The Effect of the Temporal Resolution of Uncertainty on Asset Pricing : A Survey and an Empirical Study of Japan ’ s Corporate Bond Markets

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The Effect of the Temporal Resolution of Uncertainty on Asset Pricing: A Survey and an Empirical Study of Japan's Corporate Bond Markets

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Abstract

Our paper gives an overview of studies on the effect of the temporal resolution of uncertainty (TRU) on asset pricing. It also conducts an empirical analysis using recent data on corporate bonds issued in Japan as well as from the International Brokers Estimate System (IBES) database for earnings forecasts from which we construct proxies for TRU. Our analysis does not support the hypothesis that firms with a more delayed resolution of uncertainty offer larger yields.

1. Introduction

Many papers study the determinants of corporate bond prices. A pioneer work, Merton (1974), considers the issuance of a discount bond with a default option as a European put option issued to stockholders by bondholders, and applies the Black-Sholes formula to derive corporate bond pricing. This framework, often called a structural framework, indicates that credit spreads over interest rates can be explained by only firm-specific factors such as maturity, volatility in the value of the firm, and debt-equity ratios. Many empirical works, however, do not support structural frameworks. Using various structural frameworks, Huang and Huang (2003) show that credit risk does not contribute to yield spreads in the US. In reduced-form frameworks, in which default risks are determined exogenously, Elton, Gauber, Agrawal and Mann (2001) empirically demonstrate that an expected default loss does not help to explain the premiums of corporate rates over treasuries. Instead, taxes and factors that explain risk premiums for stocks are very important.

Collin-Dufresne, Goldstein and Martin (2001) try to discover which factors account for yields spreads by using many proxies for firm-specific factors, such as default probability and recovery rates. Their regression analysis shows that firm-specific factors can only explain 25% of the observed yield spread changes in the US. Moreover, they use the residuals from these regressions to conduct a principal components analysis and they report that the residuals are mostly driven by a single common factor. The factor is not explained by any set of macro-

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economic variables to a perfect degree, but it is correlated with overall market liquidity to some extent. Focusing on liquidity factors, Houweling, Mentink and Vorst (2005) consider nine proxies and find that eight of them are important in determining credit spreads in Europe.

In Japan, Ueki (1999), Ieda and Ohba (1998), and Ieda (2001) examine possible determinants of credit risk and all of them claim that credit ratings play a major role in determining credit spreads. Nakashima and Saito (2006) find that macroeconomic factors are also responsible for credit spreads. As a new proxy for a liquidity factor, Kaguraoka (2005) proposes the kurtosis of changes in yields, and, using Japanese panel data, he finds that the kurtosis works well. (See Xu (2007) for recent studies on corporate bond markets in Japan and other Asian countries.)

As another determinant, Reisz and Perlich (2006) find in their empirical work that the temporal resolution of uncertainty (TRU) plays an important role in determining US corporate bond yields. TRU, defined later in a more rigid way, is the extent to which incoming information may change expectations about cash flows. One industry's uncertainty is resolved later than others, even though they need the same developing time and face the same (overall) risks and returns. For example, most pharmaceutical companies' uncertainty will not be resolved before the very last approval by the government. The structure involved in the arrival of information is an important element in the capital budgeting process that might affect investors' decisions.

Some theoretical papers investigate the effect of TRU on asset pricing. A pioneer work, Epstein and Turnbull (1980), shows that because the release of information makes it risky to hold assets, the returns on risky assets are larger when uncertainty is resolved earlier. However, they assume that no production decisions are taken after the experiment results become known and that the manager communicates observations truthfully. That is, their model does not take into consideration the possibility of moral hazard in that the manager may release spurious information.

Apart from Epstein and Turnbull's (1980) assumption, Reisz and John (2002) integrate TRU considerations in an agent model. In their model, the manager can change investment policy using a private signal regarding the pattern of TRU. They prove that the later the uncertainty is resolved for a given firm, the larger the yield premiums are. The later resolution of uncertainty makes the distribution of the final cash flows of the firm riskier and thus increases the probability of bankruptcy. Bondholders, who know the pattern of TRU but do not observe the private signal, rationally demand a larger yield premium at the time of issuance.

Miyazaki and Saito (2006) give another explanation of why firms with later resolutions of uncertainty are required to have higher yields. Epstein (1980) demonstrates that consumers with a high elasticity of inter-temporal substitution tend to postpone commitment to an irreversible decision. Instead, they choose to hold flexible assets when they expect uncertainty to be resolved subsequently. Using Kreps-Porteus (1979) preferences, Miyazaki and Saito (2004) show that consumers hold more flexible assets not only because of a higher elasticity of inter-temporal substitution but also because of a preference for the early resolution of uncertainty. However, Epstein (1980)'s and Miyazaki and Saito (2004)'s implications are based on partial equilibrium models. On the other hand, Miyazaki and Saito (2006) numerically demonstrate that premiums over risk-free assets are generated in a general equilibrium framework. They call such premiums waiting-options premiums.

Reisz and Perlich (2006) study the effect of TRU on corporate debts. They design proxies for TRU, and find that the later the uncertainty is resolved, the larger the yields are on US corporate debts issued between 1987 and 1996. To distinguish whether agency-driven increases in risk or intrinsic timing preferences explain larger premiums for firms with a later resolution of uncertainty, they construct an ordered probit model, find that TRU is not another risk factor, and conclude that investors display the intrinsic timing preferences proposed by Kreps-Porteus (1979). Although they do not mention Miyazaki and Saito (2006) as a reference, their results may imply that corporate spreads are explained not only by risk premiums but also by waiting-options premiums.

This paper gives an overview of studies on the effect of TRU on asset pricing, and it conducts an empirical analysis using recent data on corporate bonds issued in Japan. We describe three theoretical frameworks: those proposed by Epstein and Turnbull (1980), Reisz and John (2002), and Miyazaki and Saito (2006). Following Reisz and Perlich (2006)'s methodology, we perform an empirical analysis, and find that this analysis does not work well. Our primary contribution in this paper is to investigate the effect of TRU on *Japan'*s corporate bond yields.

The paper is organized as follows. In the next section, we give mathematical definitions of TRU as well as for three theoretical frameworks proposed by Epstein and Turnbull (1980), Reisz and John (2002), and Miyazaki and Saito (2006). In section 3, we present Reisz and Perlich (2006)'s empirical methodology and include empirical proxies for TRU, and we conduct an empirical analysis of the effect of TRU on Japan's corporate bonds. Section 5 concludes the paper.

2. Theoretical Framework

This section gives mathematical definitions of TRU, then it summarizes the main results of Epstein and Turnbull (1980), Reisz and John (2002), and Miyazaki and Saito (2006).

1. Temporal resolution of uncertainty

Let us consider the following general decision problem:

$$\max_{x_1 \in c_1} E_Y \max_{x_2 \in c_2(x_1)} E_{Z|Y} W(x_1, x_2, Z),$$

where x_1 and x_2 are real scalars representing decision variables at periods 1 and 2, respectively; C_1 and $C_2(x_1)$ are convex sub-sets of the non-negative real line with non-empty interiors; U is a concave and twice continuously differentiable in (x_1, x_2). The random variable Z reflects uncertainty about the future economic environment. The true value of Z becomes known at the end of period 2. Before choosing x_2, the agent receives some information about Z by observing a random variable Y, which is correlated with Z to some extent. As a Bayesian decision maker, the agent revises the prior probability distribution for Z at the beginning of period 1. It should be noticed that when choosing x_1 before observing Y, the agent allows for the prospect of future information about Z. The constraint set $C_2(x_1)$, which the agent faces in choosing x_2, depends on x_1.

