	0.0431 (2.27)	0.0616 (2.69)	0.0684 (2.67)		

Notes: Numbers in parentheses are t-values.

In the context of the implied volatility of the NIKKEI 225 index ($\Delta\sigma_t^{NKY}$), no coefficient, $\beta_{4,i,j}$, is statistically significant (see Table 4).

Table 4: Coefficients on the implied volatility of the NIKKEI 225 index: $\beta_{4,i,j}$

	j					
i	1	2	3	5	7	9
AA	0.000045 (0.53)	0.000092 (1.14)	0.000129 (1.57)	0.000039 (0.50)	0.000084 (1.04)	0.000097 (1.26)
A	0.000083 (0.82)	0.000150 (1.41)	0.000114 (0.95)	–0.000044 (–0.40)	–0.000072 (–0.52)	0.000179 (1.62)
BBB	0.000061 (0.56)	0.000025 (0.21)	0.000163 (1.16)	–0.000091 (–0.58)		

Note: Numbers in parentheses are t-values.

These results imply that the aggregate stock price indices are inappropriate proxies for firms' values in Japan. Although the cause of these results is unclear, possible explanations include aggregation bias in stock price indices, differences between firms covered by stock price indices and firms covered by our measurements of credit spreads, and the lack of nonarbitrage conditions between the prices of stocks and corporate bonds. We leave further investigation of this issue for future research. In Section 4, we utilize alternative proxies to examine the role of firms' values in determining credit spread changes.

3.4. Other variables related to the corporate bond market

There remain two variables to be discussed in our estimation: the LIBOR spreads and the on-the-run JGB premiums. For the LIBOR spreads (ΔTL_t), most of the coefficients, $\beta_{5,i,j}$, are statistically significant and positive, as expected (see Table 5).

Table 5: Coefficients on LIBOR spreads: $\beta_{5,i,j}$

	j					
i	1	2	3	5	7	9
AA	–0.000113 (–1.36)	0.000057 (0.72)	0.000272 (3.37)	0.000270 (3.57)	0.000190 (2.41)	0.000368 (4.84)
A	–0.000151 (–1.54)	0.000190 (1.82)	0.000591 (5.03)	0.000760 (7.00)	0.000702 (5.24)	0.000852 (7.76)
BBB	–0.000223 (–2.12)	0.000234 (2.05)	0.000694 (5.02)	0.000677 (4.40)		

Notes: Numbers in parentheses are t-values. Shaded cells contain estimated coefficients that are statistically significant and of the expected signs.

In each column, the coefficients on the AA-rated bonds are smaller than those on the A- and BBB-rated bonds. In each row, the coefficients increase in general as maturities lengthen. One interpretation of these results is that the lower the credit rating, or the longer the maturity, the more sensitive the price of the corporate bond is to changes in market liquidity conditions. Given that the LIBOR spreads represent evaluations on the soundness of the banks' financial standings, we can interpret these results in the following way; the lower the credit rating of the debtor, or the longer the maturity of the debt, the greater the effect is from the financial conditions of the banks' (lenders') on the credit spread of the debtor.

The coefficients on the on-the-run government bond premium ($\Delta onoff_t$), $\beta_{6,i,j}$, are statistically significant and negative for AA-rated bonds and for most A-rated bonds, but are not significant for the BBB-rated bonds, except the one-year ones (see Table 6).

Table 6: Coefficients on the on-the-run government bond premium: $\beta_{6,i,j}$

	j					
i	1	2	3	5	7	9
AA	–0.1674 (–3.17)	–0.1161 (–2.30)	–0.1587 (–3.10)	–0.2439 (–5.09)	–0.2034 (–4.07)	–0.1003 (–2.10)
A	–0.2567 (–4.11)	–0.1585 (–2.40)	–0.1722 (–2.32)	–0.1236 (–1.80)	–0.1806 (–2.13)	–0.0869 (–1.26)
BBB	–0.2129 (–3.18)	–0.1357 (–1.87)	–0.1361 (–1.56)	–0.1302 (–1.34)		

Notes: Numbers in parentheses are t-values. Shaded cells contain estimated coefficients that are statistically significant and of the expected signs.

These results are consistent with the finding of Churm and Panigirtzoglou (2005) that corporate bonds with higher credit ratings are sensitive to the liquidity of the government bond market because AA- or A-rated bonds are, to some extent, treated as alternatives to corporate bonds.

3.5. What do we know from the empirical results based on daily data?

Among the variables from the structural models, only the risk-free rate, $\Delta r_{j,t}$, has coefficients of the expected sign. Coefficients on the stock price, $\Delta \log(TPX_t)$, and its implied volatility, $\Delta\sigma_t^{NKY}$, have signs that contradict the predictions of the structural model. Among other variables incorporated in this paper, the implied volatilities of interest rates, $\Delta\sigma_t^r$, have statistically significant and positive coefficients. This result indicates that increased uncertainty about future interest rate widens credit spreads. It is consistent with our expectation that most of the estimated coefficients on ΔTL_t and $\Delta onoff_t$ are statistically positive and negative, respectively. This suggests that financial conditions surrounding corporate bond market are also ones of determinants of credit spread changes in Japan.

Note that the goodness-of-fit measures (the adjusted R^2s) for the model are poor regardless of the credit ratings and maturities, which is in line with studies of the U.S. and European markets (see Table 7). These results suggest that other factors not incorporated in our model influence changes in credit spreads.

