IMES DISCUSSION PAPER SERIES

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Discussion Paper No. 2016-E-9

INSTITUTE FOR MONETARY AND ECONOMIC STUDIES

BANK OF JAPAN

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JAPAN

IMES Discussion Paper Series 2016-E-9

August 2016

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Abstract

On the basis of the residual income model, this paper proposes a statistical model for inferring implied cost of equity (COE) from cross-sectional data on stock prices and firms' attributes. The model is estimated using a quasi-maximum likelihood approach to simultaneously identify the COE, expected earnings growth rates, and expected excess earnings durations of individual Japanese firms listed on the First Section of the Tokyo Stock Exchange (excluding the financial industry sector). The estimation results show that the individual firms' attributes, such as industry sector, cash-flow/price, and dividend/price, are key determinants of the COE. Besides, the distribution of individual firms' COE has changed over time, which suggests that it is crucial to take account of market conditions and financial situations of the firms in the estimation. Moreover, our estimates of the firms' COE have a positive relation with expected returns on their stocks, and that relation is stronger than those obtained with existing models.

Keywords: Implied cost of equity; Residual income model; Quasi-maximum likelihood approach

JEL classification: C14, C31, G31, M41

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The authors would like to thank Hiroyuki Ishikawa (Osaka City University), Toshiaki Watanabe (Hitotsubashi University), Yoshitaka Fukui (Aoyama Gakuin University), Marlene Amstad (Chinese University of Hong Kong, Shenzhen), participants at the 24th annual conference of Nippon Finance Association, and the staff at the Institute for Monetary and Economic Studies of the Bank of Japan for their useful comments and discussions. The views expressed in this paper are those of the authors and do not necessarily reflect the official views of the affiliated institutions of the authors. All the remaining errors are our own.

Table of Contents

Ⅰ. Introduction

From a firm's viewpoint, the cost of equity (COE) is the expected cost for equity financing. On the other hand, from a stockholder's viewpoint, the COE is the expected (required) return on its investment. The COE also indicates the hurdle rate of return on equity (ROE) in that a firm needs to achieve the higher ROE than the level of the COE in order to enhance the stockholder value. The concept of the hurdle rate began to gather attention after the publication of Final Report of the Ito Review (Ministry of Economy, Trade and Industry [2014]), claiming as follows: "A value-creating company is one that has an ROE above its cost of capital, and while the actual cost of capital differs between companies, the first step in receiving recognition from global investors is for a company to commit to achieving a minimum ROE of 8%, while continually seeking to generate an ROE higher than 8%." As the view of the report came to be broadly accepted, the managers of Japanese firms have been gradually taken the levels of the COE into account.

As explained above, there has been a growing interest in the levels of the COE, particularly among practitioners. Nonetheless, all existing models for inferring the individual firms' COE have pros and cons, so no model has yet become a *de facto* standard, and there is no consensus on the factors determining the firms' COE. Therefore, to provide the practitioners with valuable research, the main purpose of this paper is to propose a statistical model for inferring the firms' COE and unraveling key determinants of the COE.

In our model, individual firms' COE is estimated with data on market prices of individual stocks because each firm's COE is conceptually equal to the expected return on its stock, and the expected returns should be reflected in the current stock price.[1] Existing inference methods using data on stock prices are classified into two types as follows:

(1) Estimating the COE with statistical models such as market models (e.g., Sharpe [1964], Lintner [1965], derived from capital asset pricing models) or multi-factor

[1] Yanagi (2015a) estimates the COE from survey results. In his research, the COE is estimated as 8% by adding the consensus value of the equity risk premium in developed countries (6%, according to survey results by Fernandez and Campo [2011]) to the risk-free rate in Japan (2%, from the historical average of 30-year government bonds yields). Moreover, this paper states, "the most recent survey (Yanagi [2015b]) concludes the COE is 7.3% (6.8% for domestic investors, and 7.6% for overseas investors), and both the mode and majority of the COE distribution are 8%. This reconfirms that an 8% targeted (ROE) is sufficient to exceed expected returns for about 90% of investors." (Translated from Japanese by the authors)

models (e.g., Fama and French [1993, 1997, 2015]) from historical data on the stock returns.

(2) Estimating the implied COE with equity valuation models such as the residual income model which assumes an identity between the market value and the theoretical value of a stock based on the efficient market hypothesis (Botosan [1997], Gebhardt, Lee, and Swaminathan [2001], Easton [2004, 2009], Ohlson and Juettner-Nauroth [2005]).

The method (1) has a crucial shortcoming in that estimated values heavily depend on the sample periods used for the estimation but nevertheless no reasonable method to select appropriate sample periods exists. In fact, Fama and French (1997) admits inaccuracy in risk premiums (i.e., COE minus risk-free rate) estimated with their multi-factor model.

The method (2) does not have the problem mentioned above. However, existing research suggests that estimated implied COE contains considerable estimation errors. The two main factors behind such estimation errors are as follows:

- The expected earnings level and growth rate forecasted by (financial) analysts contain measurement errors, and these errors harm the accuracy of estimated COE (Hou, Dijk, and Zhang [2012], Larocque [2013]).
- The lengths of time over which firms continue to earn excess profits (expected excess earnings durations) are exogenously and unfoundedly assumed, and the assumption may distort the estimates of the COE (Gebhardt, Lee, and Swaminathan [2001], Claus and Thomas [2001], Gode and Mohanram [2003]).

These disadvantages in estimating implied COE may be improved by explicitly considering those measurement errors in estimation processes, and employing simultaneous estimation of the COE and the expected earnings growth rate. This is because these steps could, to some extent, reduce harmful impacts of the measurement errors on COE estimates (errors-in-variables problem; see, e.g., Griliches and Ringstad [1970], Chesher [1991]) by dispersing the impacts to both of the estimates of the COE and those of the expected earnings growth rate (e.g., Easton *et al*. [2002], Huang, Natarajan, and Radhakrishnan [2005], Nekrasov and Ogneva [2011]).[2]

Therefore, on the basis of the residual income model, we propose a statistical model for inferring implied COE from cross-sectional data on stock prices and firms' attributes, and identify the COE, expected earnings growth rates, and expected excess earnings

[2] Note that the increase of the number of parameters to be estimated could enlarge the estimation errors.

durations of individual firms simultaneously. The samples of this research are Japanese firms listed on the First Section of the Tokyo Stock Exchange (excluding the financial industry sector). The proposed model explicitly considers the existence of stochastic noise between a firm's market value (stock price) and theoretical value calculated from the residual income model, and thus it admits that discrepancies between them are non-negligible. Since a variety of factors including market inefficiency, model risks (e.g., misspecification risks) and measurement errors in analyst forecasts are intricately intertwined and affect the stochastic structures of the noises (cross-sectional dependency), it is difficult to accurately specify the structure of the noises. Therefore, in our research, we estimate the model by the quasi-maximum likelihood (QML) approach, which does not need the correct knowledge of the stochastic structures of noises, and the COE estimates are obtained as QML estimators.

Our research addresses two disadvantages of existing implied COE models listed in the previous page as the following. First of all, regarding the measurement errors in analyst forecasts, our research uses only short-term (one-year-ahead) forecasts as inputs to limit the impact of the errors on estimates. Next, with respect to the expected earnings growth rate, we simultaneously identify the rate and COE (Huang, Natarajan, and Radhakrishnan [2005][3], Ishikawa [2014]) in contrast to the existing research on estimating the implied COE, in which only the COE is estimated and earnings forecasts are replaced by proxies complied from mid- to long-term forecasts. This difference is crucial because the compiled proxies for expected earnings growth rates used in existing research include serious measurement errors and might amplify the harmful impact on the COE estimates.

Further, our statistical model identifies the expected excess earnings duration simultaneously with the COE and the expected earnings growth rate, while existing research assumes a finite or infinite duration (Gebhardt, Lee, and Swaminathan [2001], Claus and Thomas [2001]). Note that the estimator could take virtually infinite values, so our strategy is more comprehensive than the ones used in the existing research.

Employing our model, we analyze issues examined in Nekrasov and Ogneva (2011). Specifically, we attempt to unravel the interrelations of firms' attributes to (both of) the individual firms' COE (and the expected earnings growth rate). That is, we aim to identify key determinants of the firms' COE. The cross-sectional interrelation between estimated firms' COE and expected (realized) returns on their stocks is examined as in

[3] The cited paper was the first to propose simultaneous estimation of the individual firms' COE and the expected earnings growth rates, assuming that COE is time-invariant. Easton *et al.* (2002) is regarded as the first research to consider simultaneous estimation of market- and industry-based COE and the expected earnings growth rates.

the existing research (e.g., Easton and Monahan [2005], Botosan, Plumlee, and Wen [2011], Nekrasov and Ogneva [2011]).[4] We also conduct comparative analysis on the estimated COE between our statistical model and four existing models, those of Gebhardt, Lee, and Swaminathan (2001), Claus and Thomas (2001), Easton (2004), and Ohlson and Juettner-Nauroth (2005).

The main findings of our research are as follows. First, we identify a positive cross-sectional interrelation between our estimates of the individual firms' COE and the corresponding expected returns on their stocks, and find that relation is stronger than those obtained with existing models. In addition, the cross-sectional distribution of individual firms' COE has changed over time, which suggests that it is important to take account of market conditions and financial situations of the firms in the estimation. Moreover, firms' attributes, such as industry sector, cash-flow/price and dividend/price, are unraveled to be key determinants of the COE.

The reminder of this paper is organized as follows. Section 2 shows the derivation of our statistical model from a standard residual income model. Section 3 explains our methodology (the QML approach) for inferring the COE, the expected earnings growth rate and the expected excess earnings duration. That section also illustrates the data used for estimation. Section 4 provides the estimation results and some analyses of them, and Section 5 concludes the paper.

II. Residual Income Model and Statistical Model

In this section, we derive our statistical model from an existing residual income model. First, a clean-surplus relation between net assets (B_t), net earnings after tax (e_t) and dividend (d_t) are assumed. Then, the residual income (e_t^{ex}) is defined with COE $(R_{E,t})$ as follows. Here, the index $t\,(\geq 0)$ indicates the period, and the interval between period $t-1$ and t is assumed as one year (i.e., constant time-interval).

<u>Clean Surplus Relation</u>

$$B_t - B_{t-1} = e_t - d_t. \tag{1}$$

<u>Residual Income</u>

$$e_t^{ex} \equiv e_t - R_{E,t}B_{t-1} \left(= \left(ROE_t - R_{E,t}\right)B_{t-1}\right). \tag{2}$$

[4] Here, "the cross-sectional interrelation between firms' COE and expected returns on their stocks" means that firms with higher (lower) COE would earn better (worse) stock returns on average in the future.

Here, $ROE_t \equiv e_t/B_{t-1}$ holds. From equation (1) and (2), the dividend (d_t) is expressed as

$$d_t = e_t^{ex} + R_{E,t}\, B_{t-1} - B_t + B_{t-1} = e_t^{ex} + (1 + R_{E,t})B_{t-1} - B_t. \quad (3)$$

We denote the theoretical value of the stock at period $t\ (\geq 0)$ as V_t, and assume that the COE $(R_{E,t})$ is determined from information available at period t and takes the same value over the forecast horizon.[5] The COE is also assumed to be larger than the expected earnings growth rate. Denoting the operator of taking expectation value from the information available at period t as $\mathbb{E}_t[\cdot]$, a standard residual income model is derived from dividend discount models with finite forecast horizon ($T < \infty$) as follows:

$$\begin{aligned} V_t &= \sum_{j=1}^{T-t} \frac{\mathbb{E}_t[d_{t+j}]}{(1 + R_{E,t})^j} = \sum_{j=1}^{T-t} \frac{\mathbb{E}_t[e_{t+j}^{ex} + (1 + R_{E,t})\, B_{t+j-1} - B_{t+j}]}{(1 + R_{E,t})^j} \\ &= \sum_{j=1}^{T-t} \frac{\mathbb{E}_t[e_{t+j}^{ex}]}{(1 + R_{E,t})^j} + B_t + \sum_{j=1}^{T-t} \frac{\mathbb{E}_t[(1 + R_{E,t})\, B_{t+\mathrm{j}} - (1 + R_{E,t})\, B_{t+\mathrm{j}}]}{(1 + R_{E,t})^j} - \frac{\mathbb{E}_t[B_T]}{(1 + R_{E,t})^{T-t}}. \end{aligned}$$

Taking the limit $(T \to \infty)$ and denoting the limiting value as V_t, the residual income model with infinite forecast horizon is derived as

$$V_t = B_t + \sum_{j=1}^{\infty} \frac{\mathbb{E}_t[e_{t+j}^{ex}]}{(1 + R_{E,t})^j}. \quad (4)$$

With the additional assumption that firms do not gain positive excess earnings after certain periods $(T < \infty)$ have passed $\left(\mathbb{E}_t\left[e_{t+j}^{ex}\right] = 0\ (t + j > T)\right)$, equation (4) is transformed into the following equation:

$$V_t = B_t + \sum_{j=1}^{T-t} \frac{\mathbb{E}_t[e_{t+j}^{ex}]}{(1 + R_{E,t})^j}. \quad (5)$$

We derive our statistical model for inferring the COE based on the residual income model with infinite forecast horizon, given as equation (5). Denote as $P_{i,t}$ the stock price of a firm $i\ (\in \{1, \cdots, N\})$ at period $t\ (t \geq 0)$, and as $V_{i,t}$ the theoretical value of the stock calculated from the model. Note that the competitive power of each firm to gain excess earnings (i.e., ROE minus COE retains positive) is assumed to persist only over a finite horizon, $\tau_t\ (< \infty)$. We set this novel assumption because assuming that positive or negative excess earnings will continue forever is unrealistic, potentially causing significant biases on the estimates of the COE and the expected earnings growth

[5] In our model, the term structure of COE is assumed to be flat (i.e., constant over time).

rate unless the assumption captures a true parameter value.[6]

We assume that the excess earnings of firm i ($e_t^{ex,i}$) uniformly grow at the conditional and unbiased expected earnings growth rate ($g_{E,t}^i$), which is determined from the information available at period t ($t \geq 0$)[7] as

$$e_{s+1}^{ex,i} = e_s^{ex,i}\left(1 + g_{E,t}^i\right) + \epsilon_{s+1}^i, \ s \geq t, \tag{6}$$

where ϵ_{s+1} expresses the stochastic error terms. The terms are assumed to be stochastically independent of other variables, and the expected values of the terms with respect to i ($\in \{1, \cdots, N\}$) are assumed to be zero ($E_t\left[\epsilon_{s+1}^i\right] = 0, s \geq t$). Substituting equation (6) into equation (5), we obtain

$$V_t^i = B_t^i + \sum_{j=1}^{\tau_t} \frac{e_t^{ex,i}\left(1 + g_{E,t}^i\right)^j}{\left(1 + R_{E,t}^i\right)^j}. \tag{7}$$

We calculate residual incomes from forecasts ($\hat{e}_{t+1}$) on the net income after tax described as $\hat{e}_{t+1}^{ex,i} \equiv \hat{e}_{t+1} - R_{E,t}^i B_t$.[8] We then input the calculated incomes into equation (7) as proxies for the investors' expected excess earnings at period $t+1$. Since $\hat{e}_{t+1}$ may suffer from measurement errors, we explicitly consider the error as

$$\hat{e}_{t+1}^{ex,i} = e_t^{ex,i}\left(1 + g_{E,t}^i\right) + \zeta_{t+1}^i, \tag{8}$$

where ζ_{t+1}^i represents the measurement errors in the forecast. Substituting equation (8) into equation (7), we obtain

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[6] Flexibility in estimations may be enhanced by adding new parameter (the expected excess earnings duration, τ) to the estimation of the COE (R_E) and the expected earnings growth rate (g_E).