Consider another signal Y', which is correlated with Z to some extent. The signal Y is said to be more informative than Y' when using Y is at least as good as using Y' before making a decision concerning x_1. Following Marschak and Miyasawa (1968), Y is more *informative than Y'* if and only if

$$E_Y \max_{x_2 \in c_2(x_1)} E_{Z|Y} W(x_1, x_2, Z) \geq E_{Y'} \max_{x_2 \in c_2(x_1)} E_{Z|Y'} W(x_1, x_2, Z)$$

for all x_1, W, and $C_2(x_1)$ as far as the maximum exists. When a signal is more informative, the uncertainty is said to be resolved *earlier*.

When Z and Y are discrete random variables, Marschak and Miyasawa (1968) present an alternative definition, which they prove is necessary and sufficient for the former definitions. The variables Z and Y take $(z_1, ..., z_m)$ and $(y_1, ..., y_n)$, respectively. The corresponding probability vectors are $p= (p_1, ..., p_n)'$ and $q= (q_1, ..., q_n)'$, where $p_i= Pr\ (Z= z_i)$ and $q_j= Pr\ (Y= y_j)$. The posterior probability matrix is denoted by $\Pi=[\pi_{ij}]$, where $\pi_{ij}=Pr\ (Z= z_i \mid Y= y_j)$. When another signal Y' takes $(y_1, ..., y_n)$, q' and Π' are defined in an obvious way. Then the signal Y is more informative than Y' if

$$\sum_{j=1}^{n} q_j \Phi(\pi_j) \geq \sum_{j=1}^{n} q_j \Phi(\pi_j)$$

for any convex function Φ. Clearly the reverse inequality holds if Φ is concave. Using the definition, Epstein (1980), Miyazaki and Saito (2004), and Miyazaki and Saito (2006) obtain some interesting propositions.

When m=n=2, Jones and Ostroy (1984) presents a more parsimonious definition. Let $p^1=q_1=\alpha$ $(p_2=q_2=1-\alpha)$, and Π is characterized as

$$\begin{bmatrix} \pi_{11} \pi_{12} \\ \pi_{21} \pi_{22} \end{bmatrix} = \begin{bmatrix} \rho + \alpha(1-\rho) & \alpha(1-\rho) \\ 1-\rho-\alpha(1-\rho) & 1-\alpha(1-\rho) \end{bmatrix}.$$

The parameter ρ takes a value between zero and one. As ρ approaches one, the signal is more informative, and the uncertainty is resolved earlier. Using this definition, Jones and Ostroy (1984) and Miyazaki and Saito (2006) provide interesting examples.

Epstein and Turnbull (1980) prove that when Z and Y have a bi-variate normal distribution, there exists a convenient intuitive parameterization. Let (Z, Y) and (Z', Y') have bi-variate normal distribution with identical marginals. Then, Y is more informative than Y' if $corr\ (Z, Y)^2 \geq corr\ (Z, Y')^2$ where $corr\ (Z, Y)$ denotes the correlation coefficients. When $corr\ (Z, Y)=0$, consumers cannot receive a useless signal and no uncertainty is resolved at an intermediate date. This definition drives the theoretical implications from Epstein and Turnbull (1980) and Reisz and John (2002).

2. Epstein and Turnbull (1980)

Epstein and Turnbull (1980) show that because the release of information makes it risky to hold assets, the returns on risky assets are larger when the uncertainty is resolved earlier. An investor faces a three-period time horizon and makes consumption-savings decisions to maximizes the expected value of $u\ (c_1)+\beta u\ (c_2)+\beta^2 u\ (c^2)$. Here $u\ (c)$ is defined as $u\ (c)= -\exp\ (Ac)$, in which A is the coefficient of absolute risk aversion with respect to uncertainty in consumption. $\beta \in (0, 1)$ is the subjective rate of discount. Markets for risk-free bonds and risky equities are open at t =1 and t =2. Bonds are traded in unlimited amounts with fixed yields r_t at period t. On the other hand, the number of equities is fixed and normalized to unity in each period. The return on equities Z is a random variable and the value is realized at t =3.

The investor solves the following problem:

$$\max_{s_1, \alpha_1, b_1} u(w_1 - s_1) + E_Y \max_{s_2, \alpha_2, b_2} \left\{ \beta u(w_2 - s_2) + \beta^2 E_{Z|Y}\, u(r_2 b_2 + \alpha_2 Z) \right\},$$

subject to

$$s_1 = p_1 \alpha_1 + b_1,$$
$$w_2 = P_2 \alpha_1 + r_2 b_1,$$
$$s_2 = P_2 \alpha_2 + b_2,$$

Here p_1 is the first period price of the risky asset; P_2 is the first period expectation of the t-th period asset price. It should be noted that the realization of P_2 is uniquely determined by the realization of Y. For t =1 and 2, α_t and b_t denote holdings of risky assets and of the bond, respectively. w_t is the investor's wealth at the beginning of period t. We assume $w_1=p_1+\bar{b}$, where $\bar{b}$ is the initial endowment of bonds. s_t denotes the t-th period savings from w_t from the beginning of the period. E_Y denotes the expected value with respect to Y, and $E_{Z|y}$ denotes the expected value with respect to Z, conditional on $Y=y$. It should be noted that s_2, α_2, b_2 s2, a2 and b2 are chosen after observing Y, and that the return on purchasing the risky assets in period 1 is capital gains due to the change in asset prices between periods 1 and 2.

As with TRU concerning Z, we assume that Z and Y follow both normal distribution with $Z \sim N\ (\mu_z, \sigma_z^2)$ and $Z \sim N\ (\mu_Y, \sigma_Y^2)$, respectively. When $\rho \equiv corr(Y,Z)$ is larger, the signal Y is more informative, and the resolution of uncertainty concerning Y is resolved earlier.

Let us consider the second period problem for a given w_2 and the realization y of Y. Both savings (s_2) and portfolio (α_2, b_2) decisions must be made. We determine the latter conditional on s_2 and then determine the optimal s_2. The portfolio problem is

$$\max_{\alpha_2} - E_{Z|y} \exp\left[- A\alpha(Z - r_2 P_2(y))\right]. \tag{1}$$

Since Z and Y have a multi-variate normal distribution, the objective function is $-\exp\left[- A\alpha E\left[Z\,|\,y\right]\frac{1}{2} A^2\alpha^2 \bullet V(Z\,|\,y) + A\alpha r_2 P_2(y))\right]$. In equilibrium, $\alpha_2=1$. Thus

$$P_2(y) = \frac{1}{r_2}\left\{E\left[Z|y\right] - A \bullet V(Z|y)\right\}. \tag{2}$$

Let us return to the savings decision. It is determined as the solution of the problem

$$\max_{s_2} - \beta\exp\left[- Aw_2 + As_2\right] - \beta^2\exp\left(- Ar_2 s_2 - \frac{1}{2}A^2 V(Z|y)\right).$$

The solution is straightforward, and the maximum value of the objective function is defined as $J\,(w_2, y)$ where

$$J(w_2, y) = -\beta B\exp\left(-\frac{r_2}{1+r_2}Aw_2\right), \tag{3}$$

$$B = (\beta r_2)^{1/(1+r_2)}\left(\frac{1+r_2}{r_2}\right)\exp\left(-\frac{1}{2}\frac{A^2}{1+r_2}V(Z|y)\right).$$

