Decomposing and Pricing of Corporate Bond Yields and Disentangling a Flight-to-Quality from a Flight-to-Liquidity

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We analytically decompose corporate bond yields into eight risk and yield curve factors and find that five factors among them are important determinants of corporate bond yield spreads and that there exists a non-linear relation between bond yields and betas. Our model explains 99.4% of the cross-sectional variations of corporate bond yield spreads compared to 72.9% of Fama-French two factor models in terms of R-squared. We claim that each risk contribution among interest rate, credit and illiquidity may be wrong if the illiquidity factor is simply added to the existing Fama-French two factor models when each risk premium is estimated. Specifically, the illiquidity premium is underestimated by 34% and the credit premium is overestimated by 39% when an inaccurate model is used. We also show that the relationship between credit and illiquidity varies depending on the economic situation. Specifically, the liquidity premium showed a positive correlation with the credit premium in global financial crisis, whereas it showed a negative one in European national debt crisis. We find that liquidity black holes arise at the beginning of a financial crisis and financial markets quickly become unstable. Our method disentangles a flight-to-quality from a flight-to-liquidity and identifies the risk contributions of credit and illiquidity and among the yield curve factors (level, steepness, and concavity). Our model also explains a flight-from-maturity phenomenon.

***Keywords*:** Analytic factor decomposition method, Credit premium, Illiquidity premium, Yield curve factors, Liquidity black holes

***JEL Classification*:** G12, G14

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1 Introduction

Liquidity in financial markets has attracted much attention since Fisher (1959) found that corporate bond yields reflect not only the default risk, but also the liquidity premium, and Amihud and Mendelson (1986) incorporated the liquidity effect in asset pricing. Since the global financial crisis started in 2007, and recognizing the importance of liquidity risk management for well-functioning financial markets, the Basel Committee on Banking Supervision announced new basic principles in 2008 to strengthen liquidity risk management by banks. The International Accounting Standards Board (IASB) also announced a revised public draft for Phase II of the IFRS4 that requires insurance companies to use discount rates that reflect liquidity risk when measuring the fair value of an insurance liability (IASB, 2013). Consequently, liquidity has become an important part of policies that stabilize financial systems, risk management, asset allocation, and profit management. In addition, policymakers, financial institutions such as banks and insurance companies, and related institutions have become more interested in finding ways of managing liquidity risk more effectively while complying with relevant regulations.

Liquidity has many dimensions and meanings.[1] Here, we use liquidity to refer to market liquidity. Prior studies on liquidity have focused mainly on equity markets (Amihud et al., 2006), with relatively few studies examining bond markets. Amato and Remolona (2003) studied bond liquidity to explain the credit spread puzzle, most of which can be explained by incorporating an illiquidity premium into a bond pricing model, as has been shown in subsequent research (see, e.g., Driessen, 2005; Longstaff et al., 2005; Chen et al., 2007; De Jong and Driessen, 2012)

[1] According to Foucault et al. (2013), liquidity has three dimensions. First, market liquidity indicates the ability to trade a security quickly at a price close to its consensus value. Second, funding liquidity refers to having enough cash or the ability to obtain credit at acceptable terms to meet obligations without incurring large losses. Third, monetary liquidity is identified with money itself, whether defined as the cash held by households, firms, and bank reserves (“monetary base”), or as broader monetary aggregates, which include various types of bank deposits (M1, M2, M3).

The objectives of this study are as follows. First, we attempt to extract those factors that determine excess bond yields, defined as corporate bond yields less risk-free rates, by decomposing corporate bond yields using an analytic decomposition method. Second, we examine whether the extracted factors explain corporate bond spreads better than the Fama–French two-factor models do, and investigate the meanings and characteristics of the information each extracted factor possesses. Third, we examine whether the illiquidity factor may be a risk price for determining corporate bond spreads. Lastly, we use our model to analyze the roles and contributions of each extracted factor under different economic circumstances. More specifically, we examine how risk factors, such as credit and illiquidity, affect corporate bond spreads differently during and after a financial crisis period. Here, we consider two financial crises, namely the global financial crisis and the European national debt crisis of the late 2000s.

Our study contributes to the current literature on corporate bond pricing. To the best of our knowledge, this is the first attempt to apply an analytic factor decomposition method to corporate bond pricing. We extend the Fama–French two-factor model by extracting an illiquidity factor implied in corporate bond yields, and reflecting yield curve information. This makes it possible for us to consider the determinants of corporate bond yields consistently and systematically.

Many studies on the U.S. and European bond markets have used bid–ask spread or trading volume data for liquidity measures (see, e.g., Roll, 1984; Amihud, 2002; Pastor and Stambaugh, 2003; Bekaert et al., 2007). In this study, as a market liquidity measure for corporate bond pricing, we use the KfW (Kreditanstalt fur Wiederaufbau) spread. The spread refers to the difference in yields between German government bonds and KfW agency bonds, because two maturity-matched bonds share an identical credit guarantee from the German government, but differ in liquidity. Schwarz (2015) argues that the KfW spread is entirely free from credit influences and that it captures all effects of market liquidity, including the forward-looking concept of liquidity risk. Schuster and Uhrig-Homburg (2015) also argue that the measure includes the risk premium and market expectations, in addition to the severity of frictions.

The remainder of this paper is structured as follows. Section 2 briefly reviews the relevant literature. Section 3 describes the main characteristics of our data and derives an extended Fama–French model based on yield curve information. Sections 4 and 5 report on the time series regression and cross-sectional regression, respectively, and Section 6 analyzes the relationship between credit and illiquidity. Lastly, Section 7 summarizes our main findings and concludes the paper.

2 Related Literature

2.1 Fama–French Models

Fama and French (1993) found that the term spread and credit spread together explain over 90% of corporate bond spreads. Thus, we refer to the multi-factor models that have attempted to explain corporate bond spreads as Fama–French models. Gebhardt et al. (2005) introduce bond characteristic variables, such as remaining maturity and credit ratings, in addition to the two factors that Fama and French consider, and Houweling et al. (2005) analyze the liquidity of bond markets using the model proposed by Gebhardt et al. (2005). Lin et al. (2011) add a liquidity factor to the five Fama–French factors (equity premium, size, book-to-market ratio, term spread, and credit spread), and find that liquidity risk is an important determinant of corporate bond spreads and the flight-to-quality phenomenon that occurs during a recession in the business cycle. Acharya et al. (2013) analyze the effect of liquidity shocks on asset prices using a regime-switching model, and find that the effect is conditional in that it is stronger during recessions.

2.2 Illiquidity Premium of Corporate Bonds

Prior studies that estimate the illiquidity premium of corporate bonds are classified into three approaches: a market microstructure approach, a structural model approach, and a no arbitrage approach. According to the market microstructure approach, information risk arising from asymmetric information, time change, and liquidity discrepancies among firms affect long-term equilibrium prices. The central issue in the empirical studies of market microstructure is how to specify the correct liquidity measure (see, e.g., Roll, 1984; Amihud, 2002; Pastor and Stambaugh, 2003; Bekaert et al., 2007). Dick-Nielsen et al. (2012), Lin et al. (2011), and De Jong and Driessen (2012) are examples of this approach. The structural model approach estimates illiquidity premiums by subtracting bond yields estimated from structural models (e.g., the Merton model) from bond yields observed in the markets (Webber, 2007). According to the no arbitrage approach, an illiquidity premium is regarded as the difference in bond yields of identical bonds in terms of quality of credit, maturity, tax, and collateral. Examples of illiquidity premiums using this approach are spreads between T-Notes and T-bills, spreads between off-the-run and on-the-run, CDS negative spreads, covered bond spreads, and spreads between government bonds and government-guaranteed agency bonds.

Longstaff (2004) tests the effect of liquidity on bond yields using the spreads in yields between U.S. treasury bonds and bonds issued by the Resolution Funding Corporation (Refcorp), a government agency. He finds that the average yield premium on Refcorp bonds ranges from 10 to 16 basis points and is statistically significant, and that the illiquidity premium reacts to varying market conditions (flight-to-liquidity). Schwarz (2015) proposes a new market liquidity measure of KfW spreads and a new interbank credit measure of Bank Tiering spreads. She finds that her measures can explain changes in interbank and sovereign bond spreads very well, and that illiquidity drives spread changes 1.5 to 3 times more than credit does. She also argues that the KfW spread measure captures all effects of market liquidity because it reflects both current and future transaction costs expected by investors, whereas traditional measures of market liquidity, such as bid–ask spreads, reflect only current transaction costs. Schuster and Uhrig-Homburg (2015) estimate the term structure of illiquidity premiums using a two-regime Markov-switching AR model. They find that the illiquidity premiums calculated from KfW spreads are related to intermediaries' capital and foreign flows only in the stress regime and that it is a priced risk factor. Monfort and Renne (2014) analyze the joint dynamics of credit and liquidity that constitute bond yield spreads using a regime-switching affine-term structure model, and find that KfW spreads can explain the liquidity of bond markets.