Table 7: Adjusted R^2s and Durbin–Watson statistics

	j											
i	1	2	3	5	7	9	1	2	3	5	7	9
	Adjusted R^2						Durbin–Watson stat.					
AA	0.11	0.09	0.04	0.03	0.16	0.17	2.38	2.25	2.16	2.15	2.31	2.35
A	0.11	0.02	0.03	0.11	0.16	0.16	2.09	2.20	2.18	2.17	2.21	2.23
BBB	0.12	0.03	0.04	0.06			2.00	1.97	2.00	1.92		

4. Estimation based on alternative proxies for firm's values

As shown in Section 3, the stock price indices are not suitable proxies for firms' values in Japan. In this section, we adopt the following three variables as alternative proxies for firms' values: the revision index of corporate earnings forecasts; profitability indicators; and the financial positions of firms. Because it is not possible to observe all of these variables on a daily basis, we use monthly data to estimate the model.

We first reestimate equation (1) by using monthly data as the preliminary step in the analysis. According to the results,[14] the coefficients on $\Delta r_{j,t}$, ΔTL_t, and $\Delta onoff_t$ are insignificant when monthly data are utilized, but are statistically significant based on the daily data. This suggests that the effects of these three variables are too small to be extracted on a monthly basis. On the other hand, the estimated coefficient on $\Delta\sigma_t^r$ is statistically significant and positive even when monthly data are used. Thus, we utilize $\Delta\sigma_t^r$ in the monthly model. The specification of the monthly model is as follows:

$$\begin{aligned}
\Delta CS_{i,j,t} &= a_{i,j}^1 + \gamma_{i,j}^{11}\Delta\sigma_t^r + \gamma_{i,j}^{12} RI_{t-1} + u_{i,j,t} & u_{i,j,t} &\sim N(0,\sigma_{1,i,j,t}^2) \\
\Delta CS_{i,j,t} &= a_{i,j}^2 + \gamma_{i,j}^{21}\Delta\sigma_t^r + \gamma_{i,j}^{22}\Delta ROA_{t-3} + v_{i,j,t} & v_{i,j,t} &\sim N(0,\sigma_{2,i,j,t}^2) \\
\Delta CS_{i,j,t} &= a_{i,j}^3 + \gamma_{i,j}^{31}\Delta\sigma_t^r + \gamma_{i,j}^{32}\Delta DI_{t-1} + o_{i,j,t} & o_{i,j,t} &\sim N(0,\sigma_{3,i,j,t}^2)
\end{aligned} \quad (2)$$

where CS, σ^r, RI, ROA, and DI denote the credit spread, the implied volatility of interest rates, the revision index of the earnings forecasts, the return on assets, and the diffusion index for corporate financial positions, respectively. The subscripts i, j, t, and Δ are the same as those in equation (1).

[14] Details are in Appendix 3.

RI_t is the revision index of the corporate earnings forecasts published by Toyo Keizai Inc.. The definition of RI_t is given in equation (3). Data on RI_t is released monthly and we use a one-month lag to adjust for the timing of the data release.

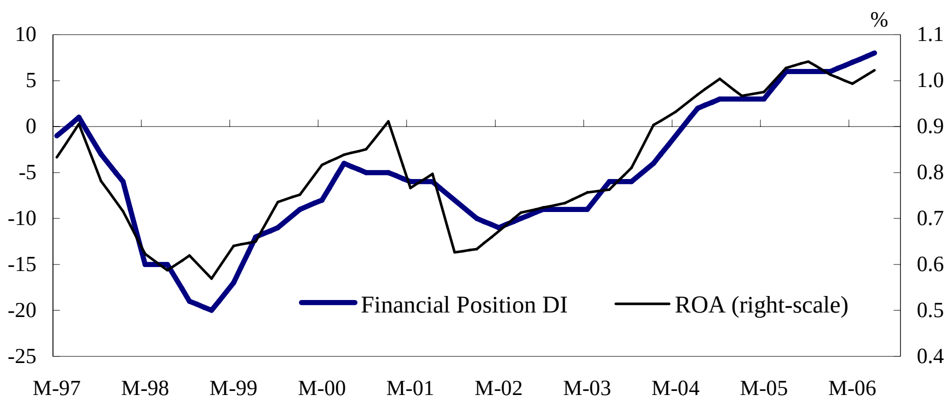
$$RI_t = \frac{(\text{Number of upward revisions} - \text{Number of downward revisions})}{\text{Number of corporations covered}} \times 100 \qquad (3)$$

ROA_t is the return on the total assets of all industries from the 'Financial Statements Statistics of Corporations by Industry' (obtained from the Ministry of Finance). We seasonally adjust the original quarterly data by using the X–11 method and linearly interpolate the monthly data. We use a three-month lag of this variable for estimation.

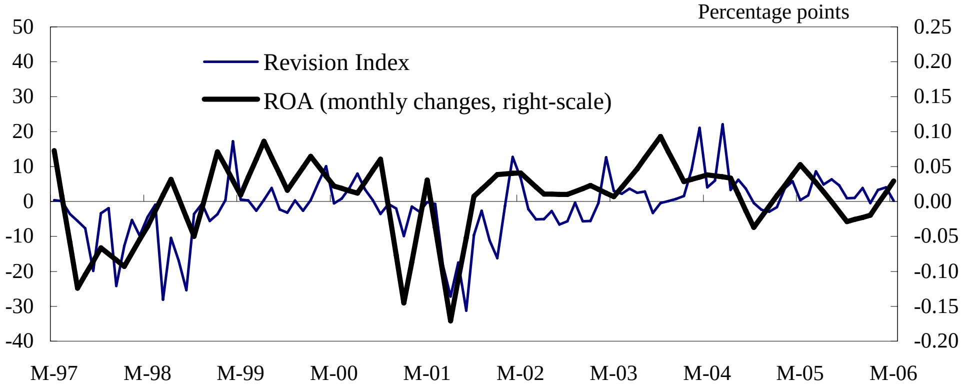
DI_t is the diffusion index of the financial positions of all industries in TANKAN released by the Bank of Japan. DI_t is a summary of the index of inside-and-outside judgments of firms' financial positions, which relate to, for example, the level of cash and the lending attitudes of banks. Given that the original index is released on a quarterly basis, we linearly interpolate the monthly data. The lag used in estimation is one month.