Now we consider the first period problem. For given s_1, the portfolio decision is determined as a solution to the problem

$$\max_{\alpha_1} - \beta \bullet B \bullet E_Y J\left[r_1 s_1 + \alpha_1(P_2(y) - r_1 p_1), y\right],$$

where the expected value is taken with respect to the realization y of Y. The function J is a negative exponential function with the absolute risk aversion measure $r_2A/(1+r_2)$, so (3) is similar to (1). Equilibrium in the market for a risky asset ($\alpha_1=1$) implies that the asset price is

$$p_1 = \frac{1}{r_1}\left\{E\,(P_2) - \frac{r_2 A}{1+r_2}V(P_2)\right\}.$$

The first period savings solve the problems

$$\max_{s_1} - \exp\left[- Aw_1 + As_1\right] - \beta \bullet B \bullet C \bullet \exp\left(-\frac{r_2 A}{1+r_2}r_1 s_1\right),$$

where $C = \exp\left(-\frac{1}{2}\frac{A^2 r_2^2}{(1+r_2)^2}V(P_2)\right)$. The maximum value of the objective function is

$$V(w_1) = -\exp\left(-\frac{r_1 r_2 Aw_1}{1+r_2+r_1 r_2}\right)\left(\frac{1+r_2+r_1 r_2}{r_1 r_2}\right)\left(\frac{\beta \bullet B \bullet C \bullet r_1 \bullet r_2}{1+r_2}\right)^{\frac{1+r_2}{1+r_2+r_1 r_2}}.$$

The solution of the period 1 decision problem implies a derived utility function for wealth w_2, which is a negative exponential function. Therefore, the period 1 decisions may be viewed in a standard two-period framework and readily determined. Equilibrium in the period 1 markets implies

$$p_1 = \frac{1}{r_1}\left\{E(P_2) - \frac{r_2 A}{1 + r_2} V(P_2)\right\}.$$

Let us denote the correlation between Z and Y by ρ. Since Z and Y have a multi-variate normal distribution, $E(Z|Y = y) = \mu_Z + \rho\frac{\sigma_Z}{\sigma_Y}(y - \mu_Y)$ and $V(Z|Y) = (1 - \rho^2)\sigma_Z^2$. Thus, we can obtain,

$$E(P_2) = \frac{1}{r_2}\{\mu_Z - A(1 - \rho^2)\sigma_Z^2\},$$

$$V(P_2) = \rho^2\sigma_Z^2/r_2^2.$$

This indicates that the more informative Y is for Z, as measured by ρ^2, the larger both the mean and the variance of P_2 are. Substituting the above equations into (2) leads to

$$p_1 = \frac{1}{r_1 r_2}\left\{\mu_Z - A\left(1 - \frac{r_2\rho^2}{1 + r_2}\right)\sigma_Z^2\right\}.$$

That is, the equilibrium price of equities increases with ρ^2. It should be noticed that if the signal Y provides no information about Z, then $p_1 = E(P_2)/r_2$, implying that the expected value of the asset at t =2 is discounted at risk free rates of interest to determine its present value. The systemic risk for the return over the first period is zero.

The value of the signal Y, as measured by its effect on the market value of the cash flow Z, is equal to $A\frac{r_2 p^2}{1 + r_2}\sigma_Z^2$. Thus, we have the intuitive result that the firm's valuation of a signal varies inversely with the risk free rates of interest, and directly with the investor's aversion to risk, the variance of X, and the informativeness of the signal. The overall market risk associated with Z is unambiguously reduced by specific information about the assets.

In sum, because the release of information makes it risky to hold assets, returns on risky assets are larger when the uncertainty is resolved earlier. However, Epstein and Turnbull (1980) assume that no production decisions are taken after the experimental results become known and that the manager communicates the observation truthfully. That is, their model does not take into consideration the possibility of moral hazard in that the manager may release spurious information. In the next sub-section, we integrate TRU considerations in an agent model.

3. Reisz and John (2002)

Here we present a three-date, two period model proposed by Reisz and John (2002). The sequence of events is as follows. At t =0, the entrepreneur, who owns the rights to a firm but does not have enough capital to finance it, sells claims consisting of debt and equity to outside investors. The debt is sold entirely to outsiders, whereas the entrepreneur may retain some of the equity or sell all of it. In both cases, the entrepreneur has an incentive to maximize the combined value of both types of claims..

At t =1, the manager of a firm with cash resources of I is faced with two possible investments: a riskless one yielding the risk-free rate r_2 and a risky one yielding the stochastic rate Z with $E(Z) > r_2$. The manager makes a decision by observing a signal Y. The signal and the risky technology are assumed to have bi-variate normal distribution with each other, implying that the signal gives some information to the manager about the risky technology. The manager allocates his or her cash between the risky technology (a fraction Q) and the riskless investment (I–Q). At period t =2, the risky technology Z is revealed and the firm is liquidated.

Before the mathematical presentation, we provide several assumptions that are used in the model. Investors are assumed to be risk-neutral. The firm has two types of marketed claims outstanding: debt and equity. The debt matures at t =2 and has the form of a pure discount bond with a promised payment of F. We ignore bankruptcy costs and the tax advantages of debt financing. The manager cannot issue further debt at t =1 after observing the result of the signal and cannot invest a negative amount in the risky technology. The manager acts to maximize the wealth of current shareholders. In a rational expectations equilibrium, debt holders and stock-holders correctly understand the effect of the debt structure and of TRU on the investment decision and the effect of the decision on asset pricing, therefore the entrepreneur bears the agency costs of any debt when selling securities at t =0.

TRU is defined in the same way as in Epstein and Turnbull (1980). That is, Z and Y follow both normal distribution with $E(Z)=\mu_Z$, $V(Z)=\sigma_Z^2$, $E(Y)=\mu_Y$, and $V(Y)=\sigma_Y^2$. When $\rho\equiv corr(X,Z)$ is larger, the signal X is more informative, and the resolution of uncertainty concerning Y is resolved earlier.

At t =1, the manager tries to maximize the objective function:

$$\max_{Q\in[0,1]}\frac{1}{r_2}U(Q,\rho,y,F),$$

where $U(Q,\rho,y,F)\equiv E\left[\max(0,QZ+(I-Q)r_2)\,|\,Y=y\right]$. For an all-equity firm, which does not issue bonds, the face value of the debt F has to be zero. The pay-off to the shareholders is positive if and only if $QZ+(I-Q)r_2\geq F$ or $Z\geq\left[F-(I-Q)/r_2\right]/Q\equiv Z^*$. If the manager chooses to invest very little money in the risky technology, two cases occur. First, when $Ir_2\geq F$, the threshold value Z^* approaches $-\infty$, so the firm will be solvent in all states of nature since its final wealth will be Ir_2. Second, when $Ir_2<F$, Z^* tends to be ∞, the firm will never be solvent since its final wealth is insufficient to cover its debt obligations. Since no bank would lend money with a face value greater than Ir_2 to our firm, we must assume that $F\geq Ir_2$.

Using the notation Z^* and denoting the probability distribution of Z conditional on Y by $P(Z\,|\,Y)$, we can re-write the objective function $U(Q,\rho,y,F)$ as

$$\begin{aligned}U(Q,\rho,y,F)&=\int_{Z^*}^{\infty}\left[QZ+(I-Q)r_2\right]dP(Z\,|\,Y=y)\\&=\left[QE(Z\,|\,Y=y)+(I-Q)r_2-F\right]\Phi(B_y)+Q\sqrt{V(Z\,|\,Y=y)}\cdot\varphi(B_y),\end{aligned}$$

where $B_{x1}=\left[E(Z\,|\,Y=y)-Z^*\right]/\sqrt{V(Z\,|\,Y=y)}$, and Φ and φ are respectively the standard normal commutative probability function and the density function.