[7] The expected earnings growth rate is specified parametrically as $\mathbb{E}_t\left[e_{s+1}^{ex,i}\right] \equiv e_s^{ex,i}\left(1 + g_{E,t}^i\right)$ ($s \geq t$). Given that the net income grows at the ratio of the internal reserve to the net asset (the expected earnings growth rate is $g_{E,t} \equiv \frac{(1-\rho)e_t}{B_{t-1}}$, where ρ is the dividend payout ratio), the net income, the expected excess earnings and the net asset grow at the expected earnings growth rate $g_{E,t}$ ($x_{t+1} = \left(1 + g_{E,t}\right)x_t, (\forall t), x \in \{e, e^{ex}, B\}$) under the clean surplus relation.

[8] We use one-year-ahead forecasts on the individual firms' ROE (consensus value) as proxies for the one-year-ahead unbiased ROE forecasts. We do not use mid- to long-term horizon forecasts, because measurement errors in forecasts are broadly recognized as non-negligible (e.g., Harris [1999], Chan, Karceski, and Lakonishok [2003], Guay, Kothari, and Shu [2011]). Measurement errors exist even in short-term horizon earnings forecasts (e.g., Hou, Dijk, and Zhang [2012], Larocque [2013]), but since many studies have indicated smaller measurement errors in short-term forecasts (e.g., La Porta [1996], Dechow and Sloan [1997], Chan, Karceski, and Lakonishok [2003], Hong and Kubik [2003], Barniv *et al*. [2009], Jung, Shane, and Yang [2012]), and because it is difficult to find other good proxies for the short-term true forecasts, we use short-term forecasts as inputs. The existing research suggests that short-term horizon forecasts have smaller measurement errors because the enrollment periods of analysts are typically too short, and consequently they do not have incentives to frequently update longer forecasts (Hong and Kubik [2003]).

$$V_t^i = B_t^i + \sum_{j=1}^{\tau_t} \frac{\hat{e}_{t+1}^{ex,i}\left(1 + g_{E,t}^i\right)^{j-1}}{\left(1 + R_{E,t}^i\right)^j} + \eta_t^i. \tag{9}$$

Note that η_t^i shows the cumulative impact of measurement errors in the theoretical stock value $(-\sum_{j=1}^{\tau_t} \frac{\zeta_{t+1}^i(1+g_{E,t}^i)^{j-1}}{(1+R_{E,t}^i)^j})$. This term exists because unbiased expected values of the residual income at future period $t+1$ ($\mathbb{E}_t[e_{t+1}^{ex,i}] \equiv e_t^{ex,i}(1 + g_{E,t}^i)$) are replaced by forecasts on residual incomes $\hat{e}_{t+1}^{ex,i}$.

Next, we use the stock price $P_{i,t}$ instead of the theoretical value of the stock V_t^i. The issue here is that the stock price of firm i at period t ($P_{i,t}$) may not necessarily coincide with the theoretical value of the stock (V_t^i) in equation (9) for a variety of reasons, including model risks or market inefficiency. Therefore, the relation between the stock price ($P_{i,t}$) and the theoretical value of the stock (V_t^i) is defined with noise terms (ξ_t^i) as

$$\begin{aligned} P_{i,t} &= V_t^i + \xi_t^i \\ &= B_t^i + \sum_{j=1}^{\tau_t} \frac{\hat{e}_{t+1}^{ex,i}\left(1 + g_{E,t}^i\right)^{j-1}}{\left(1 + R_{E,t}^i\right)^j} + \eta_t^i + \xi_t^i \\ &= B_t^i + \frac{\hat{e}_{t+1}^{ex,i}}{\left(R_{E,t}^i - g_{E,t}^i\right)}\left(1 - \left[\frac{1 + g_{E,t}^i}{1 + R_{E,t}^i}\right]^{\tau_t}\right) + \tilde{\varepsilon}_t^i. \end{aligned} \tag{10}$$

Here, $\tilde{\varepsilon}_t^i \equiv \eta_t^i + \xi_t^i$ holds, and $\{\tilde{\varepsilon}_t^i\}_{i=1}^N$ is assumed to follow a distribution with zero mean at each period t.

Dividing both sides of equation (10) with B_t^i, a residual income model with finite expected excess earnings duration is derived as

$$\frac{P_t^i}{B_t^i} = 1 + \frac{\left(ROE_{t+1}^i - R_{E,t}^i\right)}{\left(R_{E,t}^i - g_{E,t}^i\right)}\left(1 - \left[\frac{1 + g_{E,t}^i}{1 + R_{E,t}^i}\right]^{\tau_t}\right) + \varepsilon_t^i, \tag{11}$$

where $\varepsilon_t^i \equiv \tilde{\varepsilon}_t^i / B_t^i$ holds.[9]

We assume that the individual firms' COE ($R_{E,t}^i$) and expected earnings growth rate ($g_{E,t}^i$) are determined from the relative values of the firms' attributes (see Section Ⅲ. D. 2.). We then apply a linear relation for the determining formulas of $R_{E,t}^i$ and $g_{E,t}^i$ as

$$R_{E,t}^i = \sum_{h=1}^{M_X} \lambda_{h,t} X_{h,t}^i = \boldsymbol{X_t^i}^{\boldsymbol{T}} \boldsymbol{\lambda_t} \; (\forall i \in \{1, \cdots, N\}, t \geq 0),$$

[9] This specification is consistent with existing research that assumes convergence of PBR (Vuolteenaho [2002]).

$$g_{E,t}^{i} = \sum_{h=1}^{M_Y} \gamma_{h,t} Y_{h,t}^{i} = \boldsymbol{Y_t^i}^{\boldsymbol{T}} \boldsymbol{\gamma_t} \ (\forall i \in \{1, \cdots, N\}, t \geq 0). \tag{12}$$

Here, $\boldsymbol{X_t^i}$ $(M_X \times 1)$ and $\boldsymbol{Y_t^i}$ $(M_Y \times 1)$ are vectors of firm i's attributes determining its COE and expected earnings growth rate, and M_X and M_Y indicate the number of attributes determining the individual firms' COE and expected earnings growth rate, respectively. The first elements of the vectors are "1". $\boldsymbol{\lambda_t}(M_X \times 1)$ and $\boldsymbol{\gamma_t}$ $(M_Y \times 1)$ are premium vectors for the COE and weight vectors for the expected earnings growth rate.

In the following sections, the firms' COE $(R_{E,t}^{i}, \forall i \in \{1, \cdots, N\})$, the expected earnings growth rate $(g_{E,t}^{i}, \forall i \in \{1, \cdots, N\})$ and the expected excess earnings duration (τ_t) at period $t(\geq 0)$ are simultaneously identified based on equations (11) and (12).

III. Methodology and Data

A. Methodology

Individual firms' COE $(R_{E,t}^{i}, \forall i \in \{1, \cdots, N\})$, expected earnings growth rates, $\left(g_{E,t}^{i}, \forall i \in \{1, \cdots, N\}\right)$ and (common) expected excess earnings durations (τ_t) are estimated from the cross-sectional data on stock prices and firms' attributes at period t by employing the statistical model described in equations (11) and (12).[10] For inferring parameters, maximum-likelihood approach is a standard approach and, to apply this method to equations (11) and (12), the stochastic structure (e.g., information on the cross-sectional dependency at each period) of the stochastic error terms ε_t^i in equation (11) must be identified *ex ante*. However, since the stochastic error terms $\{\varepsilon_t^i\}_{i=1}^{N}$ are affected by a variety of factors such as model risks (e.g., misspecification risks) and measurement errors in earnings forecasts, it is unrealistic to *ex ante* specify the stochastic structures of the terms. We therefore employ QML approach which does not require *ex ante* identification and specification of the structures of $\{\varepsilon_t^i\}_{i=1}^{N}$ in order to obtain consistent estimators. Thus, parameters including the COE are estimated as QML estimators.

In detail, as given by equation (13), the estimators are obtained by maximizing

[10] Parameters in equation (11) are estimated from cross-sectional data at each period as a cross-section model, and we do not infer panel data models incorporating time-series information into the estimation. This is because the "implied cost of capital" is the estimates from the currently available market information for investors, and we would like to observe how distributions of individual firms' COE change over time. Further, we intentionally avoid to select the sample periods for the estimation, because the estimates may be affected by the choice of the periods for the estimation.

quasi-logarithm likelihoods, which are set by assuming normality of the distribution of each error term. In reality, it is possible that each error term $\{\varepsilon_t^i\}_{i=1}^N$ does not follow a normal distribution. Even so, estimators obtained by maximizing quasi-likelihoods are still consistent (e.g., White [1994]).

$$\max_{\lambda_t,\gamma_t,\tau_t} \quad \ln\left[(2\pi)^{-\frac{N}{2}}\left|\boldsymbol{\Sigma}_{\boldsymbol{\varepsilon},\boldsymbol{t}}\right|^{-\frac{1}{2}} exp\left(-\frac{1}{2}(\boldsymbol{Z_t}-\boldsymbol{M_t})^{\top}\boldsymbol{\Sigma}_{\boldsymbol{\varepsilon},\boldsymbol{t}}^{-\boldsymbol{1}}(\boldsymbol{Z_t}-\boldsymbol{M_t})\right)\right] \quad (\forall t) \tag{13}$$

where

$$\boldsymbol{Z_t} = \begin{pmatrix} P_t^1/B_t^1 \\ P_t^2/B_t^2 \\ \vdots \\ P_t^N/B_t^N \end{pmatrix} : N \times 1 \qquad \boldsymbol{M_t} = \begin{pmatrix} 1+\dfrac{\left(ROE_{t+1}^1 - R_{E,t}^1\right)}{\left(R_{E,t}^1 - g_t^1\right)}\left(1-\left[\dfrac{1+g_{E,t}^1}{1+R_{E,t}^1}\right]^{\tau_t}\right) \\ 1+\dfrac{\left(ROE_{t+1}^2 - R_{E,t}^2\right)}{\left(R_{E,t}^2 - g_{E,t}^2\right)}\left(1-\left[\dfrac{1+g_{E,t}^2}{1+R_{E,t}^2}\right]^{\tau_t}\right) \\ \vdots \\ 1+\dfrac{\left(ROE_{t+1}^N - R_{E,t}^N\right)}{\left(R_{E,t}^N - g_{E,t}^N\right)}\left(1-\left[\dfrac{1+g_{E,t}^N}{1+R_{E,t}^N}\right]^{\tau_t}\right) \end{pmatrix} : N \times 1,$$

$$R_{E,t}^i = \boldsymbol{X_t^i}^{\boldsymbol{T}}\boldsymbol{\lambda_t}, \qquad g_{E,t}^i = \boldsymbol{Y_t^i}^{\mathbf{T}}\boldsymbol{\gamma_t}, \qquad \forall i \in \{1,\cdots,N\},$$

hold and $\boldsymbol{\Sigma}_{\boldsymbol{\varepsilon},\boldsymbol{t}}$ ($N \times N$ matrix) shows the covariance matrix for the standard errors under heteroscedasticity ($\boldsymbol{\Sigma}_{\boldsymbol{\varepsilon},\boldsymbol{t}} = \sigma_{\varepsilon,t}^2\boldsymbol{I}_{\boldsymbol{N}\times\boldsymbol{N}}$ holds under homoscedasticity). If $\boldsymbol{\Sigma}_{\boldsymbol{\varepsilon},\boldsymbol{t}} = \sigma_{\varepsilon,t}^2\boldsymbol{I}_{\boldsymbol{N}\times\boldsymbol{N}}$ holds, then equation (13) can be simplified as

$$\max_{\lambda_t,\gamma_t,\tau_t} \ln\left[(2\pi)^{-\frac{N}{2}}{\sigma_{\varepsilon,t}^2}^{-\frac{N}{2}} \exp\left(-\frac{1}{2\sigma_{\varepsilon,t}^2}(\boldsymbol{Z_t}-\boldsymbol{M_t})^T(\boldsymbol{Z_t}-\boldsymbol{M_t})\right)\right](\forall t). \tag{14}$$

Although consistent estimators can be obtained by optimization of the problem above, the calculation of standard errors (and *t*-values) remains an issue. We need to employ a method for inferring the standard errors of the QML estimator instead of the method for maximum likelihood estimators (e.g., White [1994]). Detailed information on the method for inferring the standard errors of the estimators and the asymptotic distribution of the QML estimator are shown in Appendix 1.