3 Data and Methodology

3.1 Data

The European corporate bond indices used in this study are 23 rating and maturity class broad Markit iBoxx EUR Corporate bond indices.[2] Eight of the indices are composite indices for three different credit ratings (Corporates AA, A, BBB) and five different maturities (Corporates 1-3, 3-5, 5-7, 7-10, 10+).

Following the bond liquidity literature, we use a bond’s yield to maturity, rather than its realized return, as a proxy for its expected return, because yields are forward looking, while realized returns are backward looking (see, e.g., Longstaff, 2005; Houweling et al., 2005; Chen et al., 2007; Ilmanen, 2011). Bond index yields are the weighted average of individual bond yields generated by Markit Group Limited. Our sample covers the period from January 2003 to August 2015. The reason for choosing this period is that Markit iBoxx EUR Corporate indices were launched on 18 April 2001, while its rating and maturity indices have been available since 2002.

We use the zero-coupon rates of Bunds and KfW with the same modified durations[3] as those of corporate bond indices. We use duration-matching rates rather than maturity-matching rates because differences in yields can occur when the coupons of maturity-matching Bunds and KfWs are not the same. We apply the Svensson method to estimate the zero yield curves for Bunds and KfWs, which have been adopted by the central banks of the United States and many European countries, including Germany. To improve the flexibility of the curves and the fit, Svensson (1994) extended Nelson and Siegel’s function by adding a further term that allows for a second hump.

We collect issue and price information of corporate bonds from Bloomberg to estimate the zero yield curves and to maintain the consistency of the data by abiding by the same bond selection rules

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[2] Refer to Markit (2015) for the bond selection rules and index calculations of Markit iBoxx EUR Corporate indices.

[3] Hereafter, we refer to the modified duration simply as the duration.

as those of the Markit iBoxx EUR Corporates indices. For the durations of corporate bond indices, we use the data generated by Markit Group Limited.

Table 1 provides the descriptive statistics for the sample bond indices. The duration of corporate composite bond indices is 4.39 years and the durations of the rating indices are in the range of 4.14~4.53 years. These indicate that the differences in duration due to the rating classes are not big. The mean yield spread of corporate composite bond indices is 2.34%, while those of the rating and maturity class corporate bond indices increase consistently as the duration increases or the credit rating decreases.

[Table 1 is about here.]

3.2 Methodology

3.2.1 Analytic Factor Decomposition Method

In general, yield curve relationships are analyzed from three perspectives: bond yields, forward rates, and expected returns. Each perspective contains information on the short-term rates and the risk premiums (Cochrane and Piazzesi, 2009). We analyze the yield curve relationships based on the Fama–French two-factor model from the perspective of bond yields. As shown in Eq. (1), corporate bond yields are composed of short-term rates[4] and risk premiums, and risk premiums are further decomposed into the yield spread of long-term corporate bonds (*DEF)*, the term spread of risk-free rates (*TERM*), and the yield spread between individual corporate bonds and long-term corporate bonds.[5] From Eq. (1), we know that the $-(Y_{i,l} - Y_i)$ term appears (i.e., the difference between the

[4] The bill rate is a proxy for the general level of expected returns on bonds. Thus, TERM is a proxy for the deviation of long-term bond returns from expected returns due to shifts in interest rates (Fama and French, 1993, p. 7). The interest rate can be measured by any maturity yield on the yield curve and the information contained in the yield is identical, regardless of its maturity (Duffee, 1998, p. 2228).

[5] An arbitrage opportunity cannot arise only if long-term rates are the average of risk-adjusted short-term rates.

yields of individual corporate bonds and long-term corporate bonds), which was not mentioned in the Fama–French two-factor model:

$$Y_i = Y_{f,s} + (Y_{i,l} - Y_{f,l}) + (Y_{f,l} - Y_{f,s}) - (Y_{i,l} - Y_i), \tag{1}$$

where Y_i is the yield of corporate bond i, $Y_{f,s}$ is the short-term risk-free rate, $Y_{f,l}$ is the long-term risk-free rate, and $Y_{i,l}$ is the long-term corporate bond yield.

Using Fig. 1, we can explain the meaning of the term $-(Y_{i,l} - Y_i)$. If we denote Y_i^{LI} as the yield with the same maturity as that of corporate bond i, a linear interpolation of the long-term and short-term corporate bond yields, then $-(Y_{i,l} - Y_i)$ can be expressed as the difference between Y_i-Y_i^{LI} and $Y_{i,l} - Y_i^{LI}$.

[Fig. 1 is about here.]

Applying the property of similar right triangles[6] to the term $-(Y_{i,l} - Y_i)$, Eq. (2) shows that it contains information on the steepness factor and the concavity factor:

$$\begin{aligned} Y_i &= Y_{f,s} + (Y_{i,l} - Y_{f,l}) + (Y_{f,l} - Y_{f,s}) - \{(Y_{i,l} - Y_i^{LI}) - (Y_i - Y_i^{LI})\} \\ &= Y_{f,s} + (Y_{i,l} - Y_{f,l}) + (Y_{f,l} - Y_{f,s}) \\ &\quad - \begin{bmatrix} \frac{D_{i,l} - D_i}{D_{i,l} - D_{i,s}} \{(Y_{f,l} - Y_{f,s}) + (Y_{i,l} - Y_{f,l}) - (Y_{i,s} - Y_{f,s})\} \\ -(Y_{f,i} - Y_{f,i}^{LI}) - \{(Y_i - Y_{f,i}) - (Y_i^{LI} - Y_{f,i}^{LI})\} \end{bmatrix} \\ &= Y_{f,s} + (Y_{i,l} - Y_{f,l}) \\ &\quad + \left(1 - \frac{D_{i,l} - D_i}{D_{i,l} - D_{i,s}}\right)(Y_{f,l} - Y_{f,s}) - \frac{D_{i,l} - D_i}{D_{i,l} - D_{i,s}} \{(Y_{i,l} - Y_{f,l}) - (Y_{i,s} - Y_{f,s})\} \\ &\quad + (Y_{f,i} - Y_{f,i}^{LI}) + \{(Y_i - Y_{f,i}) - (Y_i^{LI} - Y_{f,i}^{LI})\}, \end{aligned} \tag{2}$$

[6] The ancient Greek philosopher Thales was able to measure the height of King Khufu's pyramid, the tallest in Egypt, using the property of similar right triangles.

where Y_i, $Y_{f,s}$ $Y_{f,l}$, $Y_{i,l}$, and Y^{LI} are defined in the same way as above, D is the bond duration, and $Y_{f,i}$ denotes the zero-coupon rates of German government bonds with the same duration as that of corporate bond i.

Eq. (2) tells us that corporate bond yields can be decomposed into four factors: a short-term risk-free rate factor, and the three factors of the term structure of yield spreads (level factor, steepness factor, and concavity factor). Our result looks similar to that of Litterman and Scheinkman (1991), who use a principal component analysis to show that the three factors of level, steepness, and curvature determine bond yields. However, we decompose corporate bond yield spreads into short-term risk-free rates and each yield curve factor in a clearer and more intuitive way. Furthermore, in addition to explaining corporate yield spreads better than existing models do, our model reduces measurement errors because it incorporates the "missing factor" of corporate bond yields that is not considered in the Fama–French two-factor models, and because it reflects the characteristics of bond yield curves in a more systematic way.

Since government bonds are more liquid than corporate bonds, the yield spreads between them, with the same maturities, generally include a liquidity factor as well as a credit factor. Thus, we argue that the *DEF* factor of the Fama–French two-factor model can be regarded as a "gross credit factor," which includes a credit factor and a liquidity factor. Furthermore, we should consider a "net credit factor," which is calculated by subtracting the liquidity factor from the *DEF* factor in order to measure the credit risk premium more accurately and to specify a more precise relationship between credit risk and liquidity risk. In a similar vein, Longstaff et al. (2005, p 2223) claim that the Refcorp curve may provide a more accurate measure of the riskless curve than does the treasury curve because Refcorp bonds have the same default risk as treasury bonds, but do not have the same liquidity.