The above expression $U(Q,\rho,y,F)$ is the expected value at period 1 of cash flows that shareholders received at period 2. The first term tells us that the firm is solvent with a probability of $\Phi(B_y)$, bondholders have been repaid, and the shareholders get any remaining cash flows. The second term tells us that the shareholders should be worried not only about whether but also about how much the market value is above F. Reisz and John (2002) show that $U(Q,\rho,y,F)$ is convex, leading to a corner solution. Whether Q =0 or $Q=I$ depends on the value of x_1 the manager observes. They also show $\lim\partial U(Q,\rho,y,F)/\partial Q=-\infty$ as $y\to-\infty$ and $Q\to 0$, implying that investing everything in riskless bills may earn a higher yield in the case of low y.

A risk-shifting region is defined as a range of y values for which a leveraged firm will invest in the risky technology, whereas an all-equity firm will prefer to put the money into riskless bills. Reisz and John (2002) show that given a certain pattern of TRU, there exists a unique cut-off value Y^0 above which the manager of an all-equity firm will invest in the risky-technology. Similarly Y^F exists for a leveraged firm. It should be noted that $U(I,\rho,y,F)>U(0,\rho,y,F)$ for all $y\geq Y^F$, whereas $U(I,\rho,y,0)\leq U(0,\rho,y,0)$ for all $y<Y^0$.

Reisz and John (2002) prove that for a given ρ, a leveraged firm will invest more than an all-equity firm when $Y^F<Y^0$, and that in the Rothschild and Stiglitz sense investing in risky technology is riskier when $y \geq Y^F$ than when $y \geq Y^0$. The quantity $Y^0 - Y^F$ is called the extent of risk-shifting, and the extent of risk-shifting strictly increases with the face value F of the firm's debt, hence the larger F is, the riskier the terminal cash flow distribution is.

As for the effect of the pattern of TRU ρ on investment policy, Theorem 1 in Reisz and John (2002) shows that the cutoffs Y^0 and Y^F strictly increase with ρ, therefore the risk of the firm's terminal cash flow distribution and the probability of investing in the risky technology decrease with ρ. Theorem 2 in Reisz and John (2002) proves that a higher ρ strictly lowers the extent of risk shifting $Y^0–Y^F$.

The above two theorems intuitively indicate that rational bondholders will demand a larger price or equivalently a lower yield for the bonds of a firm in which uncertainty is resolved earlier. Now we price the bond of the firm in a more rigid way.

At period 1, when $y<Y^F$, the manager purchases riskless bills and the bond will be worth F at period 2. When $y \geq Y^F$, the manager invests in the risky technology and the bond will be worth max[0, min (IZ, F)] at period 2. Therefore, under the condition of a purchase of riskless bonds, the period-1 value of the bond is F/r_2. Under the condition of an investment in risky technology, on the other hand, the period-1 value of the bond, denoted by $B_1(\rho, F, y)$, is

$$\begin{aligned} B_1(\rho,F,y\,|\,y>Y^F) &= \frac{1}{r_2}\left\{F\int_{F/I}^{\infty} dP(Z\,|\,Y=y) + I\int_0^{F/I} Z\,dP(Z\,|\,Y=y)\right\} \\ &= \frac{1}{r_2}\left\{F\Phi(C_y) + I\cdot E(Z\,|\,Y=y)\left[\Phi(A_y)-\Phi(C_y)\right]\right. \\ &\quad \left. + V(\theta\,|\,Y=y)\left[\varphi(A_y)-\varphi(C_y)\right]\right\} \end{aligned}$$

where $A_y = E(Z\,|\,Y=y)/(\sigma_Z(1-\rho^2)^{1/2})$ and $C_y = A_y - F/(I\sigma_Z(1-\rho^2)^{1/2})(<A_y)$ for all y. The last line tells us that at period 1, bondholders expect the firm to be solvent and receive F with probability $\Phi(C_y)$, and even if the firm becomes insolvent, it still has a positive value $I\cdot E(Z\,|\,Y=y)$ on average with probability $\Phi(A_y)-\Phi(C_y)$. The last term is a convexity adjustment. Because of $Var(Z\,|\,Y=y) = \sigma_Z^2(1-\rho^2)$, we can obtain

$$B_1(\rho,F,y\,|\,y>Y^F) = \frac{I\cdot\sigma_Z(1-\rho^2)^{1/2}}{r_2}\left\{A_y\Phi(A_y)+\varphi(A_y)-C_y\Phi(C_y)-\varphi(C_y)\right\}.$$

At period 0, the equilibrium price is equal to

$$\begin{aligned} B_0(\rho,F,Y^F) &= \frac{1}{r_1}\left\{F\int_{-\infty}^{Y^F} dP(y) + \int_{Y^F}^{\infty} B_1(\rho,F,y\,|\,y>Y^F)\,dP(y)\right\} \\ &= \frac{1}{r_1 r_2}\left\{F\Phi\left(\frac{Y^F-\mu_y}{\sigma_y}\right) + \frac{I\cdot\sigma_Z(1-\rho^2)^{1/2}}{r_2}\right. \\ &\quad \left.\times\int_{Y^F}^{\infty}\left[A_y\Phi(A_y)+\varphi(A_y)-C_y\Phi(C_y)-\varphi(C_y)\right]dP(y)\right\}. \end{aligned}$$

According to Theorem 3 in Reisz and John (2002), the prices of corporate bonds increase with ρ. The risk premium demanded on corporate bonds decreases with ρ. It should be noted that this result stems from two effects. First, the higher ρ is, the higher the market value of the firm is because the manager can carry out investment policy based on more reliable information. Bondholders share this benefit with shareholders. This effect is called the "total firm value effect". Second, the higher ρ is, the narrower the extent of risk-shifting is and bondholders benefit from a smaller deviation from the optimal investment policy. This is called the "reduction-in-agency-games effect".

In sum, we show that the later the uncertainty is resolved for a given firm, the larger yield premiums are. The later resolution of uncertainty makes the distribution of the final cash flows of the firm riskier and thus increases the probability of bankruptcy. Bondholders, who know the pattern of TRU but do not observe the private signal, rationally demand a larger yield premium at the time of issuance. In the next sub-section, we consider a different interpretation.

4. Miyazaki and Saito (2006)

As shown, models proposed by both Reisz and John (2002) as well as by Epstein and Turnbull (1980) are based on partial equilibrium frameworks in the sense that risk-free rates are fixed. On the other hand, Miyazaki and Saito (2006) numerically demonstrate that premiums over risk-free assets are generated in a general equilibrium framework. Such premiums, which they call waiting-options premiums, are essentially different from Reisz and John (2002)'s premiums. As the source of premiums, Reisz and Kose consider agency-driven increases in risk, whereas Miyazaki and Saito (2006) consider intrinsic timing preferences.

Before introducing Miyazaki and Saito (2006)'s general equilibrium model, we provide a partial equilibrium model. This model follows Epstein (1980) and Miyazaki and Saito (2004). Epstein (1980) demonstrates that consumers with a high elasticity of inter-temporal substitution tend to postpone commitment to an irreversible decision and instead choose to hold flexible assets when they expect uncertainty to be resolved subsequently. Using Kreps and Porteus (1979) preferences, Miyazaki and Saito (2004) show that consumers hold more flexible assets not only because of the larger elasticity of inter-temporal substitution, but also because of a preference for the early resolution of uncertainty. Epstein (1980) examined rational choice between non-durable consumption and liquid assets (free of both risk and transaction costs) under the expectation of some resolution of uncertainty.