B. Data

Data samples were selected to satisfy the following criteria: 1) listed on the First Section of the Tokyo Stock Exchange (excluding the financial industry sector), 2) a fiscal year ending in March, 3) having all necessary variables for the inference and 4) having non-negative net assets (book value) and one-year-ahead ROE forecast.[11] The sample periods are from January 2002 to May 2015, and thus there are 161 single-month periods. There are 500–650 sample firms for each sample period. Data sources for financial statements, analyst forecasts and stock markets were NIKKEI NEEDS, IFIS and Bloomberg, respectively. Detailed information on these data sources, compilation methods and descriptive statistics of the input variables are provided in Appendix 2.

For the statistical inference, we assume that financial variables for account settlements in March for the previous fiscal year were disclosed in June of the current fiscal year. Variables for the year before the previous fiscal year are input for estimation of the COE in April and May, and variables for the previous fiscal year are input for estimation of the COE from June through the following March. The most recent ROE forecasts for the previous fiscal year's results of account settlement are input for estimation of the COE in April, and the most recent forecasts for the same fiscal year's results are input for estimation from May to the following March.[12] The forecasts used for our estimation are updated on a monthly basis.

C. Steps for Estimation and Statistical Tests

Estimations and statistical tests are conducted by the following processes (Table 1). First, QML approach is applied assuming homoscedasticity. We then apply the Breusch–Pagan test (Breusch and Pagan [1979]) for the calculated *ex post* errors. If this test detects heteroscedasticity, we re-apply QML approach with the weighting matrix calculated from information on the *ex post* errors. The appropriate method for calculating the standard errors of the estimators depends on whether each error follows a normal distribution. We then apply the Jarque–Bera test (Jarque and Bera [1980, 1981, 1987]) to examine normality of the errors. When non-normality is detected, the standard errors and *t*-values are calculated based on White (1994).[13] Otherwise, we calculate the

[11] Negative one-year-ahead earnings forecasts contradict model assumptions that earnings grow at the same rate over the horizon. On the other hand, we consider firms with negative ROE forecasts and *ex post* negative residual incomes in our estimation, because it is consistent with our idea that earnings and COE (volume) grow at the same rate. Our idea thus conceptually admits negative residual income if the firm's COE (rate) is greater than the firm's ROE.

[12] This input rule causes a discrepancy of the timing between inputs for financial variables (results for the year before the previous fiscal year) and inputs for analyst forecasts (forecasts on the results for the previous fiscal year). Even so, no modification is performed, because the modified results (e.g., correction of forecast values using historical payout ratios) are not critically different from unmodified ones.

[13] The asymptotic normality theorem of the QML estimator is applied to calculate *t*-values, because we have more than 500 samples. Nonetheless, the number of the samples might be too few to ensure

standard errors and t-values based on the calculation method for the maximum likelihood estimators. These procedures are repeated for all sample periods.

Table1: Steps for estimation and statistical tests.

1)	First-round estimation assuming homoscedasticity.
2)	Breusch–Pagan test for heteroscedasticity.
3)	Second-round estimation with weighting matrix (calculated based on the errors obtained from the first-round estimation) if the Breusch–Pagan test detects heteroscedasticity.
4)	Jarque–Bera test to detect non-normality of the errors.
5)	Calculating standard errors and t-values. The method suggested by White (1994) is applied if non-normality is detected, the method for maximum likelihood estimators otherwise.
Repeat steps 1)–5) for all sample periods (January 2002 to May 2015)	

D. Estimation of Market-, Industry-, and Individual-based Cost of Equity

1. Market- and industry-based cost of equity

The QML approach is applied to estimate the market-based COE ($R_{E,t}$), assuming that all firms share the same COE ($R_{E,t} = R^i_{E,t}$,$\forall i$),[14] and to interpret the results. We also estimate the industry-based COE for industry sectors with more than twenty samples within the industry. The industry classification basically follows the 33 Tokyo Stock Exchange industry sectors, but we merge industries with few samples into a similar industry (see Appendix 3 for details). The estimates of the industry-based COE are described in Appendix 4.

2. Individual-based cost of equity

a. Selection of the determinants of the COE and expected earnings growth rate

In the empirical finance literatures, cross-sectional variations in the expected stock

accuracy of the approximation values about the true distribution of the QML estimator. Other calculation methods such as bootstrap methods may therefore be more appropriate.

[14] Individual firms' COE ($R^i_{E,t}$) and the expected earnings growth rate ($g^i_{E,t}$) are estimated with the assumptions $R_{E,t} = R^i_{E,t}$, $g_{E,t} = g^i_{E,t}$, $\forall i \in \{1, \cdots, N\}$, based on the optimization problem given by equation (13). When the expected earnings growth rate ($g_{E,t}$) and the expected excess earnings duration (τ_t) are simultaneously identified with COE ($R_{E,t}$), the combination of $g_{E,t}$ and τ_t may not be uniquely identified. We therefore conduct other estimations: simultaneously identifying $R_{E,t}$ and τ_t by exogenously inputting $g_{E,t}$, and simultaneously identifying R_E and $g_{E,t}$ by exogenously inputting τ_t.

returns of individual firms tend to be effectively explained by 1) market beta (β_{Mkt}), 2) book-to-market value factor beta (β_{HML}), 3) market cap factor beta (β_{SMB}), 4) earning/price (E/P) or 5) financial leverage (market value basis)[15] (e.g., Fama and French [1992]). Studies on Japan's equity markets report that 4') cash-flow/price (C/P) has a strong interrelation with differences in individual firms' expected stock returns (Chan, Hamao, and Lakonishok [1991]). Further, many studies have found that 6) Dividend/Price (D/P) has a stronger interrelation with expected stock returns (Campbell and Shiller [1988], Kothari and Shanken [1997], Stambaugh [1999], Campbell and Yogo [2006], Binsbergen and Koijen [2010], Bilson, Kang, and Luo [2015], Maio and Santa-Clara [2015]). Following the existing research, six variables are selected as candidate attributes of firms determining individual firms' COE in our model (Table 2).[16]

Table 2: Candidate attributes

1)	β_{Mkt}: Beta coefficients for market factors of Fama–French 3 (FF3) factors.
2)	β_{HML}: Beta coefficients for the HML factor of FF3 factors. (Note 1)
3)	β_{SMB}: Beta coefficients for the SMB factor of FF3 factors. (Note 2)
4')	C/P: Cash-flow/price (CF/market capitalization; CF = net income after tax + depreciation expenses + interest expenses and commissions).
5)	Financial Leverage (market value basis) : Debt/market capitalization
6)	D/P: Dividend/price

Note 1: HML is an abbreviation for high-minus-low. The HML factor is the portfolio returns of the net zero position composed of the long position on higher book-to-market stocks and the short position on lower book-to-market stocks.

Note 2: SMB is an abbreviation for small-minus-big. The SMB factor is the portfolio returns of the net zero position composed of the long position on larger market cap stocks and the short position on smaller market cap stocks.

[15] According to Fama and French (1992) and Bhandari (1988), there is a positive interrelation between the market values of financial leverage and expected stock returns and a negative interrelation between the book values of financial leverage and the returns.

[16] There may exist important candidates other than the six variables listed here. For example, in the empirical finance literature, "stock-price momentum" (the tendency for increasing stock prices to rise further, and decreasing prices to keep falling) and "stock-return reversal" (the tendency for increasing stock prices to go down later, and decreasing prices to go up later) have been recently acknowledged as main factors explaining cross-sectional variations in expected stock returns of individual firms. We categorize those variables as "technical" variables which are derived only from the market variables such as past movement of stock prices or trading volume of the stocks. In this sense, our research focuses on the "fundamental" variables which are derived based on the individual firms' financial variables such as profit, cash flow, dividend and net assets.

With respect to the attributes determining individual firms' expected earnings growth rates, following Nekrasov and Ogneva (2011), industry-based ROE forecasts – individual-based ROE forecasts[17] and ratio of R&D expenses to sales[18] are selected. We assume no large differences among firms' expected excess earnings durations, and thus estimated them as a common parameter.

b. Standardization of individual firms' attributes

As explained above, our model assumes that the relative values of the firms' attributes determine individual firms' COE. When we transform absolute values to relative values, we standardize original distributions of the attributes to distributions with mean zero and variance one. We apply two types of the standardization: 1) standardization among all firms in the same period (Method 1), and 2) standardization among firms within the same industry at the same period (Method 2; see, e.g., Goodman and Peavy [1983], Cohen and Polk [1998]). Note that the industry sector classification for industry-based standardization is the same as estimation of industry-based COE (see Appendix 3).

Table 3: Standardization of attributes

Method 1) market-based	The relative values of each attribute among all firms determine individual firms' COE.
Method 2) industry-based	The relative values of each attribute within the industry determine individual firms' COE within the industry.

c. Candidate models

Considering the existing research, candidate models were selected as follows. First, models with only FF3 factors (Table 4: 1, 4), models with only three financial variables (2, 5) and models with both FF3 factors and financial variables (3, 6) are the baseline models. Moreover, since correlations between financial variables (C/P, financial leverage and D/P) tend to be high (Table 5), we add models eliminating one of the

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17 ROE is reported to have a mean-reverting property (e.g., Fama and French [2000], Healy *et al.* [2014]), and it is theoretically hypothesized that firms with higher ROE cannot maintain strong competitive power; in the long term, the ROE would converge to the mean level. The sign condition on the variable is supposed to be positive.

18 Ratio of R&D expenses to sales is considered as a representative indicator for measuring a firm's growth capability (e.g., Leonard [1971]). We thus adopt the hypothesis that firms with more R&D intensity tend to grow at higher rates than other firms, despite being affected by the mean-reverting property of ROE. The sign condition on variables is supposed to be positive.

variables (Table 4: 7–12) to the candidates. Further, we also examine models with E/P in place of C/P (13–20). Both standardization methods are applied to every candidate for COE estimation and expected earnings growth rate.

d. Criteria for model selection

Our main model is selected from the candidates listed in (c.), based on the Akaike's information criterion (AIC, Akaike [1973])[19] or the Bayesian information criterion (BIC, Schwarz [1978])[20], calculated from quasi-likelihoods.

Table 4: Candidate models

Models		Standarization	Fama-French 3 Factors			Financial Variables			
			βMkt	βHML	βSMB	C/P	Leverage	D/P	E/P
Baseline	1	Market-based	○	○	○	-	-	-	-
	2		-	-	-	○	○	○	-
	3		○	○	○	○	○	○	-
	4	Industry-based	○	○	○	-	-	-	-
	5		-	-	-	○	○	○	-
	6		○	○	○	○	○	○	-
without D/P	7	Market-based	○	○	○	○	○	-	-
	8	Industry-based	○	○	○	○	○	-	-
witout C/P	9	Market-based	○	○	○	-	○	○	-
	10	Industry-based	○	○	○	-	○	○	-
without Leverage	11	Market-based	○	○	○	○	-	○	-
	12	Industry-based	○	○	○	○	-	○	-
E/P in place of C/P	13	Market-based	-	-	-	-	○	○	○
	14		○	○	○	-	○	○	○
	15		○	○	○	-	○	-	○
	16		○	○	○	-	-	○	○
	17	Industry-based	-	-	-	-	○	○	○
	18		○	○	○	-	○	○	○
	19		○	○	○	-	○	-	○
	20		○	○	○	-	-	○	○

[19] Denote the quasi-likelihood as f and the number of explanatory variables as k. Then AIC $= -2\ln f + 2k$ holds.

[20] Define the quasi-likelihood as f, the number of explanatory variables as k, and the number of samples as n. Then BIC $= -2\ln f + k\ln(n)$ holds.

Table 5: Correlations between attributes (after standardization)

＜Market-based standardization＞

	1) β_{Mkt}	2) β_{HML}	3) β_{SMB}	4) E/P	4') C/P	5) Leverage	6) D/P
1) β_{Mkt}	1.00	-0.01	0.06	-0.05	0.02	0.10	-0.16
2) β_{HML}	-0.01	1.00	-0.04	-0.08	0.06	0.19	0.12
3) β_{SMB}	0.06	-0.04	1.00	0.05	0.00	0.03	0.01
4) E/P	-0.05	-0.08	0.05	1.00	0.61	-0.15	0.16
4') C/P	0.02	0.06	0.00	0.61	1.00	0.48	0.20
5) Leverage	0.10	0.19	0.03	-0.15	0.48	1.00	0.07
6) D/P	-0.16	0.12	0.01	0.16	0.20	0.07	1.00

＜Industry-based standardization＞

	1) β_{Mkt}	2) β_{HML}	3) β_{SMB}	4) E/P	4') C/P	5) Leverage	6) D/P
1) β_{Mkt}	1.00	0.03	0.07	-0.04	0.06	0.19	-0.13
2) β_{HML}	0.03	1.00	-0.05	-0.08	0.08	0.20	0.08
3) β_{SMB}	0.07	-0.05	1.00	0.06	0.04	0.07	0.01
4) E/P	-0.04	-0.08	0.06	1.00	0.59	-0.13	0.23
4') C/P	0.06	0.08	0.04	0.59	1.00	0.45	0.24
5) Leverage	0.19	0.20	0.07	-0.13	0.45	1.00	0.01
6) D/P	-0.13	0.08	0.01	0.23	0.24	0.01	1.00

IV. Results

A. Market-based Cost of Equity

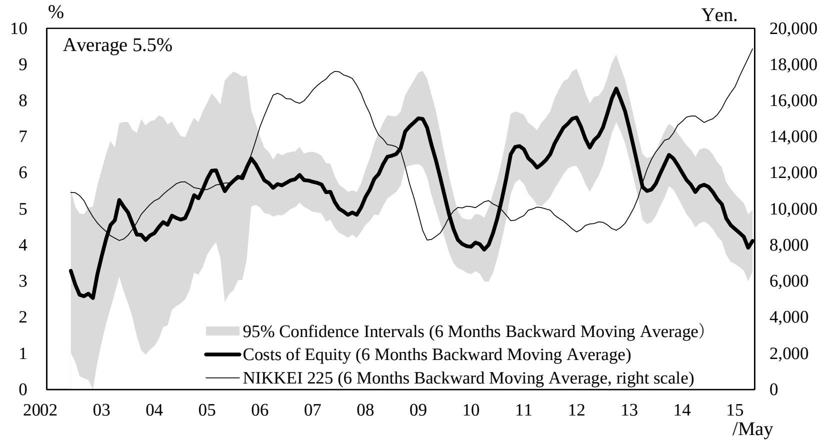
1. Cost of equity

Figure 1(a) shows the estimates of market-based COE. The COE values drifted around 5% until the collapse of Lehman Brothers, and the values rose sharply to 8% in 2009, immediately following that event. Thereafter, values declined suddenly in 2010, but rose again through 2011–13. This upward movement is connected with the increases in one-year-ahead ROE forecasts (Figure 1(c)) and with the deterioration of the diffusion index (Figure 1(d)). Then those movements can be interpreted as the increases of the risk premium for the uncertainty of future business conditions. After these periods, the COE peaked in mid-2012, and then values uniformly declined until May 2015 (the last sample period). Around the same time, equity spreads (ROE forecasts – COE) had become wider because ROE forecasts had increased, whereas COE had declined sharply (Figure 1(b)). Therefore, the increase of the stockholder values of the firms caused by widening of the equity spreads might contribute to the increase of the stock prices during the periods.