If we decompose yield spreads between corporate bonds and government bonds using KfW bonds, as in Eq. (3), the corporate bond yields are determined by the three term-structure factors (level, steepness, and concavity) of the risk-free rate, net credit, and illiquidity. The KfW spread can be regarded as common factor of illiquidity because it is the illiquidity factor for Bund (see, e.g., Monfort and Renne, 2014; Schwarz, 2015; Schuster and Uhrig-Homburg, 2015). There are two advantages to decomposing yield spreads based on KfW bonds. First, we can reflect the net credit factor and the illiquidity factor systematically according to the term structure theory of interest rates. Second, it is more convenient to estimate the illiquidity term structure of bonds when we use KfW spreads as an illiquidity measure. Prior studies examine either the sources of risk (interest rate, credit, and illiquidity) or one or a partial aspect of the term structure of interest rates. In contrast, our model enables us to perform a comprehensive analysis by decomposing yield spreads into each term-structure factor of interest rate, net credit, and illiquidity:

$$
\begin{aligned}
Y_i = Y_{f,s} &+ \left[\left(Y_{i,l} - Y_{KfW,l}\right) + \left(Y_{KfW,l} - Y_{f,l}\right)\right] \\
&+ \begin{bmatrix} \left(1 - \frac{D_{i,l}-D_i}{D_{i,l}-D_{i,s}}\right)\left(Y_{f,l} - Y_{f,s}\right) \\ -\frac{D_{i,l}-D_i}{D_{i,l}-D_{i,s}}\left\{\left(Y_{i,l} - Y_{KfW,l}\right) - \left(Y_{i,s} - Y_{KfW,s}\right)\right\} \\ -\frac{D_{i,l}-D_i}{D_{i,l}-D_{i,s}}\left\{\left(Y_{KfW,l} - Y_{f,l}\right) - \left(Y_{KfW,s} - Y_{f,s}\right)\right\} \end{bmatrix} \\
&+ \begin{bmatrix} \left(Y_{f,i} - Y_{f,i}^{LI}\right) \\ +\left\{\left(Y_i - Y_{KfW,i}\right) - \left(Y_i^{LI} - Y_{KfW,i}^{LI}\right)\right\} \\ +\left\{\left(Y_{KfW,i} - Y_{f,i}\right) - \left(Y_{KfW,i}^{LI} - Y_{f,i}^{LI}\right)\right\} \end{bmatrix},
\end{aligned}
\tag{3}
$$

where all variables are as defined in Eq. (1) and (2).

3.2.2 Extended Fama and French Model

We show that in Eq. (3), the corporate bond yield spread, which is the difference between a corporate bond yield and the short-term risk-free rate, can be decomposed into the three term-structure factors (level, steepness, and concavity) of interest rate, credit, and illiquidity. We apply an "extended Fama–French model" (Model 3) to European corporate bond markets to investigate whether each factor may be a determinant and/or priced risk factor of corporate yield spreads. In addition, we examine the impact of gross credit and net credit on illiquidity premiums using the proposed "extended Fama–French model." The expected signs of the coefficients of regressions estimated by the "extended Fama–French model" are negative for β_{p,crd_s} and $\beta_{p,illiq\_s}$ and positive for all the others. Furthermore, we compare the Fama–French two-factor model (Model 1) with Model 2, which has an additional term of $-(Y_{i,l} - Y_i)$:

Model 1: $Y_{p,t} - Y_{f,s,t} = \alpha_p + \beta_{p,ir\_s} TERM_t + \beta_{p,crd\_l} DEF_{l,t} + \varepsilon_{p,t}$

Model 2: $Y_{p,t} - Y_{f,s,t} = \alpha_p + \beta_{p,ir\_s} TERM_t + \beta_{p,crd\_l} DEF_{l,t} + \beta_{p,neo} NEO_t + \varepsilon_{p,t}$

Model 3:
$$
\begin{aligned}
Y_{p,t} - Y_{f,s,t} &= \alpha_p + \beta_{p,ir\_s}(1 - DUR_{l,t}) TERM_t + \beta_{p,ir\_c} IR\_C_t \\
&\quad + \beta_{p,crd\_l} CRD\_L_t + \beta_{p,crd\_s}(DUR_{l,t} \cdot CREDIT\_S_t) + \beta_{p,crd\_c} CRD\_C_t \\
&\quad + \beta_{p,illiq\_l} ILLIQ\_L_t + \beta_{p,illiq\_s}(DUR_{l,t} \cdot ILLIQUIDITY\_S_t) + \beta_{p,illiq\_c} ILLIQ\_C_t + \varepsilon_{p,t} \\
&= \alpha_p + \beta_{p,ir\_s} IR\_S_t + \beta_{p,ir\_c} IR\_C_t \\
&\quad + \beta_{p,crd\_l} CRD\_L_t + \beta_{p,crd\_s} CRD\_S_t + \beta_{p,crd\_c} CRD\_C_t \\
&\quad + \beta_{p,illiq\_l} ILLIQ\_L_t + \beta_{p,illiq\_s} ILLIQ\_S_t + \beta_{p,illiq\_c} ILLIQ\_C_t + \varepsilon_{p,t},
\end{aligned}
$$

where the variables are defined as follows:

Y_p: yield to maturity of corporate bond portfolio p;

$Y_{f,s}$: zero-coupon rate of German government bonds (Bunds) with the same duration as that of a short-term corporate bond portfolio;

$TERM$: term spread measured as the difference in zero-coupon rates between short-term and long-term German government bonds with the same durations as those of short-term and long-term corporate bond portfolios;

DEF: credit spread measured as the difference in yields between a long-term corporate bond portfolio and long-term German government bonds with the same duration as that of the long-term corporate bond portfolio;

NEO: the difference in yields between a long-term corporate bond portfolio and a corporate composite;

IR_C: concavity factor for risk-free rates, measured as the difference between Bunds yields calculated by linear interpolation and Bunds yields with the same duration as that of the corporate composite;

CRD_L: the difference in yields between a long-term corporate bond portfolio and KfW bonds with the same duration as that of the long-term corporate bond portfolio;

$CREDIT\_S$: steepness factor for credit, measured as the difference between long-term credit spreads and short-term credit spreads;

CRD_C: concavity factor for credit spreads, measured as the difference between credit spreads calculated by linear interpolation and credit spreads corresponding to the duration of the corporate composite;

$ILLIQ\_L$: the difference in zero-coupon rates between Bunds and KfW bonds with the same duration as that of the long-term corporate bond portfolio;

$ILLIQUIDITY\_S$: steepness factor for illiquidity, measured as the difference between long-term illiquidity spreads and short-term illiquidity spreads;

$ILLIQ\_C$: concavity factor for illiquidity spreads, measured as the difference between the illiquidity spreads calculated by linear interpolation and the illiquidity spreads corresponding to the duration of the corporate composite; and

DUR_l: scaling factor, calculated as $(D_{p,l} - D_p)/(D_{p,l} - D_{p,s})$.

4 Time Series Regressions

Table 2 provides the descriptive statistics and correlations for the explanatory variables. The averages of the explanatory variables of the extended Fama–French model (Model 3) are 0.39% for IR_S, 0.08% for IR_C, 1.41% for CRD_L, 0.09% for CRD_S, 0.31% for CRD_C, 0.27% for $ILLIQ\_L$, 0.04% for $ILLIQ\_S$, and 0.01% for $ILLIQ\_C$. We see that the variable credit level CRD_L has the highest mean value, but that the concavity variable for illiquidity $ILLIQ\_C$ has the lowest mean value. The averages of the explanatory variables of Model 2 are 1.30% for *TERM*, 1.68% for *DEF* and 0.64% for *NEO*. Since the correlations of $TERM$ and IR_S and the correlations of DEF and CRD_L show 0.99 in Table 2, we know that the steepness factor of the interest rate and the level factor of credit reflect the same information contained in the two factors of Fama and French (1993). However, the average value~~s~~ of IR_S is lower than that of *TERM* owing to the duration adjustment factor and the average value of CRD_L is lower than that of DEF because DEF is decomposed to CRD_L and $ILLIQ\_L$.

From Eq. (3), we can decompose the traditional credit factor into a net credit factor and an illiquidity factor using KfW bonds. However, since the correlation between CRD_L and $ILLIQ\_L$ is

0.82 in Table 2, CRD_L and $ILLIQ\_L$ affect each other.[7] Consequently, we extract an "orthogonal credit level," which is not affected by the illiquidity level factor common to bond markets, as shown in Eq. (4) (Cieslak and Povala, 2015):

$$OrthoCreditLevel_t = DEF_t - \hat{a} - \hat{b} \cdot ILLIQ\_L_t. \tag{4}$$

[Table 2 is about here.]