A consumer is endowed with w_0 units of consumption goods in period 0, and has access to financial markets to allocate consumption goods between three periods. The consumer invests in risk-free assets in period 0 and in risky assets in period 1. Investment in period 0 yields a fixed return R^f per period, whereas investment in period 1 yields a random return R^x per period, which takes positive values $(r_1, ..., r_m)$ with probability $p^T=(p_1, ..., p_m)$ where $p_i=\Pr(R^x=r_i)$. In period 1, the consumer receives a signal Y, which is correlated with the period-2 realization of R^x. The arrival of such a signal may resolve uncertainty concerning a random return to some extent. The signal takes $(y_1, ..., y_n)$ with probability $q^T= (q_1, ..., q_m)$ where $q_j=\Pr(Y=y_j)$. The posterior probability distribution is denoted by $\Pi=(\pi_{ij})$, where $\pi_{ij}=\Pr(R^x=r_i|Y=Y_j)$. By construction, $\Pi q=p$.

Given the above set-up, the consumer maximizes the following objective function:

$$\max_{\alpha}\left[(w_0-a)^{\frac{\sigma-1}{\sigma}}+\beta\left(\sum_j q_j J(a,y_j)^{1-\gamma}\right)^{\frac{\sigma-1}{\sigma(1-\gamma)}}\right]^{\frac{\sigma}{1-\sigma}},$$

where

$$J(a,y_j)=\max_{x}\left[(R^f a-x)^{\frac{\sigma-1}{\sigma}}+\beta\left(\sum_i \pi_{ij}(r_i x)^{1-\gamma}\right)^{\frac{\sigma-1}{\sigma(1-\gamma)}}\right]^{\frac{\sigma}{1-\sigma}};$$

$a(0\le a\le w_0)$ and $x(0\le x\le R^f a)$ denote savings in periods 0 and 1 respectively; $\beta(>0)$ is a discount factor; σ is the elasticity of inter-temporal substitution; and γ is the degree of relative risk aversion. This functional form has an advantage in that a preference for early (late) resolution can be controlled. To be specific, if $\sigma\gamma>1$, then an early resolution of uncertainty is preferred, and vice versa. When $\sigma\gamma=1$, the above set-up reduces to the case of expected utility explored by Epstein (1980).

Miyazaki and Saito (2006) present the following proposition. An earlier resolution of uncertainty or a more informative signal increases risk-free savings in period 0 if and only if

$$\sigma > 1,\ \sigma+\gamma > 2 \quad \text{or} \quad 0 < \sigma < 1,\ \sigma+\gamma < 2,$$

and it reduces savings if

$$\sigma > 1,\ \sigma+\gamma > 2 \quad \text{or} \quad 0 < \sigma < 1,\ \sigma+\gamma < 2.$$

Under the former condition, a consumer postpones a commitment to carry out current expenditures on consumption goods with an earlier resolution of uncertainty. When $\sigma>1$, then $\sigma+\gamma>2$ jointly promotes a postponement of such a commitment when there is an early resolution of uncertainty. Since $\sigma+\gamma>2$ is a sufficient condition for the preference of early resolution, or, equivalently, $\sigma\gamma>1$, we can say that a consumer with a strong preference for both early resolution and inter-temporal substitution tends to increase savings in order to wait for uncertainty to be partially resolved.

In the above setting, an incentive to postpone consumption (irreversible expenditure) until uncertainty is resolved, to some extent, triggers demand for risk-free assets. Such demand is expected to result in decreases in risk-free rates or increases in waiting-options premiums in a general equilibrium set-up. Embedding the previous three-period model into an overlapping economy, Miyazaki and Saito (2006) present a general equilibrium model.

Each generation is called young, middle-aged, or old. The population of each generation is constant over time and normalized to be one. Each generation has access to financial markets to allocate consumption goods over three periods. Young consumers are endowed with w_0 (>0) units of goods and can lend or borrow in one-period risk-free assets. Unlike the partial equilibrium model, middle-aged consumers endowed with w_1(>0) units can invest in one-period risky assets as well as in one-period risk-free assets. We assume that they cannot hold short positions in risky assets, but can in risk-free assets. One-period returns on risky assets R_t^x are given endogenously, whereas one-period risk-free rates R_t^f are determined endogenously as a result of transactions between young and middle-aged consumers. We assume that young consumers cannot participate in risky asset markets.

For the purpose of numerical experiments, Miyazaki and Saito (2006) adopt a parsimonious characterization by Jones and Ostroy (1984). This characterization is discussed in the first sub-section in this section. As ρ approaches one, the signal is more informative, and the uncertainty is resolved earlier.

In the next section, we will consider both the case in which all generations experience a resolution of uncertainty in an identical manner and the case in which only a particular generation can receive the interim signal. Given the above initial endowments and financial opportunities, a representative consumer born at date t maximizes the following problem with respect to an investment plan (risk-free bonds a_t^t and a_{t+1}^t, and risky assets x_{t+1}^t) as follows:

$$\max_{a_t^t}\left[\left(w_0-a_t^t\right)^{\frac{\sigma-1}{\sigma}}+\beta\left\{E_t(J(a_t^t,Y_{t+1})^{1-\gamma})\right\}^{\frac{\sigma-1}{\sigma(1-\gamma)}}\right]^{\frac{\sigma}{1-\sigma}},$$

where

$$J(a_t^t,Y_{t+1})=\max_{a_{t+1}^t x_{t+1}^t}\Big[(w_1+R_t^f a_t^t-a_{t+1}^t-x_{t+1}^t)^{\frac{\sigma-1}{\sigma}}$$

$$+\beta\left\{E_{t+1}((R_{t+1}^f a_{t+1}^t+R_{t+2}^x x_{t+1}^t)^{1-\gamma})\right\}^{\frac{\sigma-1}{\sigma(1-\gamma)}}\Big]^{\frac{\sigma}{1-\sigma}},$$

a^t_t and x^t_t denote savings in risk-free bonds and in risky assets, respectively, and E_t is the conditional expectation operator based on the information available at date *t*.

An equilibrium risk-free rate is determined endogenously by the lending–borrowing process between young and middle-aged consumers. Using dynamic programming techniques, we can derive the optimal asset demands a^t_t, a^t_{t+1}, and x^t_{t+1} as:

$$a^t_t = f^t(\Omega_t),$$
$$a^t_{t+1} = g^t(a^t_t, R^f_t, R^f_{t+1}, Y_{t+1}),\text{and}$$
$$x^t_{t+1} = h^t(a^t_t, R^f_t, R^f_{t+1}, Y_{t+1}),$$

where the information set Ω_t is recursively defined as $\Omega_t = \left\{\Omega_{t-1}, x^{t-2}_{t-1}, a^{t-2}_{t-1}, a^{t-1}_{t-1}, R^f_t, R^x_t, Y_t\right\}$. (See Appendix B in Miyazaki and Saito (2006) for more detailed descriptions of f^i, g^i, and h^i.) Then, an equilibrium risk-free rate R^f_t is determined such that

$$a^t_t + a^{t-1}_t = 0.$$

Actually, it is impossible to solve the model analytically. So Miyazaki and Saito (2006) resort to numerical investigations, and demonstrate that both the level of risk of investment opportunities and the resolution of uncertainty influence an equilibrium risk-free rate. Decreases driven by risk-averse behavior are referred to as risk-premiums, whereas decreases due to a resolution of uncertainty are called waiting-options premiums. Specifically, let us denote R^f_0, R^f_ρ, $E(R^x)$ to be an equilibrium risk-free rate in the case of ρ=0, an equilibrium risk-free rate in the case of ρ>0, and the mean return on risky assets. Risk-premiums and waiting-options premiums are calculated through $E(R^x)–R^f_0$ and $R^f_0–R^f_\rho$, respectively. The authors' numerical examples show that consumers with large elasticities of inter-temporal substitution, as well as strong preferences for an early resolution of uncertainty, generate vigorous demand for risk-free assets. This results in positive waiting-options premiums.