The results also show that the standard errors of the estimates were relatively large until 2006, and these results can be explained by the huge variations in the dependent variable, price-to-book ratio (PBR), across individual firms while the small variations in the explanatory variable, forecasted ROE, in these periods (Figure 1(e)). Figure 1(e) also shows quasi-coefficients of determination (McFadden [1974]), which imply that values during this period were quite low compared to those in the other periods.

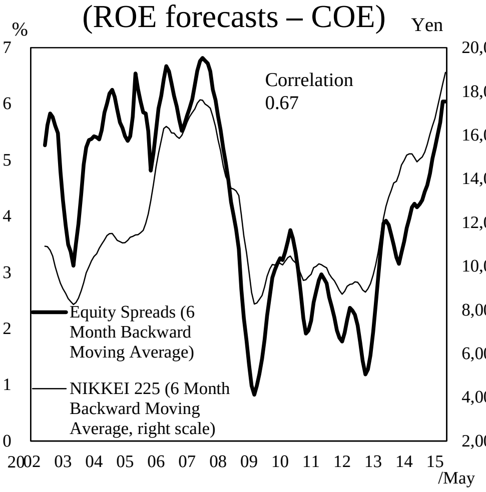
Figure 1: Market-based cost of equity (annual rate)

(a) Estimates of cost of equity

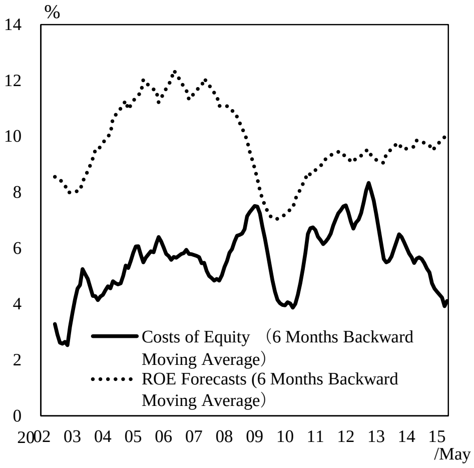


(b) Equity spreads

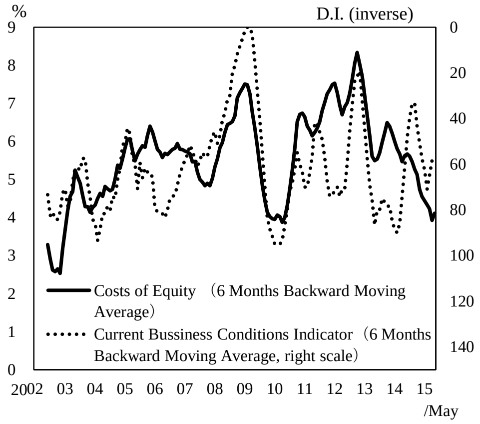
(ROE forecasts – COE)



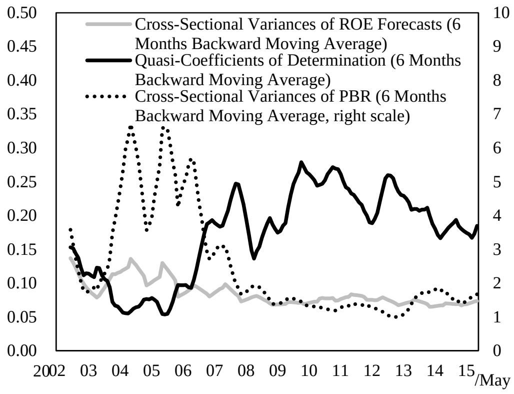
(c) Return on equity forecasts



(d) Current business conditions



(e) Quasi-coefficients of determination



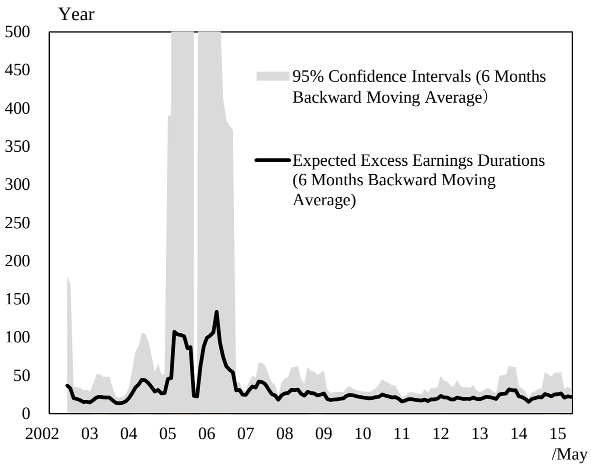
2. Expected excess earnings durations

Regarding estimates of expected excess earnings durations, the time-series average is around 31 years, and the median is around 22 years[21] (Figure 2).[22] Therefore, stock investors might expect excess earnings of each firm to decrease in the future, but the duration is long (though not infinite).

Estimated duration in 2005–06 were much longer than those in other periods, and the confidence intervals of the estimates were wide. This possibly occurs because the estimates of the COE $(R_{E,t})$ and the expected earnings growth rate $(g_{E,t})$ had almost the same values during the periods, and thus the sensitivity of quasi-likelihoods to changes in the duration (τ_t) was extremely low.[23]

Figure 2: Expected excess earnings durations

(a) Estimates



(b) Descriptive statistics of estimates

	Year
Average	31.1
Max	394.4
1st Quantile	30.6
Median	21.5
3rd Quantile	15.5
Min	9.3

[21] The mean age of Japanese firms that went bankrupt in 2014 was 23.5 years (Tokyo Shoko Research [2015]). This measure is for Japanese firms including sole proprietorships and small- and medium-sized enterprises. Given that the firms listed on the First Section of the Tokyo Stock Exchange are generally blue-chip firms, their life expectancy should be much longer than 23.5 years, and thus our estimation results (22-year median) on the expected excess earnings duration are reasonable.

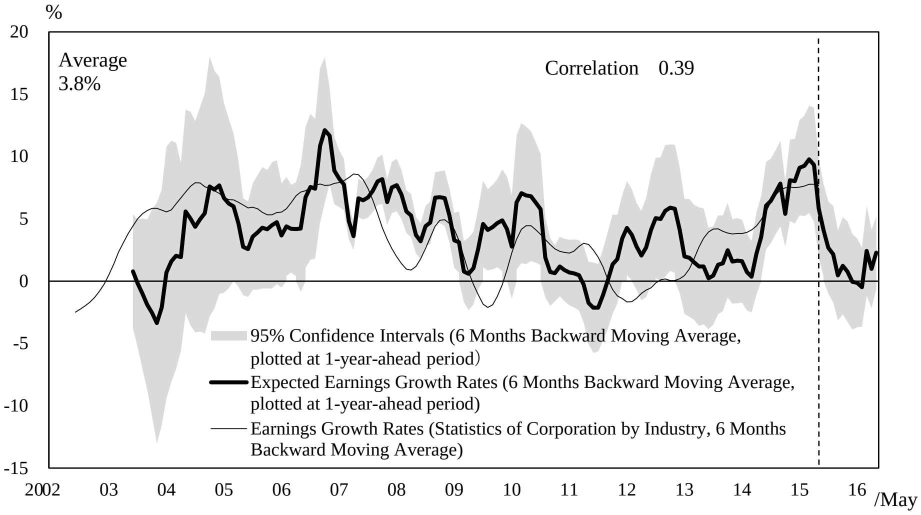
[22] These values are longer than findings of five to ten years in the existing research (Sakurai [2010], pp. 289-296). This discrepancy partly originates from differences in the assumptions on excess earnings in the long-run equilibrium; existing research estimates trends in the deviation from excess long-term earnings by allowing the value to be positive. In contrast, we explicitly assume zero excess earnings in the long-term equilibrium (on theoretical grounds) and then estimate the duration of positive excess earnings. Moreover, there is a difference between COE estimated in our model and that used in Sakurai (2010) (pp. 289-296).

[23] When only two variables $R_{E,t}$ and τ_t are simultaneously identified with the exogenously determined $g_{E,t}$, the time-series averages of the estimates for τ_t are calculated as follows. τ_t is about 117 years for $g_{E,t}$ = 0.5%, about 20 years for $g_{E,t}$= 5%, about 14 years for $g_{E,t}$ = 10% and about 9 years for $g_{E,t}$= 20%.

3. Expected earnings growth rates

Figure 3 shows estimates for the realized earnings growth rate. The developments in the estimates have been mostly linked with the realized rate calculated from "statistics of corporations by industry," and the average growth rate over all sample periods is 3.8%.[24]

Figure 3: Expected earnings growth rates (annual rate)



B. Individual-based Cost of Equity

1. Selected model

Table 6 shows the adoption rates of each candidate model over the sample periods. The model selection is based on AIC or BIC. According to the table, adoption rates for each candidate are the same between AIC- and BIC-based selection, and the rate of candidate model 6 is the largest among the candidates (around 30%).

[24] When only two variables $R_{E,t}$ and $g_{E,t}$ are simultaneously identified with the exogenously determined τ_t, the time-series averages of the estimates for $g_{E,t}$ are computed as follows. $g_{E,t}$ is about 17% for τ_t=10 years, $g_{E,t}$ =1.7% for τ_t=25 years, $g_{E,t} = -0.6\%$ for τ_t=50 years, and $g_{E,t} = -1.0\%$ for $\tau_t \to \infty$.

Table 6: Results of model selection

Models		Standarization	Fama-French 3 Factors			Financial Variables				Adoption Rates from AIC (%)	Adoption Rates from BIC (%)
			βMkt	βHML	βSMB	C/P	Leverage	D/P	E/P		
Baseline	1	Market-based	○	○	○	-	-	-	-	3.1	3.1
	2		-	-	-	○	○	○	-	6.2	6.2
	3		○	○	○	○	○	○	-	10.6	10.6
	4	Industry-based	○	○	○	-	-	-	-	0.0	0.0
	5		-	-	-	○	○	○	-	1.2	1.2
	6		○	○	○	○	○	○	-	29.8	29.8
without D/P	7	Market-based	○	○	○	○	○	-	-	4.3	4.3
	8	Industry-based	○	○	○	○	○	-	-	1.2	1.2
witout C/P	9	Market-based	○	○	○	-	○	○	-	6.8	6.8
	10	Industry-based	○	○	○	-	○	○	-	0.6	0.6
without Leverage	11	Market-based	○	○	○	○	-	○	-	3.7	3.7
	12	Industry-based	○	○	○	○	-	○	-	6.8	6.8
E/P in place of C/P	13	Market-based	-	-	-	-	○	○	○	3.1	3.1
	14		○	○	○	-	○	○	○	4.3	4.3
	15		○	○	○	-	○	-	○	3.1	3.1
	16		○	○	○	-	-	○	○	5.6	5.6
	17	Industry-based	-	-	-	-	○	○	○	1.9	1.9
	18		○	○	○	-	○	○	○	4.3	4.3
	19		○	○	○	-	○	-	○	0.6	0.6
	20		○	○	○	-	-	○	○	2.5	2.5

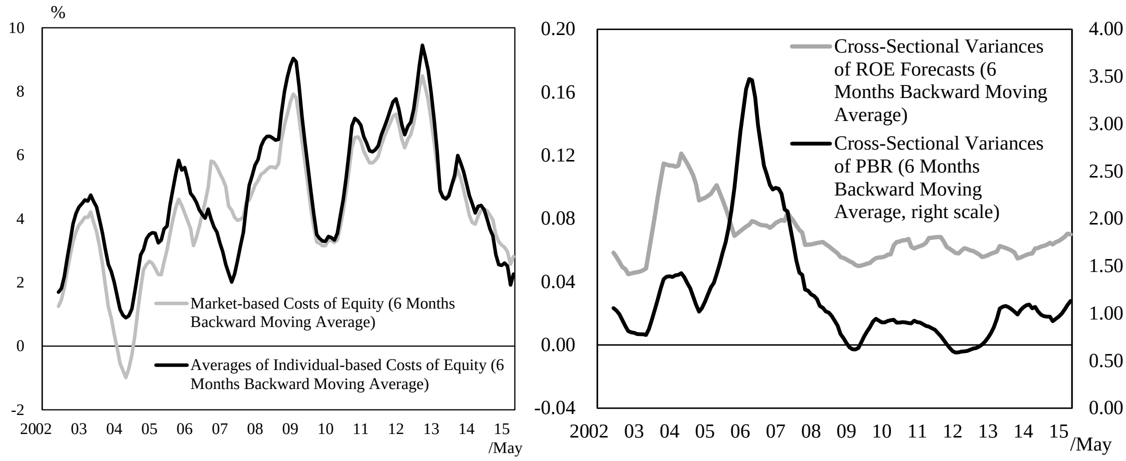
2. Distributions of individual firms' cost of equity

In this section, we estimate the individual-based COE by employing model 6. Figure 4(a) compares the averages of the estimated individual-based COE with estimates of the market-based COE (estimated from the same samples for the estimation of the individual-based COE), as inferred by model 6. The figure indicates that both values moved similarly, except for the period 2004–07. Note that variations in PBR across individual firms during these periods were large, although those in ROE forecasts were small (Figure 4(b)). According to Figure 4(c), the confidence intervals of the market-based COE are wider than the average of the individual-based COE, implying that it is essential to consider the heterogeneity across firms even when estimating the market-based COE.