Table 3 provides the results for the times series regression of 23 rating and maturity indices. Panel A shows that the two explanatory variables of the Fama and French model (1993) are statistically significant at the 1% level and that the adjusted R-squared value is at least 86%. Panel B shows that the new variable *NEO*, which was not considered in the Fama–French two-factor model, is statistically significant at the 1% level for all portfolios except BBB 10Y+, and that the adjusted R-squared value is at least 96%. This indicates that Model 2 is more suitable than the Fama–French two-factor model. Hence, we argue that the new variable *NEO*, which is added by the analytic factor decomposition method, is a meaningful factor in explaining bond yield spreads. For the extended Fama–French model (Model 3), which has all the factors of the yield curve with regard to interest rate, net credit, and illiquidity, we report two results in Panels C and D. Panel C shows the results for Model 3-1, in which the non-orthogonal credit level is used as the net credit factor. Panel D shows the results for Model 3-2, in which the orthogonal credit level is used as the net credit factor. Both panels show that all eight explanatory variables have significant coefficients and that the adjusted R-squared value is more than 97%. The coefficients of the steepness factors of net credit and illiquidity show negative signs, as expected. Comparing Panel C with Panel D, we see that all variables have the same

[7] We test the multicollinearities among variables using variance inflation factor and find that $ILLIQ\_L$ can be expressed as a linear combination of other variables. We also find that only level factor shows a significant coefficient when we run a time series regression between credit and illiquidity factors. We do not report the results of multicollinearity test and this regression due to space limitations.

coefficients, except for the illiquidity level factor, $ILLIQ\_L$, and the constants. Interestingly, not only the size of β_{illiq_l} increases but also the tendency of β_{illiq_l} to increase becomes more significant as the credit rating downgrades and the remaining maturity increases, from Model 3-1 to Model 3-2. This result implies that if we take the credit factor into account inappropriately, the liquidity risk and overestimate the credit risk at the same time.

[Table 3 is about here.]

5 Cross-Sectional Regressions

To test whether the factors of the extended Fama–French model are important risk factors in determining bond yield spreads in cross sections, we run Fama–MacBeth regressions (Fama and MacBeth, 1973).[8] Here, we estimate the betas using five-year rolling window data. We use Markit iBoxx EUR Corporates Indices as the rating and maturity class corporate bond portfolio. For the dependent variable, we use the yield spreads of the rating and maturity class corporate bond portfolio, which are calculated by subtracting the short-term risk-free rates from the yields-to-maturity of each portfolio at the end of each month. For short-term risk-free rates, we use the zero-coupon rates of Bunds with the same duration as that of the short-term (1~3 years) corporate bond portfolio. In equilibrium, bond realized returns are related to factor loadings in cross sections and, in general, have linear relations with the betas. In order to examine whether yield spreads have linear relations with the betas as realized returns, we use the following regression models, which include squared betas:

$$\text{Model 1:} \quad Y_{p,t} - Y_{f,s,t} = \gamma_0 + \gamma_1 \beta_{p,ir_s} + \gamma_3 \beta_{p,crd_l} + \gamma_9 \beta^2_{p,ir_s} + \gamma_{11} \beta^2_{p,crd\_l} + u_p \tag{5}$$

$$\begin{aligned} \text{Model 2:} \quad Y_{p,t} - Y_{f,s,t} &= \gamma_0 + \gamma_1 \beta_{p,ir\_s} + \gamma_3 \beta_{p,crd\_l} + \gamma_{17} \beta_{p,neo} \\ &+ \gamma_9 \beta^2_{p,ir\_s} + \gamma_{11} \beta^2_{p,crd\_l} + \gamma_{18} \beta^2_{p,neo} + u_p \end{aligned} \tag{6}$$

[8] Petersen (2009) suggests that when the residuals are correlated across firms and across time, OLS standard errors can be biased, in which case, the Fama–MacBeth procedure to estimate standard errors is appropriate.

$$
\begin{aligned}
\text{Model 3:} \quad Y_{p,t} - Y_{f,s,t} = {} & \gamma_0 + \gamma_1\beta_{p,ir\_s} + \gamma_2\beta_{p,ir\_c} + \gamma_3\beta_{p,crd\_l} + \gamma_4\beta_{p,crd\_s} + \gamma_5\beta_{p,crd\_c} \\
& +\gamma_6\beta_{p,illiq\_l} + \gamma_7\beta_{p,illiq\_s} + \gamma_8\beta_{p,illiq\_c} \\
& +\gamma_9\beta^2_{p,ir\_s} + \gamma_{10}\beta^2_{p,ir\_c} + \gamma_{11}\beta^2_{p,crd\_l} + \gamma_{12}\beta^2_{p,crd\_s} + \gamma_{13}\beta^2_{p,crd\_c} \\
& +\gamma_{14}\beta^2_{p,illiq\_l} + \gamma_{15}\beta^2_{p,illiq\_s} + \gamma_{16}\beta^2_{p,illiq\_c} + u_p. \qquad (7)
\end{aligned}
$$

If a bond has a relatively greater systematic risk, it should have a higher yield spread, and if a beta of some factor that determines the yield spread is an important risk factor, it should have a statistically significant positive coefficient.

Table 4 provides the Fama–MacBeth cross-sectional regression results for 23 rating and maturity class corporate bond portfolios. We find that there exists a non-linearity between yield spreads and betas because the coefficients of the squared betas are all statistically significant in the Fama–French two-factor model (Model 1) and Model 2, which includes the *NEO* factor. Specifically, since the coefficients of β_{neo} and β^2_{neo} are statistically significant at the 1% level and the R-squared value of Model 2 (92%) increases by 19% points from Model 1 (73%), it is highly likely that the factors derived from the analytic decomposition method will be crucial risk factors in determining yield spreads. In Model 3, we find that portfolio yield spreads show significant relationships with the betas in cross-sections, except in the case of the concavity factors of interest rate and illiquidity (IR_C, $ILLIQ\_C$), and that, overall, there exists a non-linearity between yield spreads and betas. In Model 3-1 and Model 3-2, it is interesting to note that as the betas of the illiquidity level factor increase, the yield spreads also increase for both models, but with opposite growth rates (the coefficients of $\beta^2_{illiq\_l}$ > 0 in Model 3-1, but the coefficients of $\beta^2_{illiq\_l}$ < 0 in Model 3-2).

[Table 4 is about here.]

Table 5 provides the risk prices of the bond risk factors. Risk prices are calculated by partial differentiation (e.g., $\partial YS_{p,t} \,/\, \partial\beta_p = \widehat{\gamma_1} + 2\widehat{\gamma_2}\beta_p$), considering the non-linear relationship between yield spreads and betas (e.g., $YS_{p,t} = \widehat{\gamma_1}\beta_p + \widehat{\gamma_2}\beta_p^2$). Here, β_p is calculated as the average of the rolling betas of each factor.

Since the risk prices of all risk factors in Model 3, as well as in Model 1 and Model 2, show positive values, we know that there are trade-offs between betas and yield spreads. In Model 3-2, when one unit of each risk factor changes, the yield spreads are affected by the following order and magnitude: interest rate factor (59.0%), illiquidity factor (26.9%), and credit factor (14.1%). The risk price of the illiquidity factor is almost 1.8 times higher than that of the credit factor. With regard to the risk factors of the yield curve, the yield spreads are affected by the following order and magnitude: concavity (44.8%), level (43.9%), and steepness (11.3%). Interestingly, the risk prices of the steepness of credit and illiquidity show negative values, implying that corporate bonds with higher betas for CRD_S and $ILLIQ\_S$ can reduce yield spreads. In addition, the main risk factors that contribute to increasing yield spreads are related to the steepness of the interest rate, the concavity of credit, and the level of illiquidity. From these results, we know that for effective bond portfolio management and risk management, we need to decompose, measure and manage the risks, according to each risk factor.

[Table 5 is about here.]

Table 6 provides the risk premiums of each risk factor and their contribution to the total risk premium when the extended Fama–French eight-factor model is applied. The risk premium is calculated by multiplying the average betas of the 23 rating and maturity class corporate bond portfolios by the risk prices estimated using the Fama–MacBeth regressions Eq. (7).[9] The betas of each corporate bond portfolio are estimated using the data from the whole sample from January 2003 to August 2015. We find the following. First, the risk premium (size/proportion) of European

[9] This is the same, because we multiply the market risk premium (the risk price of market portfolio) by the individual security's beta when we calculate the risk premium of that security.

corporate bonds is estimated in the following order when Model 3-2 is applied: level premium (1.71/52.4%), steepness premium (1.05/32.4%), and concavity premium (0.50/15.2%). This result corresponds with that of Litterman and Scheinkman (1991), who use a principal component analysis. Second, the total risk premium (size/proportion) is decomposed by each risk factor in the following order when Model 3-2 is applied: illiquidity premium (1.44/44.3%), credit premium (1.23/37.6%), and interest rate premium (0.59/18.1%). The contribution of the credit premium to the total risk premium does not exceed 53%, even for Model 3-1 (see, e.g., Elton et al., 2001; De Jong and Driessen, 2012; Huang and Huang, 2012). Third, Model 3-1, which uses the non-orthogonal net credit factor, shows a greater contribution to the credit premium (2.02%) than to the illiquidity premium (1.12%), in contrast to Model 3-2, which uses the orthogonal net credit factor. In addition, the total risk premium given by Model 3-1 (3.85%) is greater than that given by Model 3-2 (3.26%). Thus, we find that the credit premium and then total risk premium are overestimated owing to the correlation between the credit and illiquidity level factors when the orthogonality of the net credit factor is not considered.