Whether later resolution of uncertainty generates premiums or not depends on timing preference. In the set-up of Reisz and John (2002), when the uncertainty is resolved later ($\rho \to 0$), higher premiums are generated. On the other hand, Miyazaki and Saito (2006) demonstrate that more premiums are generated both when the uncertainty is resolved earlier and when investors prefer an early resolution of uncertainty. This indicates that when investors have a strong preference for late resolution, companies with a late resolution of uncertainty are required to have higher premiums over riskless assets.

3. Empirical Analysis

Section 3 presents Reisz and Perlich (2006)'s empirical methodology including empirical proxies for TRU and then applies the methodology to Japan's corporate bond markets to summarize the results.

1. Proxies for the temporal resolution of uncertainty

To design proxies for TRU, Reisz and Perlich (2006) use earnings forecasts and realizations from the international brokers estimate system (IBES) database. They pay attention to the speed at which uncertainty is resolved for a given firm through analysts' abilities to forecast the future. Analysts can predict the short-term earnings of a firm with a late resolution of uncertainty, and as the forecast horizon is extended, they find this more difficult. Reisz and Perlich (2006) construct the following three statistics that measure how much more difficult it is to forecast the long-term versus the short-term future.

First, σ_{long} and σ_{year}, respectively, denote standard deviations across analysts' forecasts of long-term earnings and the standard deviation of yearly earnings forecasts. The ratio $\sigma_{long}/\sigma_{year}$ measures how much more analysts disagree about long-term earnings versus earnings one year from the forecast date. A firm with a more delayed resolution of uncertainty should display a larger ratio.

Second, we define $RMSE_{quarter}$ as the root mean square error of standardized forecast errors $(E_t - F_{t\text{-}1,\,t})/S_{t\text{-}1}$ for a firm over the 20 quarters before the event date, where E_t is the actual earnings realization at t, $F_{t,\,t-1}$ denotes the median forecast made at date t–1 for earnings at date t, and S_{t-1} the equity price at t–1. Similarly, $RMSE_{year}$ denotes the root mean error over the five years. Firms with more delayed resolution of uncertainty should display a larger $RMSE_{year}/RMSE_{quarter}$ ratio.

Third, we define $\rho_{quarter}$ as the correlation between the time series of standardized median quarterly forecasted innovations $(F_{t-1,\,t} - E_{t-1})/S_{t-1}$ and the time series of standardized quarterly actual earnings innovations $(E_t - E_{t-1})/S_{t-1}$ for a firm over the 20 quarters before the event date. Similarly, ρ_{year} denotes the correlation over five years. Firms with a more delayed resolution of uncertainty should display a larger $\rho_{year}/\rho_{quarter}$ ratio.

2. Reisz and Perlich (2006)

To investigate whether and how TRU affects asset pricing, Reisz and Perlich (2006) use data for newly issued corporate bonds in the United States. The sample consists of 1,299 plain-vanilla, option-free, dealer-priced bonds without any unusual characteristics, quoted between January 1, 1987, and December 31, 1996, and issued by 474 different firms. The price quote is taken at the end of the second month after issuance to remove unusual volatility.

Reisz and Perlich (2006) investigate whether constructed yield spreads over Treasury, $y - y^T$ at the issue date depend on TRU. Many empirical papers indicate that yield spreads are influenced by firm size, financial leverage, operational risk, growth options, cash availability, and duration. These variables may be correlated with TRU. We control for them to avoid any omitted variable bias.

Their regression has the following form:

$$y - y^T = \alpha_0 + \alpha_1 \mathrm{TRU} + \alpha_2 SIZE + \alpha_3 (D/E) + \alpha_4 RISK + \alpha_5 GROWTH + \alpha_6 CASH + \alpha_7 DURATION + \varepsilon \quad (4)$$

where y denotes the yield to maturity on a particular bond; y^T is its Treasury yield; TRU is a relevant measure of the temporal resolution of uncertainty the firm faces; SIZE is the natural logarithm of firm sales as a measure of firm size; D/E is the book value of the firm's debt (computed as the book value of assets minus the book value of the equity) divided by the market value of its equity as a measure of its financial leverage; RISK is the variance in the changes in the logarithm of the market value of assets (computed as debt plus the market value of equity) over five years before the issue date as a proxy for overall risk; GROWTH is the ratio of market-to-book value of the firm's assets as a proxy for growth options; CASH is the earnings before interest, taxes, depreciation, and amortization (EBITDA) divided by the book value of the assets as a measure of free cash flows; DURATION is the bond's duration, and ε is an error term that they assume to be homoskedastic to and uncorrelated with regressors.

As for SIZE, they select firm sales instead of market value to avoid multi-collinearity with GROWTH (market-to-book value), and they use logarithms because the size effect is expected to be most apparent when values are low. As for CASH, they divide EBITDA by the book value of the assets rather than the market value of the assets to avoid a mechanical with

D/E:

$$\frac{EBITDA}{market value\ of\ equity} = \frac{EBITDA}{market value\ of\ assets}/(1 + \frac{book\ value\ of\ debt}{market vallue\ of\ equity}).$$

As discussed in sub-section 2.3, Reisz and John (2002) suggest that investors will demand higher yields from firms with a more delayed resolution of uncertainty. The estimate of the coefficient α_1 is thus expected to be negative when $\rho_{year}/\rho_{quarter}$ is used, and positive when $\sigma_{long}/\sigma_{year}$ or $RMSE_{year}/RMSE_{quarter}$ is used. Regardless of whether α_1 is significant or not, the estimate of α_2 is expected to be negative because larger firms are given more attention and therefore have fewer information asymmetrics. The coefficient α_6 is expected to be negative because cash-rich firms are less likely to default. The other estimates α_3, α_4, α_5, and α_7 are positive because investors will demand higher yields from firms with more default risk, more growth options, or on bonds with a longer duration.

Reisz and Perlich (2006) conduct the regression analysis of (4) and find that the coefficients on $\sigma_{Kong}/\sigma_{year}$, $RMSE_{year}/RMSE_{quarter}$, and $\rho_{year}/\rho_{quarter}$ are positive at the 1% level, positive at 5%, and negative at 5%, respectively. When all three proxies are included, the F-test of joint significance for the three proxies yields a P-value of less than 0.01%. Other coefficients of the regressors are significant at the 5% level. The evidence supports the hypothesis that even after firm size, financial leverage, operational risk, growth options, cash availability, and duration are all controlled for, firms with a more delayed resolution of uncertainty will have to offer higher yields.

Reisz and Perlich (2006) consider another regression, in which in order to deal with any potentially omitted variable in regression (4), they control for all factors that rating agencies consider relevant when assigning a grade to a bond by predicting a rating-controlled spread. They report similar results and conclude that TRU influences bond yields in a robust manner. Their conclusion could support both the agency-driven implications of Reisz and John (2002) and the argument for investors timing preferences from Kreps and Porteus (1979) and Miyazaki and Saito (2004).