Figure 4: Individual-based Cost of Equity

(a) Comparison of COE

(b) Variances of ROE forecasts and PBR



(c) 95% confidence intervals of COE estimates

Market-based COE

Average of individual-based COE

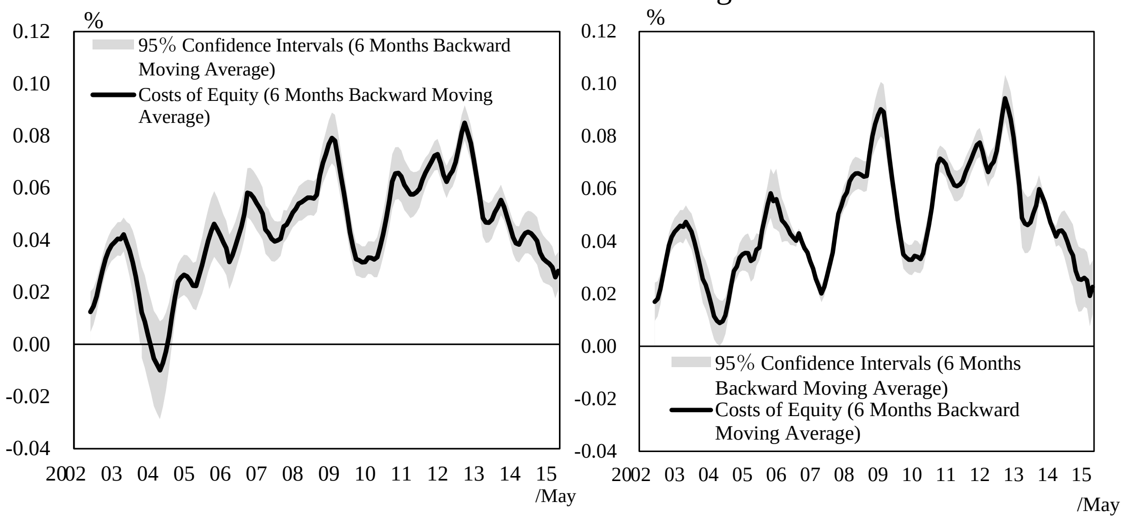
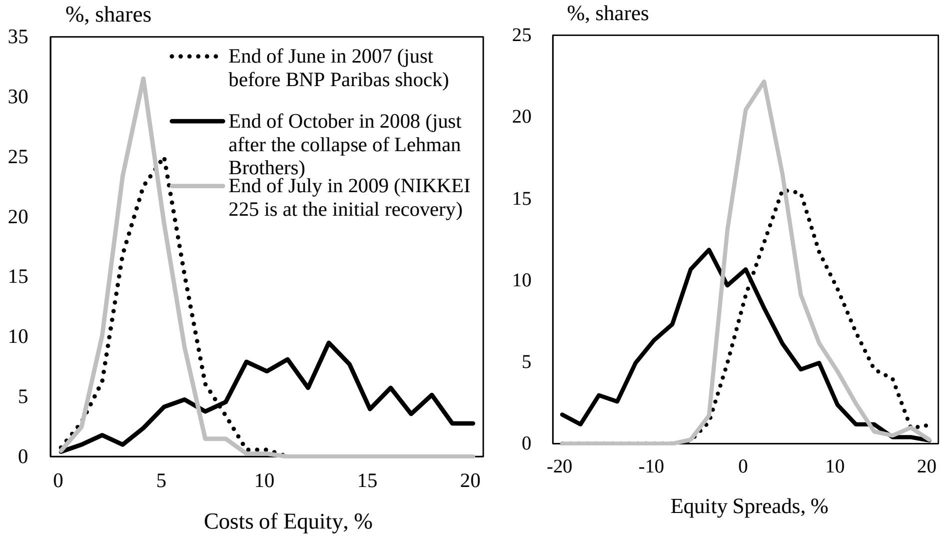


Figure 5 shows how the distributions of individual firms' COE changed around the period of recent financial crisis. The tails of the distributions apparently expanded immediately after the collapse of Lehman Brothers. Thereafter, the tails shrunk as the financial markets regained stability. These observations may imply a causal relation in which the variations of individual firms' COE increase when investors experience financial crises and consequently become more sensitive to risk.[25] In terms of distributions of the equity spreads (ROE forecasts minus COE), the variations of the equity spreads increased and more than half of all firms had negative spreads. The

[25] Another possible explanation is an increase in liquidity premiums. However, stock market turnovers (volumes) in the First Section of the Tokyo Stock Exchange increased by around 25% in October 2008 compared with June 2007, and that number had declined by about –20% in July 2009 compared with October 2008.

increase in the COE might have increased the number of firms facing negative spreads, and consequently depressed stock prices significantly.

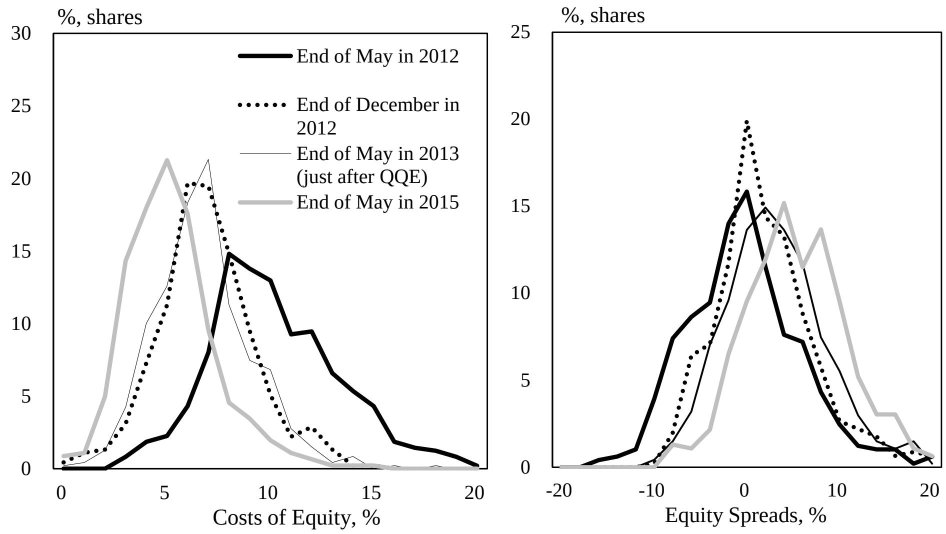
Figure 5: Distributions of COE around the global financial crisis



Similarly, Figure 6 shows how the distributions in individual firms' COE changed around the Bank of Japan's quantitative and qualitative easing (QQE). The figure indicates that the distribution means became smaller and the distribution tails thinned around the QQE.[26] Regarding equity spreads, the distributions moved in parallel to the right, significantly decreasing the number of firms facing negative equity spreads and increasing the number of firms with more than 10% equity spreads. This occurred partly because the lower COE decreased firms' hurdle rates (i.e., levels of ROE for enhancing stock values were lowered).

[26] Stock prices in developed countries rose between May 2012 and May 2015, so Japan's stock markets might have been affected by global trends. However, the increases in stock price in Japan during these periods (about +100%) exceeded those in the United States and Europe by around +50%, so we infer that changes in Japanese firms' costs of equity occurred partly because of the QQE.

Figure 6: Distributions of COE around the QQE

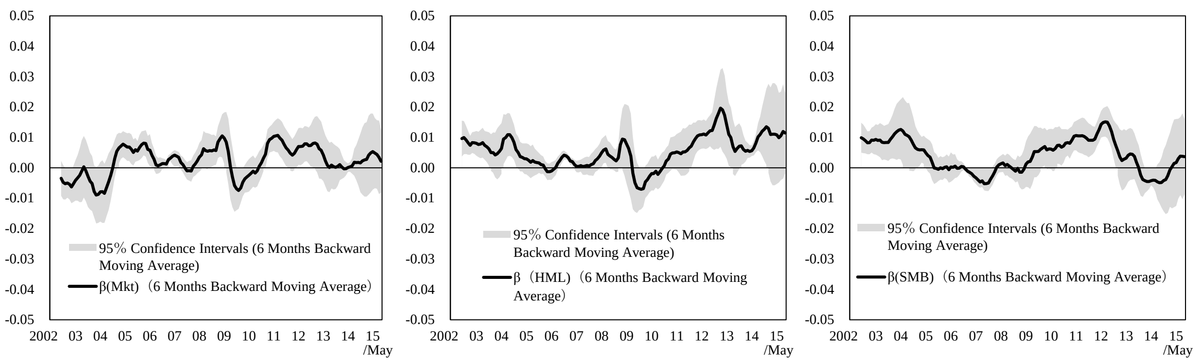


3. Relation between cost of equity and firms' attributes

Figures 7 shows estimates of the premiums (coefficients of the estimates) for the relative values of exposure to FF3 factors on individual firms' COE. According to these figures, premiums did not have positive values in a statistically significant manner through most periods.

Figure 7: Estimates of the premiums on the betas for FF3 factors

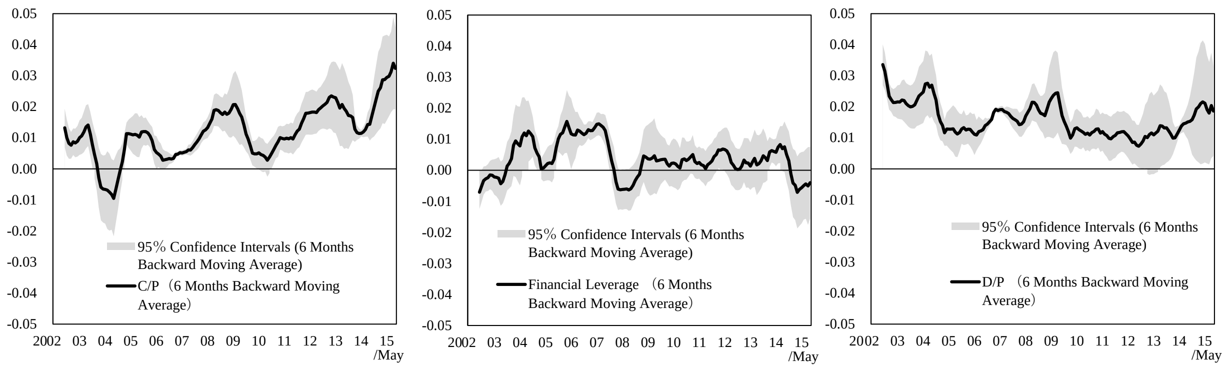
(a) β_{Mkt} (b) β_{HML} (c) β_{SMB}



Figures 8 show estimates of the premiums for the relative values of the financial variables (C/P, financial leverage and D/P) on individual firms' COE. The estimated coefficients of C/P and D/P have positive values and are significant in most of the periods. Financial leverage had statistically significantly positive values only just before the global financial crisis in 2008. Regarding the explanatory power of the variables, before the crisis, the relative values of D/P were the best explanatory variable for individual firms' COE. After the crisis, the relative values of C/P determined the COE most effectively.

Figure 8: Estimates of the premiums on the financial variables

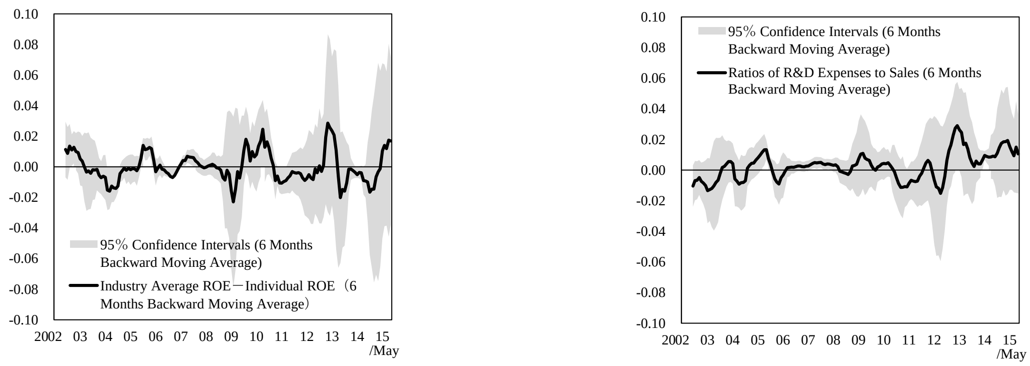
(a) C/P (b) Financial leverage (c) D/P



No coefficients of the explanatory variables for the expected earnings growth rate were significant non-zero values (Figure 9).

Figure 9: Estimates of the premiums on the financial variables

(a) Industry ROE – individual ROE (b) Ratio of R&D expenses to sales



4. Cross-sectional interrelation between cost of equity and expected stock returns

Previous studies on the estimation of implied COE (e.g., Easton and Monahan [2005], Botosan, Plumlee, and Wen [2011], Nekrasov and Ogneva [2011]) use statistical tests to measure the usefulness of COE estimates by examining cross-sectional interrelations between the estimated COE and the expected stock returns. We analyze the strength of the cross-sectional interrelation between the estimated COE and expected stock returns by constructing two portfolios based on the COE estimated by model 6 and by examining the sign and the statistical significance on the averages of the realized stock returns (details are explained in the following section). We also apply the same tests for the estimates of existing implied COE models and compare the results with those of our estimators (see Appendix 5 regarding details and estimated COE in existing models).

a. Factor-mimicking portfolio analysis

As a first step in examining the cross-sectional interrelation between the estimated COE and the expected stock returns, the following linear model is estimated at each period.

$$R_{t+1}^{i} = \alpha_t + \mu_t R_{E,t}^{i} + \epsilon_{t+1}^{i}, \ \forall\, i, t. \tag{15}$$

Here, R_{t+1}^{i} is the monthly stock returns of firm i between t and $t+1$, and $R_{E,t}^{i}$ is the COE of the firm i estimated at period t.