[Table 6 is about here.]

6 Liquidity Black Holes and Liquidity Preference

While we have been experiencing two disastrous financial crises in the twenty-first century, the yield spreads of bond markets have increased significantly and financial markets have become unstable. While prior literature has examined the relationship between credit and illiquidity, mainly during the period of the global financial crisis, which is characterized as a private sector crisis, we also investigate the relationship between the two factors during the European national debt crisis, which is characterized as a public sector crisis.

6.1 Liquidity Black Holes

Panel (A) of Fig. 2 depicts the yield spreads, which are differences between the yields-to-maturity of the Markit iBoxx EUR Corporates Indices and the zero-coupon rates of German government bonds (Bunds) from January 2003 to August 2015. On June 7, 2007, Bear Stearns announced it would temporarily stop buying back the high-grade structured credit enhanced leveraged fund, which ignited the global financial crisis. Then, on September 15, 2008, Lehman Brothers went bankrupt, which caused the yield spreads of the corporate bond markets to increase significantly. When the Euro member countries and the IMF reached an agreement on an emergency rescue plan for Greece of €110 billion on May 2, 2010, the crisis of the private sector migrated to the public sector, and on October 18, 2012, after a European summit meeting, the European national debt crisis stabilized. The sample period is divided into four periods: before the global financial crisis (2003.1~2007.5), during the global financial crisis (2007.6~2010.4), during the European national debt crisis (2010.5~2012.9), and after the European national debt crisis (2012.10~2015.8).

Panels (B) and (C) of Fig. 2 depict the time trends of the interest rate premium, credit premium, and illiquidity premium, and the level premium, steepness premium, and concavity premium, respectively. Each risk premium is calculated monthly by multiplying the average betas of the 23 rating and maturity class corporate bond portfolios by the risk prices estimated using the Fama–MacBeth cross-section regressions. The risk prices are estimated using Model 3-2, in which the orthogonal credit factor is used. The average betas of the portfolio are calculated by averaging the estimated betas using data for at least 60 months from January 2003, which is fixed. Thus, the risk premium is generated from January 2008. From Panel (B), we see that the credit and interest rate premiums rose during the global financial crisis, but decreased gradually during the European national debt crisis. However, in contrast, the illiquidity premium showed both a time-varying and an opposite trend to that of the credit premium. From Panel (C), we see that only the level and steepness premiums among the yield curve factors rose during the global financial crisis, but that they then stabilized (the concavity premiums were stable regardless the financial crises). Interestingly, in contrast to other risk premiums, the interest rate premium and steepness premium rose during the global financial crisis and maintained their high levels after the European national debt crisis.

[Fig. 2 is about here.]

Table 7 provides the results of the time-series regressions on the relationship between the illiquidity premium and the credit premium. The regression model we use is $ILLIQ_t = \alpha + \beta \cdot CRD_t + \varepsilon_t$, where $ILLIQ$ is the illiquidity premium and CRD is the credit premium. The sample period is from January 2003 to August 2015. Our findings are as follows. First, we find the same significantly negative relationship between the illiquidity premium and the credit premium in European corporate bond markets, at the 1% level, during the sample period as in Beber et al. (2009). They examined the relationship between credit quality and liquidity in the European government bond markets from April 2003 to December 2009. Second, we find that the relationship between the illiquidity premium and the credit premium during the global financial crisis was significantly positive at the 5% level, which is substantiated by the simultaneous increase in both premiums during the second half of 2008, when Lehman Brothers went bankrupt (see Panel A of Fig. 2). In normal market situations, the demand for an asset increases when its price falls, according to the endogenous feedback mechanism. However, in severe financial crises, liquidity black holes can arise where the price of an asset continues to fall because there are only sellers in the markets owing to loss limits (e.g., see Morris and Shin (2004)). Ericsson and Renault (2006) also report a positive relationship between the illiquidity factor and the credit factor in the U.S. corporate bond markets from 1986 to 2001. Third, we find that the negative relationship between the credit premium and the illiquidity premium has recently become stronger, with an adjusted R-squared value of 0.98.

In summary, we find that the relationship between illiquidity and credit differs depending on the economic situation. Furthermore, we show that liquidity black holes occur and dissipate asset prices because the self-stabilizing market mechanism gets weaker or does not work appropriately at the beginning of a financial crisis when uncertainty is profound.

[Table 7 is about here.]

6.2 Liquidity Preference

During a financial crisis, investors prefer safe assets (flight-to-quality) and/or liquidity (flight-to-liquidity). However, it is not easy to distinguish between the roles and contributions of the two factors because credit and liquidity move with a close relationship. In this section, we test the adequacy of our research model. To do so, we analyze the role of credit and illiquidity and the cause of the sudden increases in bond yield spreads discovered during the two financial crises, both from the perspective of the total risk premium of corporate bonds and from the perspective of the differences in the risk premiums between high-quality bonds and low-quality bonds. We apply Model 3-2, which includes eight factors extracted from the analytic decomposition method and uses the orthogonal net credit factor.

Table 8 provides the risk premium for each factor and its contribution to the total risk premium in three different economic situations. Each risk premium is the arithmetic average of risk premiums calculated monthly. A common feature in all three periods is that the contribution of each factor to the bond yield spreads is in descending order of credit, illiquidity, and the interest rate premium. Compared to the period after the European national debt crisis (3.18%), the total risk premium increases for both crisis periods (3.35% during the global financial crisis, and 3.38% during the European national debt crisis). However, the main risk factor that causes the increase in the risk premium is different for the two crises. During the global financial crisis, the illiquidity level premium makes the biggest contribution to the total risk premium (42.2%), which corresponds to the flight-to-liquidity phenomenon. However, during the European national debt crisis, the credit level premium makes the biggest contribution to the total risk premium (28.7%), which corresponds to the flight-to-quality phenomenon. This implies that decomposing, measuring and managing risks according to each risk factor is essential to appropriate portfolio management, risk management, and when establishing economic policies, as well as for effective crisis management.

[Table 8 is about here.]

During a financial crisis, there is a tendency for the maturities of all money market instruments to shorten, and the decrease in the duration of capital markets means economic environments are easily broken, even by a small impact (Gorton et al., 2015). Table 9 shows the changes in the term structure of the risk premium and the differences in the risk premiums between high-quality bonds and low-quality bonds, depending on the economic situation. Specifically, we estimate the differences in the risk premium between an AA rating portfolio and a BBB rating portfolio, based on the economic situation and the remaining maturities. The remaining maturities are classified as short term (1~3 years), medium term (5~7 years), or long-term (7~10 years). The differences between the risk premiums of the AA rating portfolio and the BBB portfolio are calculated by averaging the differences in the estimated risk premiums of the portfolios on a monthly basis. The differences between the risk premiums of the two portfolios are calculated monthly by multiplying the differences of the factor betas of the AA and BBB rating portfolios across each maturity, estimated by time-series regressions, by the risk prices of each factor estimated using Fama–MacBeth cross-section regressions. The monthly betas of the rating and maturity class corporate bond portfolios are estimated using data from January 2003 until the previous month when the betas are estimated. The estimation period for the betas is at least five years.

From Table 9, we find that the differences between the risk premiums of the AA and BBB portfolios are greater during the financial crises than they are after the European national debt crisis (the only exception is the short-term maturity portfolio during the global financial crisis). With regard to the term structure of the risk premiums (short term/medium term/long term) in different economic situations, the periods during the global financial crisis (1.19/1.62/1.91%) and the European national debt crisis (1.37/1.86/2.02%) have steeper term structures than does the period after the European debt crisis (1.28/1.36/0.73%). Specifically, the global financial crisis shows the steepest term structure and the lowest difference in the short-term risk premium, implying that this is the most significant flight-from-maturity phenomenon of the various periods. Interestingly, we find that the contribution of the illiquidity premium to the short-term maturity is greatest (62.2%) for the global financial crisis. The results suggest that during the global financial crisis, in contrast to the European national debt crisis, the financial markets became unstable rapidly owing to liquidity black holes and liquidity preferences.