Over time, these three variables have behaved similarly (see Figure 2). This casual comparison suggests that these variables are influenced by a common factor. We assume that this common factor represents movements in firms' values.

Figure 2: Three proxy variables for corporate financial conditions



(Figure 2 continued)



Sources: Toyo Keizai Inc., Ministry of Finance, and Bank of Japan

The variables $CS_{i,j,t}$ and σ_t^r are defined as in Section 3. Because data on ROA_t and DI_t are released within the first 10 days of each month, we use the data on $CS_{i,j,t}$ and σ_t^r corresponding to the 10th day of each month.[15]

Table 8-1 to 8-3 summarizes the estimation results.[16] Most of the estimated coefficients on the proxies representing the financial conditions of firms are statistically significant and negative, as predicted by the structural models. Closer inspection of Table 8 shows that the coefficients for BBB-rated bonds are more significant and are larger than those for AA- and A-rated bonds.

Table 8–1: Coefficients on the revision index: $\gamma_{i,j}^{12}$

	j					
i	1	2	3	5	7	9
AA	–0.00035 (–1.27)	–0.00037 (–1.28)	–0.00031 (–1.02)	–0.00053 (–1.91)	–0.00045 (–1.38)	–0.00025 (–0.78)
A	–0.00093 (–1.73)	–0.00101 (–1.87)	–0.00135 (–2.42)	–0.00111 (–2.44)	–0.00124 (–2.42)	–0.00118 (–2.55)
BBB	–0.00225 (–3.69)	–0.00265 (–4.03)	–0.00249 (–3.50)	–0.00235 (–2.74)		

Notes: Numbers in parentheses are t-values. Shaded cells contain estimated coefficients that are statistically significant and of the expected signs.

[15] If the market is closed on the 10th, we used data on the previous business day instead.

[16] Details are in Appendix 4.

Table 8–2: Coefficients on ROA: $\gamma_{i,j}^{22}$

	j					
i	1	2	3	5	7	9
AA	–0.296 (–2.54)	–0.208 (–1.64)	–0.094 (–0.70)	–0.215 (–1.78)	–0.156 (–1.08)	–0.144 (–1.04)
A	–0.783 (–3.48)	–0.561 (–2.41)	–0.438 (–1.82)	–0.449 (–2.24)	–0.237 (–1.03)	–0.319 (–1.55)
BBB	–0.959 (–3.55)	–1.019 (–3.49)	–0.698 (–2.17)	–1.166 (–3.15)		

Notes: Numbers in parentheses are t-values. Shaded cells contain estimated coefficients that are statistically significant and of the expected signs..

Table 8–3: Coefficients on financial positions, DI: $\gamma_{i,j}^{32}$

	j					
i	1	2	3	5	7	9
AA	–0.00301 (–1.06)	–0.00342 (–1.13)	–0.00271 (–0.84)	–0.00466 (–1.62)	–0.00702 (–2.07)	–0.00547 (–1.67)
A	–0.01002 (–1.79)	–0.01771 (–3.25)	–0.01688 (–3.01)	–0.01645 (–3.54)	–0.01498 (–2.81)	–0.01901 (–4.10)
BBB	–0.02879 (–4.67)	–0.03280 (–4.93)	–0.03088 (–4.28)	–0.02743 (–3.09)		

Notes: Numbers in parentheses are t-values. Shaded cells contain estimated coefficients that are statistically significant and of the expected signs.

The standard structural model implies that the lower the credit rating (that is, the closer the firm's value is to the default threshold), the more sensitive credit spreads are to changes in the firm's value. Our results are consistent with this implication.

The adjusted R^2s indicate that these models fit better than those of Section 3, particularly for BBB-rated bonds (see Table 9). Thus, these results seem to support the appropriateness of the alternative proxies for firms' values.

Table 9: Adjusted R^2s and Durbin–Watson statistics

Revision index

i	*j* = 1	2	3	5	7	9	1	2	3	5	7	9
	Adjusted R^2						Durbin–Watson stat.					
AA	0.12	0.11	0.08	0.14	0.02	0.02	1.87	2.14	2.39	2.08	2.10	1.66
A	0.02	0.02	0.04	0.09	0.04	0.07	2.09	1.74	1.84	1.87	1.70	1.67
BBB	0.14	0.14	0.11	0.07			1.37	1.75	1.82	1.98		

ROA

i	*j* = 1	2	3	5	7	9	1	2	3	5	7	9
	Adjusted R^2						Durbin–Watson stat.					
AA	0.16	0.12	0.08	0.13	0.02	0.02	1.93	2.22	2.44	2.18	2.15	1.69
A	0.10	0.04	0.02	0.08	–0.00	0.04	2.23	1.78	1.89	1.89	1.67	1.69
BBB	0.13	0.11	0.05	0.09			1.28	1.72	1.77	2.05		

Financial positions, DI

i	*j* = 1	2	3	5	7	9	1	2	3	5	7	9
	Adjusted R^2						Durbin–Watson stat.					
AA	0.12	0.12	0.08	0.13	0.05	0.03	1.87	2.24	2.44	2.21	2.26	1.76
A	0.02	0.08	0.07	0.14	0.06	0.15	2.18	1.94	2.08	2.12	1.87	1.99
BBB	0.20	0.19	0.16	0.09			1.42	1.91	2.03	2.04		

5. Conclusion

5.1. Summary of findings

In this paper, we investigated the relationship between changes in credit spreads and changes in financial and macroeconomic variables in Japan. We obtained several interesting findings.