Regarding the estimation of parameters α_t and μ_t (for which estimators are denoted as $\hat{\alpha}_t$ and $\hat{\mu}_t$, respectively), cross-sectional ordinary least squares by Fama and MacBeth (1973) (FM-OLS) is applied at each period t ($\in \{1, \cdots, T\}$), and the sign and the statistical significance of $\bar{\mu} = (1/T)\sum_{t=1}^{T} \hat{\mu}_t$ are examined.[27] The estimates of μ_t, given as $\hat{\mu}_t$, could be interpreted as realized portfolio returns between t and $t+1$ when the zero-cost position following a tilt strategy with the individual firms' COE ($R_{E,t}^{i}$) (i.e., a relative strength strategy based on the individual firms' COE) is constructed at each period t. This position is called the factor-mimicking portfolio.

We next examine the strength of the positive cross-sectional interrelation between the COE estimates and expected stock returns by considering whether the estimates of FM-OLS ($\bar{\mu}$) has a significantly positive value.[28] As a complementary analysis, pooled OLS of equation (15) with all cross-sectional and time-series data is conducted in addition to FM-OLS. Heteroscedasticity-robust standard errors (White [1980]) are applied to the calculation of *t*-values.

Table 7 shows the test results. The *t*-value of model 6 is 5.58, so the null hypothesis ($\bar{\mu} = 0$) is rejected even at the 1% significance level. Moreover, the results of the pooled OLS also show that the *t*-value of model 6 is 4.50, and thus the null hypothesis ($\mu = 0$) is rejected even at the 1% significance level. These results imply a statistically significantly positive relation between the COE estimates of our model and the expected stock returns.[29]

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[27] The standard errors and the *t*-value are calculated as $\bar{\sigma}_\mu = \sqrt{\sum_{t=1}^{T}(\hat{\mu}_t - \bar{\mu})^2 / T(T-1)}$ and $\bar{\mu}/\bar{\sigma}_\mu$, respectively.

[28] Bounded-influence estimation (e.g., Beaton and Tukey [1974]) with an efficiency of 95% is applied for the cross-sectional OLS in each period.

[29] This analysis uses the estimated COE as the explanatory variables, so explanatory variables

b. Quintile portfolio analysis

In the FM-OLS analysis, the portfolio weights are calculated from the relative values of the individual firms' COE (i.e., duplicating relative-strength strategy). It is thus possible that the stock returns of firms having high COE cause strong impacts on portfolio performance.[30] To complement the weakness of the FM-OLS in this analysis, a portfolio with an equal weight for all stocks is constructed, and the portfolio returns are calculated to examine the cross-sectional interrelation between the estimated COE and the expected stock returns. Details of this process are described below.

First, the stocks of individual firms are categorized into five groups (first through fifth quintiles) in descending order, based on the levels of the estimated COE at the end of June 2002. The equal-weighted investments to each group and firms within each group are assumed. The portfolios are rebalanced by duplicating buy and hold strategies with one-year maturity at the end of June every year until 2015. Differences between the realized first-quintile and fifth-quintile portfolio returns are calculated each month. Finally, the sign and statistical significance of differences in the time-series mean between the first and the fifth quintile are examined by *t*-tests.

Table 8 shows the results of the quintile portfolio analysis. The *t*-value of the time-series differences in the first-fifth quintile portfolio returns of model 6 is 2.96, and this value is less than the value in the factor mimicking portfolio analysis. Even so, it still has a statistically significantly positive value, suggesting a positive cross-sectional interrelation between the COE estimated with our model and the expected stock returns. Moreover, the cross-sectional interrelation is stronger than for the COE estimated with the existing models.

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include the errors and biases. Therefore, the estimates of μ_t ($\hat{\mu}_t$) may have downward biases compared to the true values (μ_t), as do the *t*-values of $\hat{\mu}_t$. However, the denominators of the *t*-values ($\bar{\mu}/\bar{\sigma}_{\mu}$,), $\bar{\sigma}_{\mu} = \sqrt{\sum_{t=1}^{T}(\hat{\mu}_t - \bar{\mu})^2/T(T-1)}$, contain upward biases from the errors and biases in COE, although they also suffer from the downward biases in $\hat{\mu}_t$. Then, the downward biases in the denominators are smaller than the biases in the nominators ($\hat{\mu}_t$), so the *t*-values calculated here include downward biases as compared to the true (unbiased) *t*-values. The downward biases in the *t*-values indicate that the results of the *t*-tests in our analyses are robust even after considering the effects of the errors-in-variables problem only if the results indicate the significances. Besides, in terms of pooled OLS, it is well known that the errors-in-variables problem causes downward biases on *t*-values, and thus the results of *t*-tests are robust only if the results indicate significance for the same reason as above.

[30] Further, quintile portfolio analysis is one of the solutions to the errors-in-variables problem in FM-OLS analysis.

Table 7: Cross-sectional interrelation between COE and expected stock returns（FM-OLS analysis）

		Attributes	Standardization	Fama-MacBeth OLS (FM-OLS) μ	S.E.	*t*-value	Pooled OLS μ	S.E.	*t*-value
Candidate Models	1	3 Factors	Market-based	0.0917	0.8585	1.36	-0.015489	0.007034	-2.20
	2	C/P+Leverage+D/P		0.0973	0.9189	1.34	0.017959	0.003525	5.09
	3	3 Factors+C/P+Leverage+D/P		0.0434	0.6287	0.88	0.043422	0.00386	11.25
	4	3 Factors	Industry-based	0.0775	0.7845	1.25	0.069878	0.004775	14.64
	5	C/P+Leverage+D/P		0.1368	0.3184	5.45	0.079909	0.00783	10.21
	6	3 Factors+C/P+Leverage+D/P		0.1236	0.2809	5.58	0.05427	0.01207	4.50
	7	3 Factors+C/P+Leverage	Market-based	0.0949	0.4033	2.99	0.015679	0.017144	0.91
	8		Industry-based	0.1187	0.3593	4.19	0.066186	0.01196	5.53
	9	3 Factors+Leverage+D/P	Market-based	0.0773	0.2843	3.45	-0.000619	0.003496	-0.18
	10		Industry-based	0.1118	0.2498	5.68	0.06647	0.006619	10.04
	11	3 Factors+C/P+D/P	Market-based	0.0926	0.3756	3.13	0.01801	0.005149	3.50
	12		Industry-based	0.1227	0.2834	5.49	0.093847	0.008829	10.63
	13	E/P+Leverage+D/P	Market-based	0.1582	2.4530	0.82	0.019231	0.004654	4.13
	14	3 Factors+E/P+Leverage+D/P		0.0790	0.3231	3.10	0.019392	0.006557	2.96
	15	3 Factors+E/P+Leverage		0.0774	0.4535	2.17	0.033208	0.004646	7.15
	16	3 Factors+E/P+D/P		0.0649	0.3596	2.29	0.020991	0.005918	3.55
	17	E/P+Leverage+D/P	Industry-based	0.1323	0.3023	5.55	0.073868	0.00924	7.99
	18	3 Factors+E/P+Leverage+D/P		0.1299	0.3015	5.47	0.073976	0.009142	8.09
	19	3 Factors+E/P+Leverage		0.1034	0.4098	3.20	0.027345	0.013959	1.96
	20	3 Factors+E/P+D/P		0.1213	0.3032	5.08	0.033258	0.013123	2.53
Residual Income Models		Gebhardt, Lee, and Swaminathan (2001)		0.1083	0.4788	2.87	-0.02023	0.014448	-1.40
		Claus and Thomas (2001)		0.0577	0.2853	2.57	-0.007572	0.01146	-0.66
Abnormal Earnings Growth Models		Ohlson and Juettner-Nauroth (2005)		-0.0043	0.1286	-0.43	0.0027	0.006967	0.39
		Easton (2004) 1) Modified PEG ratio		-0.0090	0.1007	-1.13	-0.005356	0.007791	-0.69
		Easton (2004) 2) PEG ratio		0.0168	0.1680	1.27	0.03258	0.007483	4.35
		Easton (2004) 3) EP ratio		0.0613	0.3154	2.46	0.024829	0.01398	1.78

Table 8: Cross-sectional interrelation between COE and expected stock returns (quintile portfolio analysis)

		Attributes	Standardization	1st Quintile	2nd Quintile	3rd Quintile	4th Quintile	5th Quintile	1st Quintile-5th Quintile	S.E.	*t*-value
Candidate Models	1	3 Factors	Market-based	0.0092	0.0091	0.0090	0.0077	0.0038	0.0054	0.0333	2.01
	2	C/P+Leverage+D/P		0.0100	0.0110	0.0069	0.0071	0.0037	0.0063	0.0306	2.55
	3	3 Factors+C/P+Leverage+D/P		0.0121	0.0097	0.0088	0.0056	0.0026	0.0094	0.0324	3.64
	4	3 Factors	Industry-based	0.0085	0.0100	0.0081	0.0076	0.0046	0.0040	0.0218	2.27
	5	C/P+Leverage+D/P		0.0111	0.0096	0.0077	0.0058	0.0046	0.0065	0.0262	3.12
	6	3 Factors+C/P+Leverage+D/P		0.0108	0.0098	0.0074	0.0063	0.0045	0.0063	0.0267	2.96
	7	3 Factors+C/P+Leverage	Market-based	0.0106	0.0085	0.0086	0.0063	0.0048	0.0058	0.0226	3.21
	8		Industry-based	0.0109	0.0091	0.0085	0.0060	0.0043	0.0066	0.0242	3.42
	9	3 Factors+Leverage+D/P	Market-based	0.0108	0.0086	0.0089	0.0075	0.0030	0.0077	0.0314	3.07
	10		Industry-based	0.0106	0.0099	0.0072	0.0067	0.0043	0.0063	0.0242	3.26
	11	3 Factors+C/P+D/P	Market-based	0.0098	0.0095	0.0074	0.0080	0.0041	0.0057	0.0300	2.39
	12		Industry-based	0.0112	0.0083	0.0080	0.0068	0.0046	0.0067	0.0268	3.10
	13	E/P+Leverage+D/P	Market-based	0.0116	0.0096	0.0070	0.0062	0.0043	0.0073	0.0322	2.83
	14	3 Factors+E/P+Leverage+D/P		0.0110	0.0092	0.0089	0.0072	0.0025	0.0085	0.0341	3.12
	15	3 Factors+E/P+Leverage		0.0112	0.0087	0.0082	0.0066	0.0042	0.0071	0.0307	2.88
	16	3 Factors+E/P+D/P		0.0111	0.0095	0.0073	0.0067	0.0042	0.0070	0.0314	2.77
	17	E/P+Leverage+D/P	Industry-based	0.0119	0.0084	0.0076	0.0061	0.0048	0.0071	0.0253	3.48
	18	3 Factors+E/P+Leverage+D/P		0.0108	0.0091	0.0076	0.0068	0.0046	0.0062	0.0239	3.24
	19	3 Factors+E/P+Leverage		0.0105	0.0084	0.0083	0.0066	0.0051	0.0054	0.0245	2.74
	20	3 Factors+E/P+D/P		0.0103	0.0088	0.0071	0.0070	0.0056	0.0048	0.0251	2.38
Residual Income Models		Gebhardt, Lee, and Swaminathan (2001)		0.0097	0.0077	0.0086	0.0075	0.0054	0.0043	0.0257	2.10
		Claus and Thomas (2001)		0.0099	0.0079	0.0077	0.0062	0.0071	0.0028	0.0238	1.49
Abnormal Earnings Growth Models		Ohlson and Juettner-Nauroth (2005)		0.0087	0.0066	0.0085	0.0064	0.0086	0.0001	0.0259	0.02
		Easton (2004) 1) Modified PEG ratio		0.0070	0.0098	0.0092	0.0060	0.0075	-0.0006	0.0151	-0.46
		Easton (2004) 2) PEG ratio		0.0100	0.0075	0.0074	0.0062	0.0077	0.0023	0.0316	0.92
		Easton (2004) 3) EP ratio		0.0091	0.0088	0.0076	0.0056	0.0077	0.0013	0.0254	0.66

V. Conclusion

On the basis of the residual income model, this paper proposes a statistical model for inferring implied COE from cross-sectional data on stock prices and firms' attributes. The model is estimated using a quasi-maximum likelihood approach to simultaneously identify the COE, expected earnings growth rates, and expected excess earnings durations of individual Japanese firms listed on the First Section of the Tokyo Stock Exchange (excluding the financial industry sector).

The estimation results show that the individual firms' attributes, such as industry sector, cash-flow/price, and dividend/price, are key determinants of the COE. Besides, the cross-sectional distribution of individual firms' COE has changed over time, which suggests that it is crucial to take account of market conditions and financial situations of the firms in the estimation. Moreover, our estimates of the firms' COE have a positive relation with expected stock returns on their stocks, and that relation is stronger than those obtained with existing models.

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Appendix 1. Asymptotic Distribution of QML Estimator

This appendix briefly illustrates an asymptotic distribution of the QML estimator, based on White (1994). Denote the true parameter of the estimator as θ, and the QML estimator of N samples as $\hat{\theta}_N^{QML}$. Further, define the logarithm quasi-likelihoods as $\ln f\left(\{\varepsilon_n\}_{n=1}^N\right)$ and the errors in each sample as ε_n. Then, $\hat{\theta}_n^{QML}$ asymptotically follows the standard distribution given as

$$\sqrt{N}\left(\hat{\theta}_N^{QML} - \theta\right) \rightarrow \mathrm{N}(0, A^{-1}\mathrm{B}A^{-1}),$$

where A and B are defined as

$$A = -\frac{1}{N}\sum_{n=1}^{N} E\left(\frac{\partial^2 \ln f\left(\{\varepsilon_n\}_{n=1}^N\right)}{\partial\theta\partial\theta'}\right).$$

$$B = \frac{1}{N}\sum_{n=1}^{N} E\left(\left[\frac{\partial \ln f\left(\{\varepsilon_n\}_{n=1}^N\right)}{\partial\theta}\right]\left[\frac{\partial \ln f\left(\{\varepsilon_n\}_{n=1}^N\right)}{\partial\theta}\right]'\right).$$

From the asymptotic distribution indicated above, the standard errors of the QML estimator are calculated as the square roots of the diagonal elements of the matrix $\frac{1}{N}A^{-1}\mathrm{B}A^{-1}$.