To distinguish between the two possible explanations, Reisz and Perlich (2006) conduct a testing hypothesis. Reisz and John (2002) imply that TRU is another source of risk. So rating agencies should allow for TRU when assigning grades to a firm. To investigate whether discrete ordered variables such as ratings can be predicted by other factors, Reisz and Perlich (2006) carry out an ordered probit analysis.

The ordered probit model assumes that the discrete rating R is set to be 0 for Aaa bonds, 1 for Aa bonds, 2 for A bonds, 3 for Baa bonds, and 4 for Ba bonds, and that R is a discrete categorization of a continuous unobserved measure R^*. The measure R^* is assumed to be a linear function of some regressors X plus a *normal* disturbance η. That is, $R^*=X'\beta+\eta$, where $\eta \sim N(0, \sigma^2)$. What is observed is $R = 0$ if $R^* \leq 0$, $R = 1$ if $0 \leq R^* \leq \mu_1$, ..., and $R = 4$ if $R^* > \mu_3$. The β's and μ's are parameters to be estimated.

The ordered probit regression takes the following form:

$$R^T = \beta_0 + \beta_1 \mathrm{TRU} + \beta_2 SIZE + \beta_3 (D/E) + \beta_4 RISK + \beta_5 GROWTH + \beta_6 CASH + \eta. \tag{5}$$

Unlike in the former regression (4), DURATION is not included in (5), because it is not a characteristic of a firm, and rating companies do not take it into consideration.

The estimates of the coefficients β_2, β_5 and β_6 are expected to be positive because rating agencies are likely to assign better ratings to firms of a larger size, who have more free cash or larger growth options. The estimates of β_3 and β_4 are expected to be negative because rating agencies are likely to assign lower ratings to risky firms. If, as Reisz and John (2002) suggest, TRU is another risk factor, then agencies will rate firms with a more delayed resolution of uncertainty as lower, and, accordingly, the estimate of the coefficient β_1 is supposed to be negative when $\rho_{year}/\rho_{quarter}$ is used, and positive when $\sigma_{long}/\sigma_{year}$ or $RMSE_{year}/RMSE_{quarter}$ is used.

Reisz and Perlich (2006) conduct the regression analysis of (5) to find that firm size and leverage are the most significant factors for predicting ratings and that of the three proxies for TRU, only $RMSE_{year}/RMSE_{quarter}$ is significant. They believe that since the proxy is highly correlated with D/E and $RISK$, it should be considered for overall risk rather than TRU, and they conclude that the pattern of TRU is not allowed for by rating agencies.

In addition, Reisz and Perlich (2006) conduct two other tests to investigate whether Reisz and John (2002)'s implications are right. If they are, these investment distortions can be expected to be larger as the maturity of the debt lengthens. First, they regress the maturity premiums (the yield offered on the long bond minus the yield on the short bond, divided by the difference in duration) on the same regressors in (5). Second, they regress the duration of the bonds on the same regressors. Both tests reveal that none of the proxies for TRU is significant. Along with the evidence that a firm's rating is not related to TRU, Reisz and Perlich (2006) conclude that the premiums for corporate bonds are not magnified by any agency-driven risk. Remembering Miyazaki and Saito (2006)'s discussions, we conclude that this magnification occurs because of investors' strong preference for a late resolution of uncertainty.

3. Empirical results for Japan's corporate bond markets

In this sub-section we apply Reisz and Perlich (2006)'s methodology to Japan's corporate bond markets. Our data period is from January 1, 2002, to December 30, 2004. The number of newly issued bonds is 932. We only chose 679 plain bonds that satisfied the following three criteria: 1) the coupon rate is fixed, and paid semi-annually; 2) the principal amount is fully paid at maturity; and, 3) no options (callable or convertible) are attached.

Yield data are from the Japan Securities Dealers Association (JSDA). The JSDA calculates the reference prices (yields) based on the mid-price quotations for buys and sells. We use the average quotation. The number of bonds thus priced falls to 364. To conduct an ordered probit analysis, we selected 469 out of the 679 bonds to which R&I, a major Japanese rating company, assign a BBB- rating or higher. Other financial data, except for TRU, are from the Nikkei NEEDS-Financial QUEST and the International Brokers Estimate System (IBES).

As discussed in sub-section 3.1, proxies for TRU are obtained from the IBES. Notice that the IBES covers far fewer companies in Japan than in the United States. In particular, the number of long-run profit forecasts is small. In the case of some companies, only one analyst or team gives an estimation, making it impossible to calculate the standard deviation. Therefore, in addition to the three proxies Reisz and Perlich (2006) propose, we adopt $\sigma_{2year}/\sigma_{year}$, where σ_{year} is the standard deviation across analysts' forecasts of two-year earnings. That is, when conducting an empirical analysis of Japan's corporate bond markets, we consider four proxies: $\sigma_{long}/\sigma_{year}$, $\sigma_{2year}/\sigma_{year}$, $RMSE_{year}/RMSE_{quarter}$, and $\rho_{year}/\rho_{quarter}$.

Table1. Descriptive Statistics

	Obs.	Mean	Std. Dev.	Min	Max
SPREAD	250	0.388	0.349	-0.214	1.681
SIZE	439	20.522	1.139	16.413	23.443
D/E ratio	439	1.256	1.040	0.000	7.379
RISK	471	261.673	223.699	0.091	688.234
GROWTH	445	1.514	0.764	-1.470	5.510
CASH	439	0.179	0.492	0.004	6.511
DURATION	483	7.705	4.635	2.992	29.945
$\sigma_{\text{long}}/\sigma_{\text{year}}$	202	4.748	11.073	0.000	72.574
$\sigma_{\text{2years}}/\sigma_{\text{1year}}$	401	2.010	1.679	0.201	16.000
$\text{RMSE}_{\text{year}}/\text{RMSE}_{\text{quater}}$	356	0.984	0.409	0.069	2.709
$\rho_{\text{year}}/\rho_{\text{quater}}$	355	13.807	170.341	-49.831	2272.448

Table 2. Correlation between Proxies for Temporal Resolution of Uncertainty and Firm Ratings

	$\sigma_{\text{long}}/\sigma_{\text{year}}$	$\sigma_{\text{2years}}/\sigma_{\text{1year}}$	$\text{RMSE}_{\text{year}}/\text{RMSE}_{\text{quater}}$	$\rho_{\text{year}}/\rho_{\text{quater}}$
$\sigma_{\text{long}}/\sigma_{\text{year}}$	1			
$\sigma_{\text{2years}}/\sigma_{\text{1year}}$	0.0197	1		
$\text{RMSE}_{\text{year}}/\text{RMSE}_{\text{quater}}$	0.0152	0.0611	1	
$\rho_{\text{year}}/\rho_{\text{quater}}$	0.0751	-0.0492	-0.1597	1

Table 1 summarizes the descriptive statistics of our bond sample: yield spreads, firm characteristics, and the proxies for TRU. In particular, we should notice three points. 1) For each proxy for TRU, some data are below one, implying that long-term forecasts are more precise than short-term ones. 2) The number of σ_{long} is small. 3) $\rho_{year}/\rho_{quarter}$ is very volatile. Table 2 presents the correlation between the proxies for TRU. It is worth mentioning that each variable has a very low correlation with the other variables, ranging from -0.16 to 0.075. While $\rho_{year}/\rho_{quarter}$ has negative correlations with $\sigma_{2year}/\sigma_{1year}$ and $RMSE_{year}/RMSE_{quarter}$, it has a positive correlation with $\sigma_{long}/\sigma_{year}$. To sum up, we should keep in mind that Japanese proxies for TRU may not be less reliable than those for the U.S.