First, we found the evidence to support the validity of structural models in Japan.

Among the variables incorporated in the structural models, the change in the risk-free rate has a statistically significant and negative correlation with changes in credit spreads. This result is consistent with the predictions of standard structural models and with empirical studies on the U.S. and European markets.

Our study also suggests that stock price indices may not be appropriate proxies for firms' values in Japan. When we incorporated indices of the financial conditions of firms instead of using stock price indices, we obtained results compatible with the predictions of the structural models; that is, an increase in firms' values narrows credit spreads.

The empirical results indicate that the lower the credit ratings, the more sensitive changes in credit spreads are to changes in the interest rate and changes in firms' values. This is consistent with the U.S. and European evidence.

Second, we adopted several variables other than those included in standard structural models to overcome the shortcomings of the structural models. The implied volatility of swaptions has a statistically significant and positive correlation with credit spreads. This result is consistent with the perception of market participants that the increased uncertainty about future interest rates widens credit spreads. Changes in the LIBOR spread and changes in the on-the-run premiums of JGBs have statistically significant effects on the daily dynamics of credit spreads. Credit spreads with higher credit ratings respond less to the LIBOR spread and more to the on-the-run premiums of the JGBs. These influences on credit spreads are less apparent from monthly data.

5.2. An interpretation of the dynamics of credit spreads since 2003: the role of monetary policy

Using the empirical results reported in this paper, we interpret the development of credit spreads from 2003 to 2006. There are two major explanations of the role of monetary policy in generating narrow and stable credit spreads. First, the historically low level of interest rates under the 'quantitative easing' policy contributed to lower credit spreads. This assumes that there is a positive correlation between credit spreads and the risk-free interest rate. Second, one source of narrow and stable credit spreads is reduced uncertainty about future interest rate under the 'quantitative easing' policy.

Our empirical results, and the predictions of the structural models, support the latter explanation. In other words, if the termination of the 'quantitative easing' and 'zero interest rate' policies raised uncertainty about future interest rate, then to some extent, it widened credit spreads.

Our study suggests that it is likely that the continued improvement in corporate financial conditions contributed to lowering credit spreads. However, one should be cautious in crediting the role of the 'quantitative easing' policy. This is because surveys suggest that the 'quantitative easing' policy had a limited effect on the real economy.[17]

It is also possible to assert that the 'quantitative easing' policy reduced uncertainty about the financial conditions of banks and firms and consequently lowered credit spreads. However, it is difficult to attribute the narrow and stable credit spreads solely to the effect of the 'quantitative easing' policy. This is not only because corporate financial positions behaved over time in the same way as corporate earnings, but also because other policies, such as public recapitalization of the banks, contributed to reducing uncertainty.

5.3. Final remarks

In this paper, we showed that it is appropriate to apply the structural model developed by Merton (1974), and extended by Longstaff and Schwartz (1995) and others, to analyze changes in credit spreads in Japan. Nevertheless, our analysis has several shortcomings.

First, the fit of the empirical models is relatively poor, as are those fitted to the U.S. and European credit spreads. This suggests that variables other than those incorporated in our study have been omitted. It is worth adopting proxies for a macroeconomic risk premium on financial stability, given a major financial disturbance at the end of the 1990s. We also expect proxies for the degree of risk allowances of banks to be effective because bank loans continue to dominate corporate finance. Other candidates are proxies for the effects originated in the primary corporate bond

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[17] Ugai (2006) provides a comprehensive survey of the literature on the 'quantitative easing' policy. Kimura and Small (2006) analyze the portfolio rebalancing effects of the 'quantitative easing' policy on credit spreads.

markets. Market participants point out that a large bond issue of new corporate bonds can widen credit spreads in the secondary market.

Second, although we utilized a linear version of the structural model, the relationship between credit spreads and financial and macroeconomic variables may be nonlinear. In the standard structural model, the magnitude of credit spread responses to changes in interest rates depends on the degree of financial leverage (measured by the ratio of total assets to capital) of firms.

Third, because the credit spreads analyzed in this paper are averages of spreads categorized by credit rating and maturity, our results may be affected by ratings changes or by changes in ratings policy. In addition, because we used financial and macroeconomic variables to proxy firms' values, these proxies incorporate information on firms who do not issue corporate bonds. It is necessary to analyze the dynamics of credit spreads by using disaggregated data for a fixed sample.

Finally, it is important to analyze the extent and influence of the structural changes in Japan's corporate bond market. Recently, there has been the emergence of the CDS market and changes in the behavior of institutional investors. We leave these issues for a future research.