[Table 9 is about here.]

7 Conclusions

The recognition and effective management of liquidity is more important and necessary than ever. The main results of this study are summarized as follows. First, we propose a new extended Fama–French model, based on yield curve information. To the best of our knowledge, this is the first study to propose a corporate bond pricing model that considers interest rates, credit, and illiquidity factors simultaneously, together with the three main characteristics of the yield curve (i.e., level, steepness, and concavity) by extending the Fama–French two-factor model. Second, we show the importance of the "net credit risk factor" in the determination of yield spreads of corporate bonds and the underestimation problem of illiquidity premiums (overestimation of credit premiums) that has been overlooked by current literature. Third, we find that each bond yield factor responds differently, depending on the source of the financial shock, by examining the impact (performance decomposition) of each factor on bond yield spreads. Fourth, we find that the yield curve information contained in the new extracted variables plays an important role in explaining the yield spreads of individual bonds. Fifth, we find that there exists a non-linear relationship between bond yields and betas. Sixth, we find that the relationship between credit and illiquidity differs, depending on the economic situation, and that it is essential to measure and manage risk separately for the risk factors identified in this study. Lastly, we find that liquidity black holes arise at the beginning of a financial crisis when uncertainty prevails, and that financial markets quickly become unstable because the self-stabilizing mechanism of bond markets does not work appropriately owing to the liquidity preferences of investors during the global financial crisis.

The results of this study can be used by policymakers when establishing financial policies based on the liquidity and credit situations of the bond markets, as well as by financial institutions and investors for effective risk management and for correctly calculating bond pricing.

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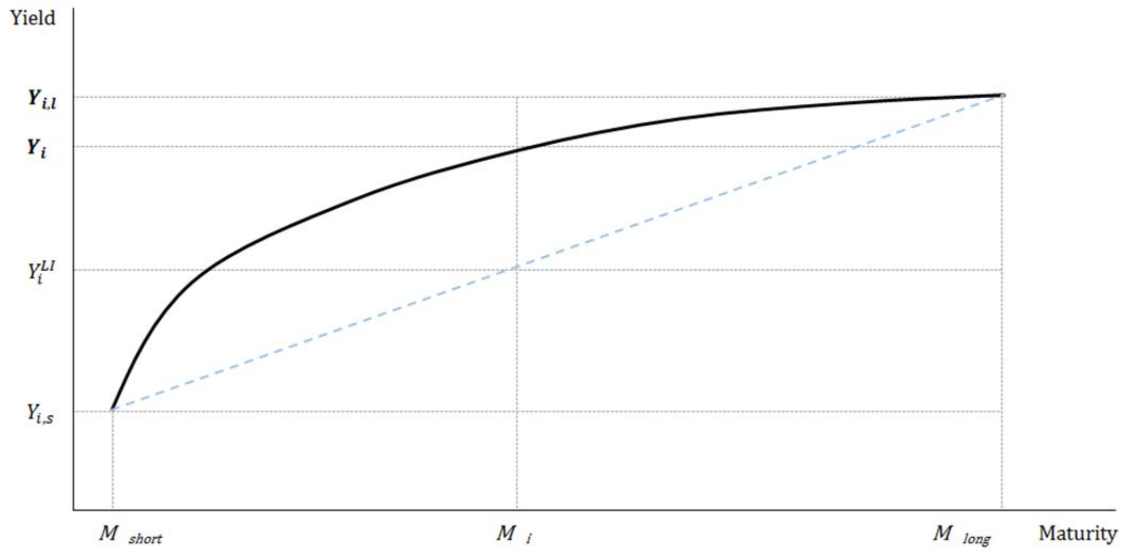

Fig. 1. This figure shows the meaning of the term $-(Y_{i,l} - Y_i)$. Here, Y_i is the yield of corporate bond i, $Y_{i,l}$ is the long-term corporate bond yield, $Y_{i,s}$ is the short-term corporate bond yield, and Y_i^{LI} is the yield with the same maturity as that of corporate bond i, a linear interpolation of long-term and short-term corporate bond yields.

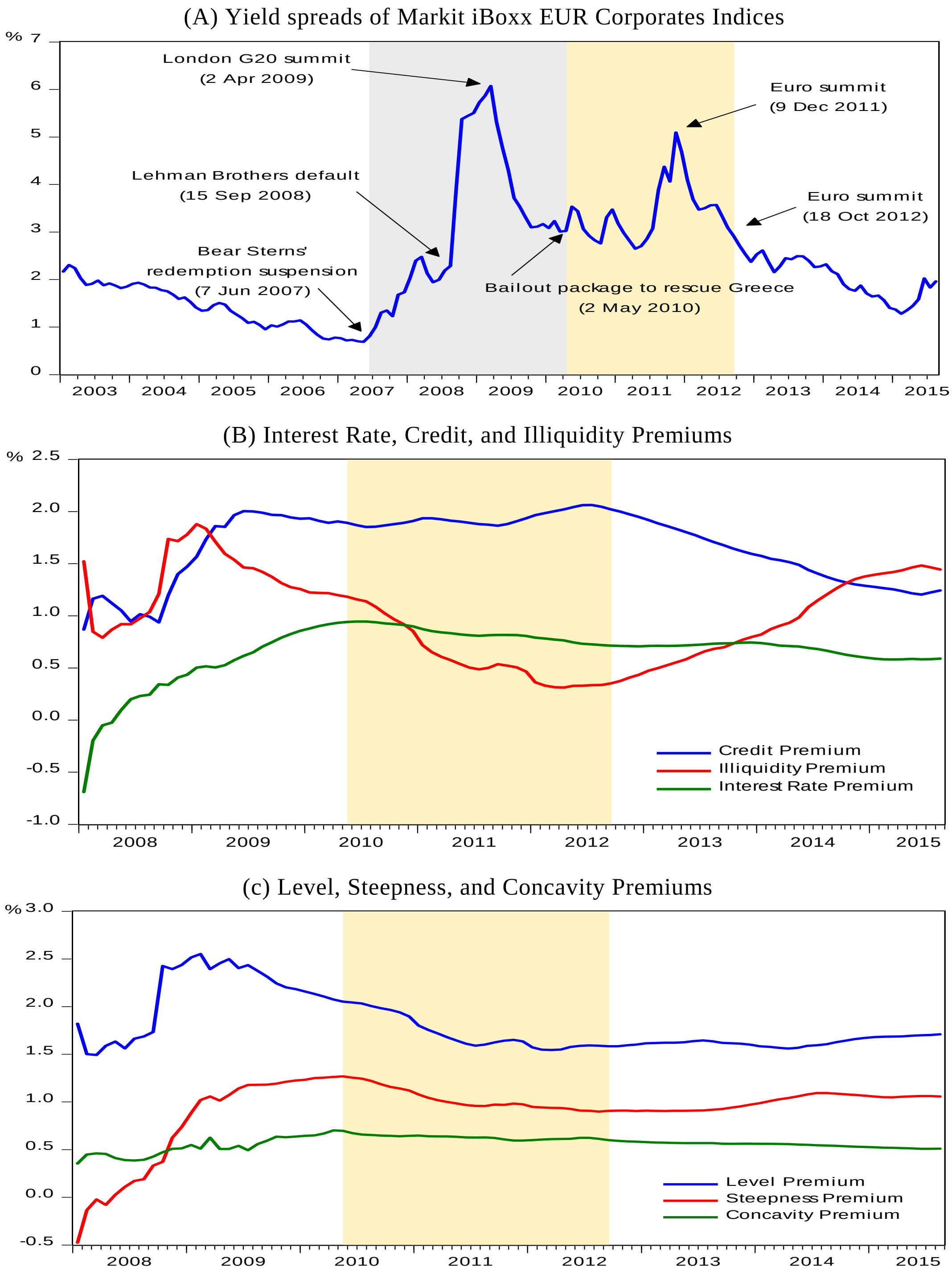

Fig. 2. Panel (A) depicts the yield spreads that are differences between the yields-to-maturity of the Markit iBoxx EUR Corporates Indices and the zero-coupon rates of German government bonds (Bunds) from January 2003 to August 2015. The sample period is divided into four periods: before the global financial crisis (2003.1~2007.5), during the global financial crisis (2007.6~2010.4), during the European national debt crisis (2010.5~2012.9), and after the European national debt crisis (2012.10~2015.8). Panels (B) and (C) depict the time trends of the interest rate premium, credit premium, and illiquidity premium, and the level premium, steepness premium, and concavity premium, respectively. The average betas of the portfolio are calculated by averaging the estimated betas using at least 60 months of data from the start of January 2003 so that the risk premium is generated from January 2008.