Appendix 2. Sources, Compilation, and Descriptive Statistics of Input Data

Table A-1: Sources and complication of input data

Data series	Sources and compilation methodologies
Price-to-book ratio	Calculated as market capitalization / net assets. Sources are Bloomberg for data on market capitalization and NIKKEI NEEDS for data on net assets.
Return on equity forecasts	Calculated as one-year-ahead earnings after-tax forecasts / net assets. The source for data on one-year-ahead earnings after-tax forecasts is IFIS analyst forecasts (consensus value).
Market factor (β_{Mkt}) Book-to-market factor (β_{HML}) Market cap factor (β_{SMB})	The exposures to each factor are estimated by OLS of the realized stock returns (calculated from historical stock prices) on the realized return of each factor. The sample period of the time-series OLS is generally 36 months on a monthly basis. Only stocks with at least 24-month historical data are counted as samples. The source for historical data on the returns of each factor (excluding financial industry stock) is Financial Data Solutions, Inc. The source for historical stock price data is Bloomberg, and prices are on an ex-dividend adjusted basis.
Dividend/price (D/P)	Calculated as dividend / market capitalization. Dividends are calculated by multiplying dividends per share by outstanding shares. The data source for both dividends per share and outstanding shares is NIKKEI NEEDS.
Earning/price (E/P)	Calculated as net income after tax / market capitalization. The source for data on after-tax net income is NIKKEI NEEDS.
Cash-flow/price (C/P)	Calculated as cash flows from operating activities / market capitalization. Cash flows from operation activities are calculated as the sum of net income after tax, depreciation expense, and interest expenses and commissions. The data source is NIKKEI NEEDS.
Financial leverage (market value based)	Calculated as debt / market capitalization. The source for data on debts is NIKKEI NEEDS.
Industry-based ROE forecasts – individual-based ROE forecasts	Calculated as the average forecast within each industry sector.
Ratio of R&D expenses to sales	Calculated as R&D expenses / sales. The source for data on both sales and R&D expenses is NIKKEI NEEDS.

Table A-2: Descriptive Statistics of Input Data

	PBR (Market-based Costs of Equity)					ROE Forecasts (Market-based Costs of Equity)					Exposure to Market Factor		Exposure to Book to Market Factor		Exposure to Market Cap Factor		Dividend/Price	
	Mean	S.D.	Max	Median	Min	Mean	S.D.	Max	Median	Min	Mean	Median	Mean	Median	Mean	Median	Mean	Median
2002	1.719	2.663	50.534	1.177	0.199	0.083	0.116	1.856	0.060	0.000	0.907	0.872	0.444	0.567	0.513	0.434	0.015	0.013
2003	1.753	3.241	65.029	1.211	0.276	0.091	0.102	1.247	0.068	0.000	1.005	0.977	0.326	0.362	0.388	0.350	0.013	0.013
2004	2.307	5.040	92.187	1.496	0.419	0.109	0.115	1.584	0.083	0.002	1.035	1.008	0.186	0.260	0.403	0.308	0.011	0.010
2005	2.647	5.630	97.444	1.721	0.535	0.117	0.104	1.247	0.094	0.001	1.018	0.961	0.061	0.183	0.401	0.324	0.011	0.010
2006	2.773	3.868	54.984	1.936	0.537	0.118	0.089	0.914	0.098	0.001	0.977	0.956	-0.008	0.110	0.428	0.374	0.010	0.010
2007	2.202	2.266	27.573	1.685	0.420	0.115	0.085	0.826	0.096	0.001	0.972	0.943	0.113	0.210	0.457	0.418	0.013	0.012
2008	1.443	1.631	21.941	1.103	0.234	0.099	0.074	0.690	0.084	0.000	1.031	1.029	0.190	0.268	0.406	0.354	0.022	0.020
2009	1.349	1.450	18.069	1.031	0.192	0.072	0.071	0.636	0.055	0.000	1.052	1.025	0.296	0.323	0.439	0.376	0.030	0.022
2010	1.337	1.252	15.372	1.066	0.245	0.083	0.076	0.847	0.066	0.000	1.108	1.121	0.325	0.341	0.323	0.262	0.023	0.018
2011	1.287	1.355	20.283	1.019	0.298	0.093	0.079	0.827	0.074	0.000	1.111	1.110	0.381	0.335	0.214	0.226	0.020	0.019
2012	1.194	1.057	14.129	0.951	0.277	0.092	0.073	0.609	0.077	0.000	1.060	1.062	0.326	0.284	0.245	0.223	0.022	0.022
2013	1.613	1.698	20.886	1.225	0.286	0.095	0.070	0.613	0.081	0.000	0.991	0.960	0.318	0.283	0.247	0.223	0.019	0.016
2014	1.646	1.546	19.071	1.267	0.312	0.097	0.069	0.795	0.085	0.000	0.965	0.924	0.379	0.334	0.298	0.266	0.027	0.015
2015(Jan-May)	1.888	1.705	20.791	1.424	0.328	0.102	0.074	0.859	0.088	0.000	0.964	0.930	0.442	0.361	0.379	0.333	0.030	0.014

	PBR (Individual-based Costs of Equity)					ROE forecasts (Individual-based Costs of Equity)					Earning/Price		Cash-flow/Price		Financial Leverage (market value based)		Ratio of R&D Expenses to Sales	
	Mean	S.D.	Max	Median	Min	Mean	S.D.	Max	Median	Min	Mean	Median	Mean	Median	Mean	Median	Mean	Median
2002	1.394	0.928	7.812	1.142	0.286	0.061	0.052	0.575	0.052	0.000	0.027	0.035	0.139	0.112	0.691	0.300	0.032	0.022
2003	1.457	1.112	13.728	1.169	0.292	0.077	0.087	1.095	0.061	0.000	0.019	0.032	0.128	0.110	0.705	0.330	0.033	0.023
2004	1.740	1.220	13.889	1.414	0.454	0.097	0.105	1.584	0.077	0.002	0.028	0.037	0.113	0.099	0.539	0.284	0.033	0.023
2005	2.047	2.069	31.466	1.634	0.538	0.105	0.084	0.890	0.088	0.001	0.042	0.043	0.110	0.096	0.406	0.214	0.032	0.022
2006	2.391	2.794	42.649	1.845	0.541	0.109	0.077	0.789	0.093	0.001	0.043	0.041	0.098	0.083	0.311	0.163	0.030	0.021
2007	1.974	1.571	21.307	1.628	0.442	0.105	0.072	0.780	0.091	0.002	0.048	0.048	0.108	0.096	0.316	0.160	0.029	0.020
2008	1.281	0.879	10.860	1.069	0.261	0.090	0.060	0.410	0.079	0.000	0.072	0.072	0.178	0.158	0.512	0.238	0.029	0.019
2009	1.204	0.808	8.429	1.025	0.192	0.061	0.053	0.420	0.049	0.000	0.043	0.057	0.156	0.135	0.608	0.214	0.030	0.017
2010	1.244	0.913	12.638	1.058	0.250	0.075	0.063	0.823	0.064	0.000	0.015	0.037	0.132	0.121	0.647	0.280	0.033	0.022
2011	1.170	0.740	9.270	1.015	0.298	0.084	0.064	0.767	0.071	0.000	0.049	0.054	0.163	0.143	0.613	0.296	0.033	0.023
2012	1.080	0.654	7.888	0.930	0.280	0.082	0.058	0.594	0.072	0.000	0.058	0.063	0.176	0.153	0.657	0.314	0.033	0.022
2013	1.449	1.053	13.745	1.204	0.296	0.087	0.059	0.582	0.078	0.000	0.034	0.048	0.118	0.108	0.489	0.228	0.033	0.022
2014	1.518	0.982	10.178	1.261	0.321	0.093	0.063	0.760	0.083	0.000	0.044	0.050	0.120	0.104	0.467	0.208	0.033	0.021
2015(Jan-May)	1.724	1.155	9.752	1.392	0.353	0.098	0.071	0.828	0.087	0.000	0.050	0.047	0.114	0.097	0.395	0.180	0.032	0.021

Note: Values for each year are averages of estimates from January to December of that year.

Table A-3: Observations

	Market-based Costs of Equity	Individual-based Costs of Equity	Industry-based Costs of Equity								
			Foods	Medicine	Chemicals/Oil and Coal Products	Electronic Appliances	Machinery	Transportation Equipment	Construction / Real Estate	Retail Trade/ WholeSale Trade	Information and Communication
Monthly Average	657	506	24	24	64	90	60	37	51	69	49
Total	105,786	81,488	3,822	3,785	10,275	14,497	9,655	5,880	8,199	11,188	7,816
2002	7,695	5,230	317	306	763	881	685	439	626	883	643
2003	7,994	5,781	343	312	785	1,064	723	423	564	823	649
2004	8,189	6,232	312	289	779	1,191	813	396	584	837	567
2005	8,049	6,119	299	304	730	1,173	697	391	579	865	590
2006	8,869	6,793	290	299	833	1,284	745	492	708	974	636
2007	9,134	6,943	309	289	827	1,266	846	480	745	1,007	645
2008	8,531	6,720	281	278	821	1,212	785	493	615	917	588
2009	6,569	5,062	236	256	673	742	497	247	575	798	567
2010	7,421	5,913	253	253	729	1,032	621	415	608	813	542
2011	7,482	6,005	262	252	818	1,048	664	455	594	750	558
2012	7,341	5,862	261	258	750	988	720	484	572	706	569
2013	7,542	5,981	263	274	718	1,025	770	496	570	744	537
2014	7,787	6,287	275	297	752	1,123	776	487	594	758	519
2015(Jan-May)	3,183	2,560	121	118	297	468	313	182	265	313	206

Note: Numbers for each year are sums of the numbers of samples from January to December of that year.

Appendix 3. Industrial Classification

Table A-4: Tokyo Stock Exchange industry sectors and those in our research

	Tokyo Stock Exchange 33 industry sectors	
①	Fishery, Agriculture & Forestry	
②	Mining	
③	Construction	
④	Foods	
⑤	Textiles & Apparels	
⑥	Pulp & Paper	
⑦	Chemicals	
⑧	Pharmaceutical	
⑨	Oil & Coal Products	
⑩	Rubber Products	
⑪	Glass & Ceramics Products	
⑫	Iron & Steel	
⑬	Nonferrous Metals	
⑭	Metal Products	
⑮	Machinery	
⑯	Electric Applicance	
⑰	Transportation Equipments	
⑱	Precision Instruments	
⑲	Other Products	
⑳	Electric Power & Gas	
㉑	Land Transportation	
㉒	Marine Transportation	
㉓	Air Transportation	
㉔	Warehousing & Harbor Transportation Services	
㉕	Information & Communication	
㉖	Retail Trade	
㉗	WholeSale Trade	
㉘	Banks	Excluded from samples of the estimation
㉙	Securities & Commodity Futures	
㉚	Insurance	
㉛	Other Financing Business	
㉜	Real Estate	
㉝	Services	

	Industry sectors for the estimation
①	Fishery, Agriculture & Forestry/ Mining/Electric Power & Gas
②	Constrction/Real Estate
③	Foods
④	Textiles & Apparels/Pulp & Paper
⑤	Chemicals/Oil & Coal Products
⑥	Pharmaceutical
⑦	Rubber Products/Glass& Ceramics Products
⑧	Iron & Steel
⑨	Nonferrous Metals
⑩	Metal Products
⑪	Machinery
⑫	Electric Applicance
⑬	Transportation Equipments
⑭	Precision Instruments
⑮	Other Products
⑯	Transportation & Warehousing
⑰	Information & Communication
⑱	Retail Trade/WholeSale Trade
⑲	Services

Note 1: Our industry classification is based on the 33 Tokyo Stock Exchange industry sectors, but we merged industries with few samples into similar industries.
Note 2: The financial industry sector is excluded from the samples.
Source: Securities Identification Code Committee (2003)

Appendix 4. Industry-based Cost of Equity

Table A-5: Estimators of Industry-based cost of equity

	Industry									All Industry
	Foods	Medicine	Chemicals/Oil and Coal Products	Electric Appliances	Machinery	Transportation Equipment	Construction / Real Estate	Retail Trade/ WholeSale Trade	Information and Communication	
Mean	0.045	0.041	0.057	0.047	0.060	0.077	0.072	0.052	0.033	0.055
S.D.	0.019	0.017	0.021	0.019	0.021	0.036	0.037	0.023	0.025	0.014
Max	0.094	0.110	0.117	0.104	0.127	0.267	0.231	0.154	0.091	0.089
1st Quartile	0.060	0.051	0.071	0.060	0.072	0.091	0.090	0.065	0.050	0.065
2nd Quartile	0.045	0.042	0.055	0.044	0.058	0.075	0.066	0.049	0.034	0.056
3rd Quartile	0.031	0.029	0.039	0.034	0.046	0.052	0.045	0.036	0.014	0.045
Min	-0.004	0.000	0.017	0.010	0.017	0.015	0.017	0.003	-0.029	0.013
2002	0.048	0.051	0.042	0.027	0.070	0.076	0.100	0.098	0.013	0.032
2003	0.055	0.068	0.047	0.057	0.071	0.113	0.130	0.063	0.023	0.047
2004	0.039	0.035	0.038	0.035	0.066	0.095	0.051	0.039	0.006	0.051
2005	0.030	0.032	0.041	0.032	0.049	0.061	0.037	0.038	0.010	0.060
2006	0.035	0.033	0.034	0.032	0.041	0.054	0.035	0.029	0.007	0.057
2007	0.032	0.029	0.046	0.038	0.041	0.047	0.051	0.047	0.019	0.051
2008	0.039	0.036	0.073	0.069	0.074	0.099	0.089	0.067	0.045	0.069
2009	0.053	0.043	0.049	0.044	0.046	0.042	0.079	0.056	0.044	0.049
2010	0.060	0.047	0.059	0.048	0.051	0.064	0.099	0.059	0.043	0.055
2011	0.065	0.057	0.081	0.065	0.075	0.091	0.101	0.049	0.063	0.069
2012	0.065	0.052	0.086	0.067	0.085	0.109	0.081	0.066	0.076	0.074
2013	0.045	0.040	0.064	0.056	0.058	0.077	0.052	0.045	0.048	0.059
2014	0.031	0.028	0.081	0.048	0.055	0.083	0.052	0.037	0.041	0.051
2015(Jan-May)	0.002	0.008	0.058	0.042	0.050	0.061	0.041	0.027	0.025	0.040

Note 1: Industry-based COE is estimated only for industries with more than twenty firms (samples).