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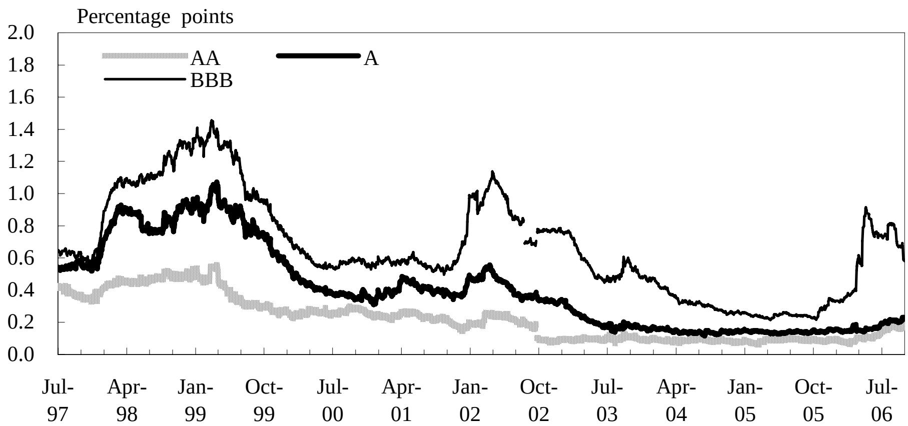
Appendix 1

Credit spread changes in Japan since 1997[1]

The primary market for corporate bonds in Japan expanded in the late 1990s. Two factors drove the growth of the corporate bond market. One is the abolition of the regulatory constraints on primary markets including 'Issue Standards'. The other is the decline in the lending capacity of the Japanese banks, given financial disturbances. Along with the growth in the issues of corporate bonds, the secondary market for corporate bonds has developed substantially. The price quotations in the market have been publicly observed since that time (see Figure). The differences between the yields of corporate bonds and those of government bonds (hereafter, credit spreads) have peaked three times: at the end of the 1990s, around 2002, and in the middle of 2006. Here, we review the movements in credit spreads chronologically.

(Figure) Credit spreads in Japan



Notes: Yields on bonds with 5-year maturity. Ratings are those of Moody's, but we express them in the more widely-used forms (for example AAA) rather than those of Moody's (for example Aaa) in this paper.
Source: Japan Securities Dealers Association, 'Over-the-Counter Standard Bond Quotations.'

1. From the end of 1990s to the middle of 2001

Credit spreads, especially those of the banks, widened during the period of

[1] This appendix is based on Kawai and Yukawa (2006), Shima (2006), and Yasuda (2002).

financial disturbance triggered by the bankruptcies of the Hokkaido Takushoku Bank and Yamaichi Securities in November 1997. Credit spreads in nonfinancial sectors also widened because of the defaults of the Yaohan Corporation and the JDC Corporation[2], and because of a series of credit-rating downgrades.

Credit spreads started to narrow in the middle of 1999 and then essentially leveled out until mid-2001.[3] One reason was that financial disruption subsided because of the nationalization of the Long-term Credit Bank of Japan and the Nippon Credit Bank in 1998, and because of governmental recapitalization of the banks. Japan's economic recovery and the consequent improvements in corporate credit ratings also contributed to the turnaround in credit spreads.

2. From the end of 2001 through 2005

Credit spreads widened dramatically from the end of 2001. At least two events drove this widening. One is the default of the Mycal Corporation in September 2001.[4] The Mycal case was the first major default of corporate bonds in Japan that involved a wide range of institutional and individual investors.[5] It was when investors' attentions were attracted to the credit risk that the 'main bank' terminated its financial support to the Mycal Corporation and triggered its default.

Another event that widened credit spreads was the bankruptcy of the Enron Corporation in the U.S.. Because several mutual funds, including money market funds (MMFs), had invested in the corporate bonds of Enron, and fell below their par values due to the Enron's bankruptcy, they were forced to cash out their funds and the subordinated debt of the banks. These sell-outs contributed to widening credit spreads.

Further, it is widely accepted that other factors widened credit spreads in this period. Factors included the decrease in the latent profits of the banking sector

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[2] Yaohan defaulted its convertible bonds (34.4 billion yen) on September 1997. JDC Corporation defaulted its straight and convertible bonds (50.0 billion yen and 7.1 billion yen, respectively) on December 1998.

[3] The credit spreads of the A- and BBB-rated bonds widened temporarily and slightly in the latter half of 2000, because of a series of bankruptcies (Dai-Hyaku Insurance and Life Corporation in May, Sogo Corporation in July, and Chiyoda Insurance in October).

[4] The Mycal Corporation filed the Civil Rehabilitation Law at first, but later switched to file the Corporate Reorganization Law.

[5] Its debt amounted to more than 300 billion yen.

because of the fall in stock prices and because of the 9/11 attacks on the U.S.

Credit spreads tightened in the middle of 2002. Most banks in Japan had disposed of their nonperforming loans with the government support. Many nonfinancial corporations had improved their earnings and financial conditions. Japan's economy showed signs of recovery. The 'quantitative easing' policy introduced in March 2001 is said to have contributed to lower credit spreads as the uncertainty about future interest rates had reduced.

3. From the end of 2005 to the middle of 2006

The BBB-rated spread increased between the end of 2005 and mid-2006 because of increasing regulation of the consumer finance industry and because of the LBO of Vodafone Japan by Softbank. The termination of the 'quantitative easing' and 'zero interest rate' policies is said to widen credit spreads to some extent as the uncertainty about future interest rates somewhat increased.