Table 1 Descriptive statistics of corporate bond indices

This table shows the descriptive statistics for the sample bond indices. The sample period is from January 2003 to August 2015. The European corporate bond indices are 23 rating and maturity class broad Markit iBoxx EUR Corporate bond Indices. Eight of the indices are composite indices for three different credit ratings (Corporates AA, A, BBB) and five different maturities (Corporates 1-3, 3-5, 5-7, 7-10, 10+).

	Duration	Yield spreads (%)						
Index	(years)	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
Corp. Composite	4.39	2.34	2.03	6.07	0.69	1.19	1.05	3.86
Corp. 1-3Y	1.81	1.47	1.13	5.46	0.31	1.15	1.46	4.77
Corp. 3-5Y	3.48	1.89	1.61	5.61	0.46	1.18	1.13	3.88
Corp. 5-7Y	5.00	2.33	2.01	6.52	0.61	1.35	1.13	3.99
Corp. 7-10Y	6.67	2.72	2.42	6.81	0.80	1.35	0.91	3.55
Corp. 10Y+	10.09	2.99	2.98	5.49	0.98	1.09	0.13	2.32
Corp. AA	4.53	1.85	1.69	4.44	0.45	0.92	0.79	3.24
Corp. A	4.50	2.29	1.96	6.59	0.72	1.27	1.46	5.25
Corp. BBB	4.19	2.88	2.41	7.23	0.85	1.52	1.06	3.56
Corp. AA 1-3Y	1.83	0.94	0.65	3.62	0.18	0.80	1.54	4.93
Corp. AA 3-5Y	3.52	1.38	1.08	4.11	0.30	0.92	1.19	3.89
Corp. AA 5-7Y	5.09	1.76	1.54	4.49	0.40	0.97	0.86	3.32
Corp. AA 7-10Y	6.77	2.16	1.97	5.27	0.46	1.11	0.60	2.82
Corp. AA 10Y+	11.03	2.63	2.71	4.89	0.71	1.05	0.05	2.25
Corp. A 1-3Y	1.81	1.41	0.88	6.13	0.30	1.30	1.85	6.12
Corp. A 3-5Y	3.48	1.79	1.39	6.45	0.46	1.26	1.63	5.68
Corp. A 5-7Y	5.01	2.22	1.84	7.01	0.57	1.38	1.46	5.19
Corp. A 7-10Y	6.68	2.72	2.36	7.41	0.84	1.49	1.29	4.70
Corp. A 10Y+	9.86	2.85	2.70	5.49	0.98	1.08	0.33	2.40
Corp. BBB 1-3Y	1.80	1.99	1.46	7.14	0.41	1.54	1.36	4.48
Corp. BBB 3-5Y	3.43	2.43	2.04	6.52	0.58	1.50	1.02	3.37
Corp. BBB 5-7Y	4.91	2.89	2.30	7.73	0.74	1.70	1.03	3.41
Corp. BBB 7-10Y	6.50	3.32	2.84	8.23	0.99	1.68	0.95	3.38
Corp. BBB 10Y+	9.78	3.68	3.68	7.02	1.25	1.34	0.39	2.69

Table 2 Summary statistics of explanatory variables

This table shows the descriptive statistics and correlations for the explanatory variables. Here, IR is the interest rate, CRD is credit, $ILLIQ$ is illiquidity, $\_L$ is level, $\_S$ is steepness, and $\_C$ is concavity. $TERM$ and DEF are the two Fama and French (1993) factors. NEO is the difference between the corporate bond composite index and the long-term corporate bond index.

Variables	Descriptive statistics of factors					Factor correlations										
	Mean	Median	Maximum	Minimum	Standard Deviation	IR_S	IR_C	CRD_L	CRD_S	CRD_C	ILLIQ_L	ILLIQ_S	ILLIQ_C	TERM	DEF	NEO
IR_S	0.39	0.44	0.69	0.00	0.19	1.00										
IR_C	0.08	0.08	0.44	-0.21	0.13	0.67	1.00									
CRD_L	1.41	1.30	2.87	0.74	0.49	0.25	-0.01	1.00								
CRD_S	0.09	0.26	0.52	-1.50	0.39	-0.49	-0.37	-0.79	1.00							
CRD_C	0.31	0.29	0.79	0.06	0.14	-0.05	-0.39	0.42	-0.12	1.00						
ILLIQ_L	0.27	0.23	0.81	0.02	0.20	0.24	0.00	0.82	-0.79	0.39	1.00					
ILLIQ_S	0.04	0.03	0.26	-0.24	0.08	0.12	-0.06	-0.02	-0.12	-0.24	0.36	1.00				
ILLIQ_C	0.01	0.00	0.20	-0.23	0.08	0.23	0.03	0.45	-0.42	-0.08	0.25	0.08	1.00			
TERM	1.30	1.51	2.42	0.00	0.67	0.99	0.68	0.33	-0.58	-0.04	0.34	0.15	0.28	1.00		
DEF	1.68	1.51	3.58	0.81	0.66	0.26	-0.01	0.99	-0.82	0.43	0.90	0.09	0.41	0.34	1.00	
NEO	0.64	0.71	1.23	-0.71	0.41	0.47	0.24	-0.54	0.43	-0.40	-0.42	0.35	-0.21	0.40	-0.53	1.00

Table 3 Time series regression

This table presents the results of following models:

Model 1: $Y_{p,t} - Y_{f,s,t} = \alpha_p + \beta_{p,ir\_s} TERM_t + \beta_{p,crd\_l} DEF_{l,t} + \varepsilon_{p,t}$

Model 2: $Y_{p,t} - Y_{f,s,t} = \alpha_p + \beta_{p,ir\_s} TERM_t + \beta_{p,crd\_l} DEF_{l,t} + \beta_{p,neo} NEO_t + \varepsilon_{p,t}$

Model 3: $Y_{p,t} - Y_{f,s,t} = \alpha_p + \beta_{p,ir\_s} IR\_S_t + \beta_{p,ir\_c} IR\_C_t + \beta_{p,crd\_l} CRD\_L_t + \beta_{p,crd\_s} CRD\_S_t + \beta_{p,crd\_c} CRD\_C_t$
$+ \beta_{p,illiq\_l} ILLIQ\_L_t + \beta_{p,illiq\_s} ILLIQ\_S_t + \beta_{p,illiq\_c} ILLIQ\_C_t + \varepsilon_{p,t}$,

where $Y_{p,t}$ is the yield to maturity of corporate bond portfolio *p*, $Y_{f,s}$ is the zero-coupon rate of German government bonds (Bunds) with the same duration as that of the short-term corporate bond portfolio, *TERM* is the term spread measured as the difference in zero-coupon rates between the short-term and long-term German government bonds with the same duration as that of the short-term and long-term corporate bond portfolios, *DEF* is the credit spread measured as the difference in yields between the long-term corporate bond portfolio and the long-term German government bonds with the same duration as that of the long-term corporate bond portfolio, *NEO* is the difference in yields between the long-term corporate bond portfolio and the corporate composite. *IR_C* is the concavity factor for risk-free rates measured as the difference between Bunds yields calculated by linear interpolation and Bunds yields with the same duration as that of the corporate composite, *CRD_L* is the difference in yields between the long-term corporate bond portfolio and the KfW bonds with the same duration as that of the long-term corporate bond portfolio, *CRD_C* is the concavity factor for credit spreads measured as the difference between credit spreads calculated by linear interpolation and the credit spreads corresponding to the duration of the corporate composite, *ILLIQ_L* is the difference in zero-coupon rates between Bunds and KfW bonds with the same duration as that of the long-term corporate bond portfolio *ILLIQ_C* is the concavity factor for illiquidity spreads measured as the difference between the illiquidity spreads calculated by linear interpolation and the illiquidity spreads corresponding to the duration of corporate composite. Panel C shows the results for Model 3-1 when a non-orthogonal credit level is used as the net credit factor. Panel D shows the results for Model 3-2 when an orthogonal credit level is used as the net credit factor. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Model 1