Table 3. Yield Spreads over Temporal Resolution of Uncertainty

Independent Variable (Predicted Sign)	model 1	model 2	model 3	model 4	model 5	model 6
$\sigma_{\text{long}}/\sigma_{\text{year}}$ (+)	.00676+					
	(.0036)					
$\sigma_{\text{2years}}/\sigma_{\text{1year}}$ (+)		.00529				.00245
		(.009)				(.0086)
$RMSE_{\text{year}}/RMSE_{\text{quater}}$ (+)			-.0382			-.0322
			(.0465)			(.0504)
$\rho_{\text{year}}/\rho_{\text{quater}}$ (−)				-.00054		-.00091
				(.002)		(.0021)
SIZE (−)	-.0414	-.0392*	-.0129	-.00982	-.0307+	-.0169
	(.0302)	(.0176)	(.0209)	(.0205)	(.0158)	(.0218)
D/E ratio (+)	.0931*	.0882**	.0467+	.048*	.076**	.0476+
	(.0367)	(.0243)	(.0243)	(.0243)	(.0222)	(.026)
RISK (+)	-.00011	-.00037**	-.00019*	-.0002*	-.00034**	-.00018*
	(1.2e-04)	(9.1e-05)	(8.8e-05)	(8.7e-05)	(8.6e-05)	(8.9e-05)
GROWTH (+)	-.0058	.0119	-.0149	-.012	.0239	-.0186
	(.0473)	(.026)	(.0271)	(.0269)	(.0242)	(.0279)
CASH (−)	.109	.0317	.0124	.00259	.0292	.0137
	(.112)	(.0319)	(.0892)	(.0888)	(.0313)	(.0901)
DURATION (+)	.0404**	.0357**	.0367**	.0364**	.0361**	.0368**
	(.0052)	(.0047)	(.0045)	(.0045)	(.0045)	(.0046)
Constant	.79	.914*	.421	.32	.724*	.496
	(.622)	(.359)	(.43)	(.411)	(.319)	(.451)
Adjusted R-squared	0.376	0.255	0.257	0.254	0.248	0.245
F-statics	11.4	13.3	11.8	11.7	16.4	8.8
Observations	122	253	221	221	280	216

Standard errors are given in parentheses under the coefficients. Individual coefficients are statistically significant at +10%, *5%, or **1% level.

Table 3 demonstrates the results of regression (4). Four proxies for TRU, except $RMSE_{year}/RMSE_{quarter}$, demonstrate correct signs. Out of them, only $\sigma_{long}/\sigma_{1year}$ is significant at the 10% level. With correct signs, DURATION is the most significant factor for predicting spreads, followed by leverage. RISK is also significant, but it gives a wrong sign for some specifications. The other factors are almost significant. SIZE gives correct signs, while CASH gives wrong signs.

The F-statistic of joint significance for our three proxies ($\sigma_{2year}/\sigma_{1year}$, $RMSE_{year}/RMSE_{quarter}$, and $\rho_{year}/\rho_{quarter}$) is $F(3,206)$. It yields a P-value of over 90%. Unlike Reisz and Perlich (2006), our results do not necessarily support the hypothesis that firms with a more delayed resolution of uncertainty will have to offer larger yields, even after we control for firm size, financial leverage, operational risk, growth options, cash availability, and duration.

Table 4. Temporal Resolution of Uncertainty and Firm Ratings: An Ordered Probit Model

Independent Variable (Predicted Sign)	model 1	model 2	model 3	model 4	model 5	model 6
rating						
$\sigma_{\text{long}}/\sigma_{\text{year}}$ (+)	-.00225					
	(.0083)					
$\sigma_{\text{2years}}/\sigma_{\text{1year}}$ (+)		.0655+				.0506
		(.0366)				(.0385)
$\text{RMSE}_{\text{year}}/\text{RMSE}_{\text{quater}}$ (+)			-.244			-.282+
			(.155)			(.163)
$\rho_{\text{year}}/\rho_{\text{quater}}$ (−)				.00111		-.0317*
				(9.9e-04)		(.0124)
SIZE (−)	-.348**	-.25**	-.229**	-.199**	-.28**	-.202**
	(.109)	(.0587)	(.0664)	(.0665)	(.054)	(.0691)
D/E ratio (+)	-.0151	-.0591	.0129	.0153	-.018	-.0162
	(.118)	(.0607)	(.0638)	(.0637)	(.0584)	(.0663)
RISK (+)	.00137**	.00086**	.001**	.00092**	.00084**	.00101**
	(4.0e-04)	(2.7e-04)	(2.9e-04)	(2.9e-04)	(2.6e-04)	(3.0e-04)
GROWTH (+)	-.355*	.167*	.125	.135	.209**	.0463
	(.17)	(.0834)	(.0952)	(.0951)	(.0784)	(.103)
CASH (−)	.56	.0568	-.269	-.325	.0549	-.206
	(.497)	(.117)	(.328)	(.328)	(.117)	(.33)
Log Likelihood	-155.18	-349.07	-317.03	-315.81	-381.51	-300.23
Observations	193	389	344	343	421	331

Standard errors are given in parentheses under the coefficients. Individual coefficients are statistically significant at +10%, *5%, or **1% level.

Although Table 3 does not support the hypothesis, three out of the four proxies give correct signs. So we conducted a test to see whether Reisz and John (2002)'s implications are right. Table 4 demonstrates the results of regression (5). Among our four proxies for TRU, only $\sigma_{2year}/\sigma_{1year}$ is significant at the 10% level. The others do not show predicted signs. The χ^2-statistic of joint significance for our three proxies ($\sigma_{2year}/\sigma_{1year}$, $RMSE_{year}/RMSE_{quarter}$, and $\rho_{year}/\rho_{quarter}$) is $\chi^3(3) = 9.66$, yielding a P-value of 2.1%. It should be noted that $RMSE_{year}/RMSE_{quarter}$ gives a wrong sign. With respect to firm characteristics, the table shows that firm size and leverage are the most significant factors with correct signs for producing ratings for all specifications. Unlike in Table 4, the D/E ratio does not give correct signs. These results imply that our estimation results may be robust.

4. Concluding Remarks

This paper gives an overview of studies on the effect of TRU on asset pricing, and it conducts an empirical analysis using recent data on corporate bonds issued in Japan. We present three theoretical frameworks proposed by Epstein and Turnbull (1980), Reisz and John (2002), and Miyazaki and Saito (2006). Following Reisz and Perlich (2006)'s methodology, we perform an empirical analysis, and find that this analysis does not work well. Our analysis does not support the hypothesis that firms with a more delayed resolution of uncertainty will have to offer larger yields.

The major reason may be data precision. We should notice three points. First, as Table 1 shows, Japanese proxies for TRU may not be less reliable. This might be due to outliers. To remove them, we should carry out a more extensive consideration of the proxies. Second, the data on yield spreads may also have some room for improvement. To calculate yield spreads, Nakashima and Saito (2006) use the swap rate instead of government bonds because yields on Japanese government bonds earn a sort of convenience and it is difficult to control for the effects of such convenience. Other yield spreads might have other implications. Finally, our sample period is not long. So a larger sample size could improve the empirical results.

Although we fail to present interesting empirical results, we still believe that the resolution of uncertainty is an important factor in determining asset pricing. In order to test the implications from Miyazaki and Saito (2006), a natural development might be to conduct an empirical analysis using stock price data, and such research is ongoing.

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