Note 2: Values for each year are averages of estimates from January to December of that year.

Appendix 5. Overview, Methodology, and Cost of Equity of Existing Models

A. Residual Income Models

A variety of residual income models have been proposed following the Edward–Bell–Ohlson model (Edward and Bell [1961], Ohlson [1991, 1995], Bernard [1995]). We select two representative models for comparative analysis, those by Gebhardt, Lee, and Swaminathan (2001) and Claus and Thomas (2001).[31] In the following, COE is denoted by x.

1. Gebhardt, Lee, and Swaminathan (2001)

In this model, forecasts of one-to-three-years-ahead ROE are input as proxies for investors' ROE forecasts. Regarding 4–12-years-ahead ROE forecasts of investors, the ROE are estimated under the assumption that the ROE uniformly decreases from the levels of three-years-ahead ROE to the median of the ROE within the industry. The industry median ROE is obtained by calculating the time-series median of the cross-sectional median in each year, and the expected earnings growth rate is calculated from historical dividend ratios and the clean surplus relation. In our estimation, since the availability of data is insufficient to apply exactly the same methodology as Gebhardt, Lee, and Swaminathan (2001), the cross-sectional median of the previous year's ROE in the industry is used instead of the time-series median of the cross-sectional median. In the following equation, the τ-years-ahead ROE forecast is denoted as $FROE_{\tau}$.

$$P_0 = B_0 + \left\{\frac{FROE_1 - x}{1+x}\right\} B_0 + \left\{\frac{FROE_2 - x}{(1+x)^2}\right\} B_1 + \sum_{\tau=3}^{11} \left\{\frac{FROE_{\tau} - x}{(1+x)^{\tau}}\right\} B_{\tau-1} + \left\{\frac{FROE_{12} - x}{x(1+x)^{11}}\right\} B_{11}. \qquad \text{(A-1)}$$

2. Claus and Thomas (2001)

In this model, forecasts of one-to-five-years-ahead ROE are input as proxies for investors' ROE forecasts, and the level of the five-years-ahead ROE is assumed to continue thereafter. The expected earnings are assumed to grow at the long-term expected inflation rates. Due to limited data availability, only forecasts of the one-to-three-years-ahead ROE are input as proxies for investors' ROE forecasts, and the

[31] Regarding COE estimators of Gebhardt, Lee, and Swaminathan (2001) and Claus and Thomas (2001), when a COE is obtained as a complex number, that COE is eliminated from the COE estimates for calculating the average COE of all firms and applying statistical tests to examine the cross-sectional interrelation between COE and expected stock returns.

level of the three-years-ahead ROE is assumed to continue forever. Moreover, the expected earnings are assumed to grow at the five-years backward-moving averages of the consumer price index (π).

$$P_0 = B_0 + \sum_{\tau=1}^{5} \left\{ \frac{FROE_\tau - x}{(1+x)^\tau} \right\} B_{\tau-1} + \left\{ \frac{(FROE_5 - x)(1+\pi)}{(1+x)^5 (x-\pi)} \right\} B_4. \tag{A-2}$$

B. Abnormal Earnings Growth Models

Ohlson and Juettner-Nauroth (2005) proposed abnormal earnings growth models, based on residual income models. Abnormal earnings growth models assume that the theoretical value of stocks equals the earnings expected in the next period plus the present values of the abnormal earnings in the future. In contrast, residual income models assume that the theoretical values of stocks equal the book values at the period plus the present values of the residual incomes in the future. Therefore, in abnormal earnings growth models, COE does not depend on the "book value"; it is implied from expected earnings, expected dividends and stock prices. In our estimation, the COE estimated with the models of Ohlson and Juettner-Nauroth (2005) and Easton (2004) are compared with that estimated from our model.[32] The i-period-ahead expected earnings per share are denoted as $FEPS_\tau$, and dividends per share are defined as DPS_τ in the following equation.

1. Ohlson and Juettner-Nauroth (2005)

$$x = A + \sqrt{A^2 + \frac{FEPS_1}{P_0}\left(\frac{\Delta FEPS_2}{FEPS_1} - 0.03\right)}.$$
$$A = \frac{1}{2}\left(0.03 + \frac{DPS_1}{P_0}\right). \tag{A-3}$$

2. Easton (2004)

Easton (2004) suggests three types of models, as follows.

a. Modified PEG ratio

$$x = \sqrt{\frac{FEPS_2 + xDPS_1 - FEPS_1}{P_0}}. \tag{A-4}$$

[32] In the COE estimated from Ohlson and Juettner-Nauroth (2005), negative values inside the square root are replaced by zero. Similarly, regarding COE estimators from Easton (2004), if the two-years-ahead forecast minus the one-year-ahead forecast is negative, then zero is assigned to the variable.

b. PEG ratio

$$x = \sqrt{\frac{FEPS_2 - FEPS_1}{P_0}}. \tag{A-5}$$

c. EP ratio

$$x = \frac{FEPS_1}{P_0}. \tag{A-6}$$

C. Comparison of Our Model with Existing Models

Table A-6 compares our model with the existing models.

Table A-6: Features of our model

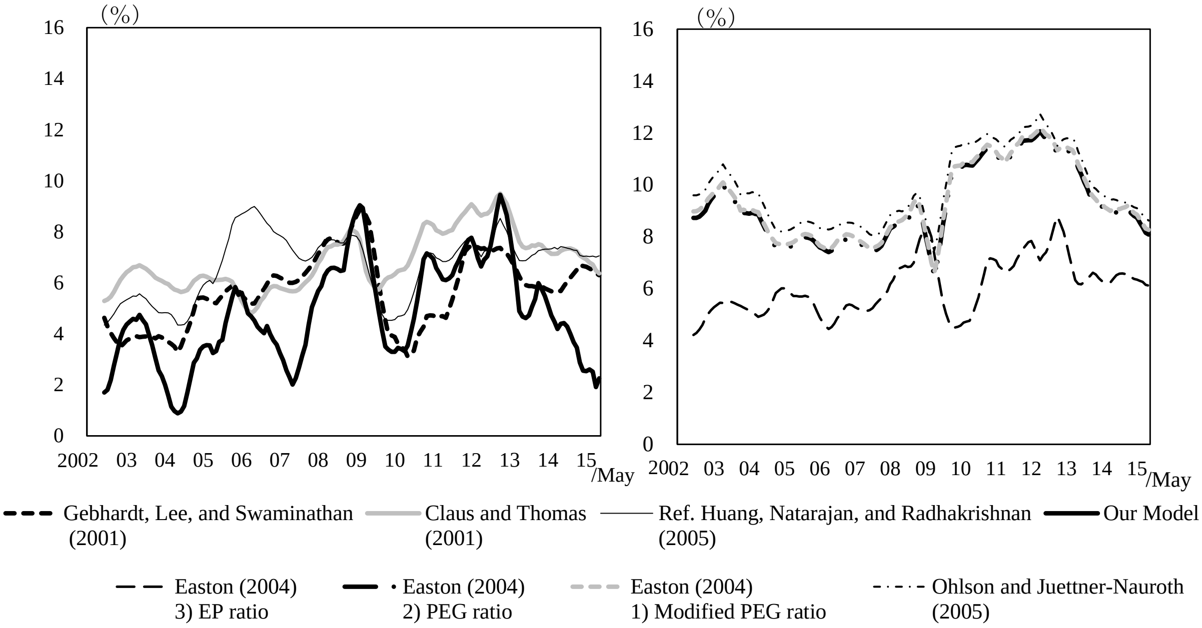
<table>
<tr><th colspan="2"></th><th>CSR</th><th>Assumptions of the models</th></tr>
<tr><td colspan="2">Gebhardt, Lee, and Swaminathan (2001)</td><td rowspan="2">Assumed</td><td>Residual incomes vary for 12 years. Afterward, values are invariant.</td></tr>
<tr><td colspan="2">Claus and Thomas (2001)</td><td>Residual incomes vary for four years. Thereafter, they grow at (expected) inflation rates.</td></tr>
<tr><td colspan="2">Ohlson and Juettner-Nauroth (2005)</td><td rowspan="4">Not Assumed</td><td>Abnormal earnings grow at the same rate forever.</td></tr>
<tr><td rowspan="3">Easton (2004)</td><td>1) Modified PEG ratio</td><td>Abnormal earnings vary for two years. Afterward, the earnings grow at a constant rate.</td></tr>
<tr><td>2) PEG ratio</td><td>Abnormal earnings vary for two years. Thereafter, the earnings grow at a constant rate. Dividend ratios are assumed to be zero.</td></tr>
<tr><td>3) EP ratio</td><td>One-year-ahead earnings rates are assumed to continue forever.</td></tr>
<tr><td colspan="2">Ref.:
Huang, Natarajan, and Radhakrishnan (2005)</td><td rowspan="2">Assumed</td><td>The first paper proposing simultaneous estimation of individual-based COE and expected earnings growth rates. The estimators are obtained by the regression of ROE on PBR.</td></tr>
<tr><td colspan="2">Our model</td><td>Residual incomes grow at the same rate until the expected excess earnings duration. Afterward, the incomes are assumed to be zero.</td></tr>
</table>

Note: CSR stands for clean-surplus relation.

D. Estimates of Cost of Equity in Existing Models

The COE in existing models is estimated from the same samples of our model. Then, the COE levels and the results of statistical tests on the cross-sectional interrelation between the COE and the expected stock returns are compared to those of our model. As a result, the COE estimates of our model are slightly higher than those of existing residual income models, and higher than those of existing abnormal growth models.[33] The COE estimates of existing models are inferred by solving equations for each firm separately, and COE in Figure A-1 and Table A-7 is obtained as the average of the individual COE. The exception is Huang, Natarajan, and Radhakrishnan (2005),[34] which estimates COE by OLS.

Figure A-1: Average of individual-based COE



[33] The differences between the COE estimated with our model and the COE estimated with existing residual income models originate in the differences in the values of the expected earnings growth rates. In the existing models, the rates are exogenously input, but the input data is much greater than the rates estimated with our model (under the assumption of infinite expected excess earnings durations). Regarding the EP ratio by Easton (2004), the COE estimates do not decline when the COE estimated with our models decrease because stock price rises entail the improvements of the expected earnings.

[34] Estimates of the COE are provided as reference values since this paper is representative research proposing simultaneous estimation of the COE and the expected earnings growth rate. However, in the paper, the COE is assumed to be time-invariant, and thus the COE is not compared to that of our model. Note that the COE is estimated by assigning assumptions differing from the original model in that the individual-based COE is assumed to be time-variant, but individual-based COE is assumed to be the same across firms (in original model, the individual-based COE is assumed to be time-invariant, but individual-based COE is assumed to differ across firms).

Table A-7: Descriptive statistics of the averages of individual-based COE

	Residual Income Models		Abnormal Earnings Growth Models				Ref.
	Gebhardt, Lee, and Swaminathan (2001)	Claus and Thomas (2001)	Ohlson and Juettner-Nauroth (2005)	Easton (2004) 1) Modified PEG ratio	Easton (2004) 2) PEG ratio	Easton (2004) 3) EP ratio	Huang, Natarajan, and Radhakrishnan (2005)
Mean	0.057	0.068	0.098	0.093	0.092	0.060	0.067
S.D.	0.015	0.012	0.015	0.015	0.015	0.012	0.014
Max	0.093	0.097	0.133	0.127	0.126	0.098	0.091
1st Quartile	0.068	0.077	0.114	0.107	0.106	0.067	0.075
2nd Quartile	0.057	0.066	0.096	0.091	0.089	0.059	0.070
3rd Quartile	0.045	0.060	0.085	0.081	0.079	0.052	0.055
Min	0.020	0.045	0.071	0.062	0.061	0.039	0.035
2002	0.041	0.058	0.099	0.093	0.091	0.047	0.048
2003	0.039	0.063	0.101	0.094	0.093	0.054	0.051
2004	0.045	0.060	0.087	0.081	0.080	0.055	0.050
2005	0.055	0.058	0.085	0.079	0.078	0.054	0.076
2006	0.058	0.055	0.084	0.079	0.077	0.050	0.084
2007	0.065	0.061	0.084	0.079	0.078	0.055	0.071
2008	0.080	0.078	0.091	0.087	0.086	0.075	0.078
2009	0.058	0.061	0.101	0.093	0.092	0.053	0.052
2010	0.040	0.077	0.117	0.112	0.111	0.062	0.062
2011	0.062	0.085	0.120	0.115	0.114	0.073	0.073
2012	0.072	0.089	0.120	0.117	0.115	0.078	0.077
2013	0.058	0.073	0.104	0.099	0.098	0.063	0.071
2014	0.063	0.071	0.093	0.090	0.089	0.064	0.072
2015(Jan-May)	0.062	0.063	0.086	0.083	0.081	0.061	0.071

Note: Values for each year are averages of estimates from January to December of that year.