Appendix 2

Estimation results for equation (1) based on daily data

$$\Delta CS_{i,j,t} = c_{i,j} + \beta_{1,i,j}\Delta r_{j,t} + \beta_{2,i,j}\Delta\sigma_t^r + \beta_{3,i,j}\Delta\log(eqp_t)$$
$$+ \beta_{4,i,j}\Delta\sigma_t^{eqp} + \beta_{5,i,j}\Delta TL_t + \beta_{6,i,j}\Delta onoff_t + \varepsilon_{i,j,t} \quad (1)$$
$$\varepsilon_{i,j,t} \sim N(0, \sigma_{i,j,t}^2)$$

i	j	c	β_1	β_2	β_3	β_4	β_5	β_6	Adj. R^2	D.W.
AA	1	-0.00014 (-0.83)	-0.1949 (-12.18)	0.00799 (11.13)	0.0172 (1.25)	0.000045 (0.53)	-0.000113 (-1.36)	-0.1674 (-3.17)	0.11	2.38
	2	-0.00012 (-0.76)	0.0749 (7.30)	0.00539 (7.59)	0.0335 (2.54)	0.000092 (1.14)	0.000057 (0.72)	-0.1161 (-2.30)	0.09	2.25
	3	-0.00011 (-0.65)	0.0215 (2.76)	0.00432 (5.88)	0.0348 (2.60)	0.000129 (1.57)	0.000272 (3.37)	-0.1587 (-3.10)	0.04	2.16
	5	-0.00013 (-0.83)	-0.0228 (-4.24)	0.00217 (3.06)	0.0276 (2.18)	0.000039 (0.50)	0.000270 (3.57)	-0.2439 (-5.09)	0.03	2.15
	7	-0.00015 (-0.93)	-0.0836 (-17.54)	0.00227 (3.04)	0.0310 (2.36)	0.000084 (1.04)	0.000190 (2.41)	-0.2034 (-4.07)	0.16	2.31
	9	-0.00015 (-0.99)	-0.0782 (-15.88)	0.00104 (1.44)	0.0112 (0.89)	0.000097 (1.26)	0.000368 (4.84)	-0.1003 (-2.10)	0.17	2.35
A	1	-0.00028 (-1.42)	-0.2628 (-13.90)	0.00695 (8.19)	0.0262 (1.61)	0.000083 (0.82)	-0.000151 (-1.54)	-0.2567 (-4.11)	0.11	2.09
	2	-0.00029 (-1.37)	-0.0226 (-1.68)	0.00542 (5.83)	0.0473 (2.74)	0.000150 (1.41)	0.000190 (1.82)	-0.1585 (-2.40)	0.02	2.20
	3	-0.00028 (-1.20)	-0.0505 (-4.46)	0.00466 (4.36)	0.0411 (2.11)	0.000114 (0.95)	0.000591 (5.03)	-0.1722 (-2.32)	0.03	2.18
	5	-0.00032 (-1.47)	-0.0921 (-11.98)	0.00412 (4.06)	0.0439 (2.43)	-0.000044 (-0.40)	0.000760 (7.00)	-0.1236 (-1.80)	0.11	2.17
	7	-0.00035 (-1.32)	-0.1310 (-16.19)	0.00288 (2.28)	0.0208 (0.93)	-0.000072 (-0.52)	0.000702 (5.24)	-0.1806 (-2.13)	0.16	2.21
	9	-0.00037 (-1.73)	-0.0975 (-13.71)	0.00163 (1.55)	0.0224 (1.24)	0.000179 (1.62)	0.000852 (7.76)	-0.0869 (-1.26)	0.16	2.23
BBB	1	-0.00043 (-2.03)	-0.3049 (-15.04)	0.00742 (8.15)	0.0242 (1.39)	0.000061 (0.56)	-0.000223 (-2.12)	-0.2129 (-3.18)	0.12	2.00
	2	-0.00045 (-1.96)	-0.0347 (-2.35)	0.00683 (6.68)	0.0431 (2.27)	0.000025 (0.21)	0.000234 (2.05)	-0.1357 (-1.87)	0.03	1.97
	3	-0.00032 (-1.16)	-0.0743 (-5.58)	0.00515 (4.10)	0.0616 (2.69)	0.000163 (1.16)	0.000694 (5.02)	-0.1361 (-1.56)	0.04	2.00
	5	-0.00020 (-0.64)	-0.0959 (-8.79)	0.00334 (2.32)	0.0684 (2.67)	-0.000091 (-0.58)	0.000677 (4.40)	-0.1302 (-1.34)	0.06	1.92

Note: Numbers in parentheses are t-values.

Appendix 3

Estimation results for equation (1) based on monthly data

$$\begin{aligned}\Delta CS_{i,j,t} &= c_{i,j} + \beta_{1,i,j}\Delta r_{j,t} + \beta_{2,i,j}\Delta\sigma_t^r + \beta_{3,i,j}\Delta\log(eqp_t) \\ &\quad + \beta_{4,i,j}\Delta\sigma_t^{eqp} + \beta_{5,i,j}\Delta TL_t + \beta_{6,i,j}\Delta onoff_t + \varepsilon_{i,j,t} \qquad (1)\\ \varepsilon_{i,j,t} &\sim N(0,\sigma_{i,j,t}^2)\end{aligned}$$

i	j	c	β_1	β_2	β_3	β_4	β_5	β_6	Adj. R^2	D.W.
AA	1	-0.09545 (-1.97)	0.0098 (3.11)	0.10980 (1.75)	0.0010 (1.21)	0.000224 (0.41)	-0.243332 (-0.88)	-0.0038 (-1.34)	0.13	2.20
AA	2	0.05841 (1.84)	0.0101 (3.66)	0.10186 (1.92)	0.0016 (2.40)	-0.000209 (-0.46)	0.096167 (0.42)	-0.0019 (-0.78)	0.28	2.36
AA	3	0.01468 (0.53)	0.0083 (2.83)	0.06153 (1.12)	0.0019 (2.78)	-0.000022 (-0.05)	-0.004433 (-0.02)	-0.0020 (-0.82)	0.18	2.13
AA	5	-0.00622 (-0.28)	0.0081 (2.78)	0.08470 (1.67)	0.0010 (1.57)	0.000207 (0.48)	-0.466705 (-2.24)	-0.0025 (-1.14)	0.18	1.77
AA	7	-0.02979 (-1.53)	0.0103 (3.63)	0.00799 (0.17)	0.0005 (0.80)	0.000326 (0.80)	-0.442408 (-2.29)	-0.0019 (-0.93)	0.18	2.15
AA	9	-0.08489 (-3.54)	0.0103 (3.06)	0.04995 (0.89)	-0.0002 (-0.23)	-0.000227 (-0.46)	-0.053217 (-0.23)	-0.0021 (-0.87)	0.08	2.03
A	1	-0.09656 (-1.32)	0.0151 (3.17)	0.12378 (1.30)	0.0017 (1.39)	-0.001162 (-1.39)	-0.052155 (-0.12)	-0.0059 (-1.35)	0.12	2.41
A	2	0.01473 (0.30)	0.0077 (1.79)	0.09791 (1.18)	0.0023 (2.23)	-0.001064 (-1.49)	-0.027326 (-0.08)	-0.0054 (-1.45)	0.09	2.04
A	3	0.00480 (0.09)	0.0068 (1.26)	-0.05384 (-0.53)	0.0026 (2.08)	-0.000395 (-0.46)	-0.126947 (-0.30)	-0.0055 (-1.23)	0.04	2.40
A	5	-0.01703 (-0.44)	0.0103 (2.07)	0.11806 (1.37)	0.0015 (1.39)	-0.000142 (-0.19)	-0.148384 (-0.42)	-0.0067 (-1.76)	0.04	1.93
A	7	-0.00895 (-0.25)	0.0068 (1.29)	-0.12087 (-1.37)	0.0016 (1.52)	0.001169 (1.54)	0.005481 (0.02)	-0.0063 (-1.64)	0.05	1.56
A	9	-0.01497 (-0.42)	0.0034 (0.68)	-0.05802 (-0.70)	0.0005 (0.53)	0.001381 (1.89)	0.262594 (0.77)	-0.0071 (-1.97)	0.00	1.88
BBB	1	-0.14575 (-1.49)	0.0120 (1.88)	0.10988 (0.86)	0.0020 (1.24)	-0.001025 (-0.92)	-0.671425 (-1.20)	-0.0097 (-1.67)	0.04	1.73
BBB	2	-0.05905 (-0.73)	0.0223 (3.18)	0.06918 (0.51)	0.0009 (0.54)	-0.000505 (-0.43)	0.038239 (0.07)	-0.0081 (-1.34)	0.06	1.72
BBB	3	0.00501 (0.06)	0.0105 (1.24)	0.00491 (0.03)	0.0028 (1.43)	0.000346 (0.26)	-0.294058 (-0.44)	-0.0063 (-0.90)	0.00	1.71
BBB	5	0.04291 (0.47)	0.0064 (0.54)	0.07312 (0.36)	-0.0003 (-0.10)	-0.000203 (-0.12)	-0.298180 (-0.36)	-0.0046 (-0.51)	-0.05	2.08

Note: Numbers in parentheses are t-values.

Appendix 4

Estimation results for equation (2)

Revision Index

$$\Delta CS_{i,j,t} = a^1_{i,j} + \gamma^{11}_{i,j}\Delta\sigma^r_t + \gamma^{12}_{i,j} RI_{t-1} + u_{i,j,t} \qquad u_{i,j,t} \sim N(0, \sigma^2_{1,i,j,t}) \qquad (2)$$

i	j	a_1	γ_{11}	γ_{12}	Adj. R^2	D.W.
AA	1	-0.00328 (-1.34)	0.01060 (4.05)	-0.00035 (-1.28)	0.12	1.87
	2	-0.00207 (-0.79)	0.01072 (3.82)	-0.00037 (-1.28)	0.11	2.14
	3	-0.00226 (-0.82)	0.00987 (3.34)	-0.00031 (-1.02)	0.08	2.39
	5	-0.00241 (-0.97)	0.01068 (4.04)	-0.00053 (-1.91)	0.14	2.08
	7	-0.00166 (-0.56)	0.00560 (1.77)	-0.00045 (-1.38)	0.02	2.10
	9	-0.00158 (-0.55)	-0.00520 (-1.70)	-0.00025 (-0.79)	0.02	1.66
A	1	-0.00550 (-1.14)	0.00665 (1.29)	-0.00093 (-1.74)	0.02	2.09
	2	-0.00440 (-0.91)	0.00260 (0.50)	-0.00101 (-1.88)	0.02	1.74
	3	-0.00502 (-1.03)	0.00643 (1.23)	-0.00131 (-2.42)	0.04	1.84
	5	-0.00420 (-1.03)	0.01179 (2.69)	-0.00111 (-2.44)	0.09	1.87
	7	-0.00400 (-0.87)	0.00471 (0.95)	-0.00124 (-2.42)	0.04	1.70
	9	-0.00340 (-0.82)	-0.00821 (-1.84)	-0.00118 (-2.55)	0.07	1.67
BBB	1	-0.00679 (-1.24)	0.01594 (2.72)	-0.00225 (-3.68)	0.14	1.37
	2	-0.00647 (-1.10)	0.01247 (1.97)	-0.00265 (-4.03)	0.14	1.75
	3	-0.00466 (-0.73)	0.01375 (2.01)	-0.00249 (-3.50)	0.11	1.82
	5	-0.00146 (-0.19)	0.01544 (1.87)	-0.00235 (-2.74)	0.07	1.98

Note: Numbers in parentheses are t-values.

ROA

$$\Delta CS_{i,j,t} = a_{i,j}^{2} + \gamma_{i,j}^{21} \Delta \sigma_{r,t} + \gamma_{i,j}^{22} \Delta ROA_{t-3} + \nu_{i,j,t} \qquad \nu_{i,j,t} \sim N(0, \sigma_{2,i,j,t}^{2}) \qquad (2)$$

i	j	a_2	γ_{21}	γ_{22}	Adj. R^2	D.W.
AA	1	-0.00228 (-0.97)	0.01019 (3.99)	-0.296 (-2.54)	0.16	1.93
	2	-0.00116 (-0.45)	0.01034 (3.72)	-0.208 (-1.64)	0.12	2.22
	3	-0.00160 (-0.59)	0.00960 (3.24)	-0.094 (-0.70)	0.08	2.44
	5	-0.00123 (-0.50)	0.01019 (3.85)	-0.215 (-1.78)	0.13	2.18
	7	-0.00068 (-0.23)	0.00519 (1.64)	-0.156 (-1.08)	0.02	2.15
	9	-0.00096 (-0.34)	-0.00545 (-1.79)	-0.144 (-1.04)	0.02	1.69
A	1	-0.00284 (-0.62)	0.00557 (1.13)	-0.783 (-3.48)	0.10	2.23
	2	-0.00192 (-0.41)	0.00159 (0.31)	-0.561 (-2.41)	0.04	1.78
	3	-0.00221 (-0.45)	0.00527 (1.00)	-0.438 (-1.82)	0.02	1.89
	5	-0.00171 (-0.42)	0.01077 (2.45)	-0.449 (-2.24)	0.08	1.89
	7	-0.00159 (-0.34)	0.00372 (0.74)	-0.237 (-1.03)	-0.00	1.67
	9	-0.00098 (-0.23)	-0.00921 (-2.03)	-0.319 (-1.55)	0.04	1.69
BBB	1	-0.00169 (-0.31)	0.01384 (2.36)	-0.951 (-3.55)	0.13	1.28
	2	-0.00060 (-0.10)	0.01006 (1.57)	-1.019 (-3.49)	0.11	1.72
	3	0.00048 (0.07)	0.01163 (1.65)	-0.698 (-2.17)	0.05	1.77
	5	0.00411 (0.55)	0.01315 (1.62)	-1.166 (-3.15)	0.09	2.05

Note: Numbers in parentheses are t-values.

Financial Positions, DI

$$\Delta CS_{i,j,t} = a^{3}_{i,j} + \gamma^{31}_{i,j}\Delta\sigma_{r,t} + \gamma^{32}_{i,j}\Delta DI_{t-1} + o_{i,j,t} \qquad o_{i,j,t} \sim N(0, \sigma^{2}_{3,i,j,t}) \qquad (2)$$

i	j	a_3	γ_{31}	γ_{32}	Adj. R^2	D.W.
AA	1	-0.00235 (-0.97)	0.01020 (3.88)	-0.00301 (-1.06)	0.12	1.87
	2	-0.00159 (-0.62)	0.01074 (3.85)	-0.00342 (-1.13)	0.12	2.24
	3	-0.00167 (-0.61)	0.00973 (3.27)	-0.00271 (-0.84)	0.08	2.44
	5	-0.00147 (-0.60)	0.01049 (3.95)	-0.00466 (-1.62)	0.13	2.21
	7	-0.00080 (-0.28)	0.00553 (1.77)	-0.00702 (-2.07)	0.05	2.26
	9	-0.00112 (-0.40)	-0.00515 (-1.70)	-0.00547 (-1.67)	0.03	1.76
A	1	-0.00348 (-0.73)	0.00608 (1.18)	-0.01002 (-1.79)	0.02	2.18
	2	-0.00196 (-0.42)	0.00211 (0.42)	-0.01771 (-3.25)	0.08	1.94
	3	-0.00207 (-0.43)	0.00568 (1.10)	-0.01688 (-3.01)	0.07	2.08
	5	-0.00142 (-0.36)	0.01103 (2.58)	-0.01645 (-3.54)	0.14	2.12
	7	-0.00127 (-0.28)	0.00402 (0.82)	-0.01498 (-2.81)	0.06	1.87
	9	-0.00034 (-0.08)	-0.00903 (-2.11)	-0.01901 (-4.10)	0.15	1.99
BBB	1	-0.00154 (-0.29)	0.01449 (2.55)	-0.02879 (-4.67)	0.20	1.42
	2	-0.00024 (-0.04)	0.01068 (1.74)	-0.03280 (-4.93)	0.19	1.91
	3	0.00066 (0.11)	0.01252 (1.89)	-0.03088 (-4.28)	0.16	2.03
	5	0.00370 (0.49)	0.01407 (1.72)	-0.02743 (-3.09)	0.09	2.04

Note: Numbers in parentheses are t-values.