Portfolio	Constant	β_{ir_s}	β_{crd_l}	*Adj. R-square*
AA 1-3Y	-0.9709***	0.0309	1.1159***	0.863
A 1-3Y	-1.7715***	0.2062***	1.7331***	0.856
BBB 1-3Y	-2.0610***	0.4548***	2.0581***	0.938
AA 3-5Y	-0.9592***	0.3050***	1.1568***	0.868
A 3-5Y	-1.3965***	0.3300***	1.6390***	0.872
BBB 3-5Y	-1.6208***	0.5819***	1.9604***	0.965
AA 5-7Y	-0.7671***	0.4931***	1.1229***	0.881
A 5-7Y	-1.3285***	0.4953***	1.7254***	0.873
BBB 5-7Y	-1.6857***	0.8788***	2.0396***	0.938
AA 7-10Y	-0.8264***	0.7510***	1.1920***	0.927
A 7-10Y	-1.1468***	0.6263***	1.8144***	0.883
BBB 7-10Y	-1.2340***	0.8998***	2.0126***	0.953
AA 10Y+	-0.1784***	1.0226***	0.8796***	0.965
A 10Y+	-0.1100***	0.9208***	1.0488***	0.991
BBB 10Y+	0.0153	1.1246***	1.3089***	0.971
AA	-0.6124***	0.5323***	1.0514***	0.916
A	-1.0038***	0.4973***	1.5760***	0.892
BBB	-1.2501***	0.7149***	1.9038***	0.964
1-3Y	-1.5356***	0.2762***	1.5749***	0.941
3-5Y	-1.2627***	0.4407***	1.5357***	0.953
5-7Y	-1.2872***	0.6282***	1.6657***	0.937
7-10Y	-0.9582***	0.7617***	1.5993***	0.950
10Y+	-0.0000	1.0000	1.0000	1.000
			Average	0.926
			Max	1.000
			Min	0.856

Panel B: Model 2

Portfolio	Constant	β_{ir_s}	β_{crd_l}	β_{neo}	*Adj. R-square*
AA 1-3Y	-0.0155	0.4621***	0.6184***	-1.0616***	0.966
A 1-3Y	-0.0632	0.9772***	0.8436***	-1.8980***	0.981
BBB 1-3Y	-1.1342***	0.8730***	1.5755***	-1.0297***	0.964
AA 3-5Y	0.1290**	0.7960***	0.5902***	-1.2090***	0.970
A 3-5Y	0.2178***	1.0585***	0.7983***	-1.7937***	0.991
BBB 3-5Y	-1.0211***	0.8526***	1.6481***	-0.6663***	0.977
AA 5-7Y	0.2739***	0.9629***	0.5808***	-1.1566***	0.965
A 5-7Y	0.4275***	1.2878***	0.8109***	-1.9511***	0.990
BBB 5-7Y	-0.4118***	1.4537***	1.3763***	-1.4154***	0.979
AA 7-10Y	0.0962	1.1674***	0.7116***	-1.0251***	0.977
A 7-10Y	0.6376***	1.4316***	0.8852***	-1.9826***	0.987
BBB 7-10Y	-0.0889	1.4166***	1.4163***	-1.2723***	0.986
AA 10Y+	0.2239***	1.2041***	0.6701***	-0.4469***	0.975
A 10Y+	0.0520	0.9940***	0.9644***	-0.1801***	0.992
BBB 10Y+	0.0088	1.1217***	1.3123***	0.0072	0.971
AA	0.2384***	0.9163***	0.6084***	-0.9453***	0.977
A	0.4853***	1.1693***	0.8006***	-1.6545***	0.992
BBB	-0.3622***	1.1157***	1.4414***	-0.9865***	0.989
1-3Y	-0.6220***	0.6885***	1.0992***	-1.0151***	0.986
3-5Y	-0.3565***	0.8497***	1.0638***	-1.0068***	0.996
5-7Y	-0.0509*	1.1861***	1.0219***	-1.3736***	0.998
7-10Y	0.1388***	1.2568***	1.0281***	-1.2189***	0.997
10Y+	-0.0000	1.0000	1.0000	0.0000	1.000
				Average	0.983
				Max	1.000
				Min	0.964

Panel C: Model 3-1

Portfolio	Constant	β_{ir_s}	β_{ir_c}	β_{crd_l}	β_{crd_s}	β_{crd_c}	β_{illiq_l}	β_{illiq_s}	β_{illiq_c}	*Adj. R-square*
AA 1-3Y	0.0184	-0.7851***	1.0847***	0.4144***	-0.7489***	0.9393***	1.5457***	-2.0954***	1.0463***	0.972
A 1-3Y	0.1884**	-1.1130***	1.4950***	0.9338***	-1.8784***	0.9030***	0.7092***	-2.2861***	1.2694***	0.986
BBB 1-3Y	-0.0808	0.4192***	-0.4249**	1.3214***	-2.0444***	0.0879	0.9078***	-0.1228	-0.2583	0.988
AA 3-5Y	-0.0433	-0.2868***	2.0712***	0.4394***	-0.5906***	1.2185***	1.8387***	-2.1619***	2.2196***	0.985
A 3-5Y	0.1098	-0.8781***	2.2086***	0.9346***	-1.6891***	2.0564***	0.2147	-1.0316***	2.1115***	0.992
BBB 3-5Y	-0.5281***	1.2438***	0.3789	1.3525***	-0.7666***	-0.1891	2.7201***	-1.6975***	0.4392	0.981
AA 5-7Y	-0.0791	0.4950***	2.0433***	0.4044***	-0.5013***	1.7257***	1.8187***	-2.1806***	2.3071***	0.988
A 5-7Y	0.1935***	-0.2088**	2.3197***	0.8456***	-1.4776***	2.0121***	1.1612***	-2.6160***	2.7278***	0.994
BBB 5-7Y	-0.0380	0.8939***	1.9579***	1.3306***	-1.8039***	1.3424***	1.0036***	0.1043	1.1699***	0.986
AA 7-10Y	-0.0987	1.3769***	1.8548***	0.5044***	-0.5531***	1.4242***	1.8944***	-1.6855***	2.2322***	0.987
A 7-10Y	0.1441*	0.0103	2.8507***	1.0529***	-1.5228***	2.7438***	0.6702***	-1.7433***	2.8125***	0.993
BBB 7-10Y	0.2391**	1.4188***	1.3481***	1.3027***	-1.6641***	1.3334***	1.2005***	-0.3649	0.7946***	0.989
AA 10Y+	-0.0425	2.8068***	1.3541***	0.6261***	-0.0244	0.5032***	1.7302***	-1.2105***	1.4142***	0.977
A 10Y+	0.1636***	2.8150***	0.3855***	0.7933***	-0.1585***	-0.0754	1.8442***	-0.6262***	0.5487***	0.992
BBB 10Y+	0.1687	3.6155***	-0.4321*	1.6607***	-0.6069***	-0.7110***	0.1215	0.9287***	-1.0735***	0.979
AA	0.0170	0.9244***	1.4079***	0.5143***	-0.4703***	1.0044***	1.5878***	-1.9921***	1.6236***	0.987
A	0.1908***	0.0562	1.9649***	0.9908***	-1.3564***	1.7803***	0.5188***	-1.6812***	2.0104***	0.993
BBB	0.0095	1.1532***	0.8773***	1.3815***	-1.3772***	0.6715***	1.2015***	-0.2751	0.4208**	0.993
1-3Y	-0.0596***	0.0555***	0.0411**	0.9911***	-1.3896***	0.0131	1.0724***	-1.4141***	0.0535***	1.000
3-5Y	-0.1825***	0.4168***	1.0047***	0.9304***	-1.0087***	0.8620***	1.4149***	-1.2041***	1.1255***	0.998
5-7Y	-0.0630*	0.5841***	1.7102***	0.9930***	-1.2987***	1.5524***	1.0811***	-1.1535***	1.7034***	0.998
7-10Y	0.0303	1.2354***	1.5462***	1.0073***	-1.1662***	1.6641***	1.0093***	-0.9175***	1.5443***	0.998
10Y+	-0.0198	3.2634***	0.1749**	0.9942***	-0.0660**	-0.1258**	1.3209***	-0.0881	0.1712**	0.997
									Average	0.989
									Max	1.000
									Min	0.972

Panel D: Model 3-2

Portfolio	Constant	β_{ir_s}	β_{ir_c}	β_{crd_l}	β_{crd_s}	β_{crd_c}	β_{illiq_l}	β_{illiq_s}	β_{illiq_c}	*Adj. R-square*
AA 1-3Y	0.3791***	-0.7851***	1.0847***	0.4144***	-0.7489***	0.9393***	2.3925***	-2.0954***	1.0463***	0.972
A 1-3Y	1.0012***	-1.1130***	1.4950***	0.9338***	-1.8784***	0.9030***	2.6175***	-2.2861***	1.2694***	0.986
BBB 1-3Y	1.0694***	0.4192***	-0.4249**	1.3214***	-2.0444***	0.0879	3.6082***	-0.1228	-0.2583	0.988
AA 3-5Y	0.3392***	-0.2868***	2.0712***	0.4394***	-0.5906***	1.2185***	2.7366***	-2.1619***	2.2196***	0.985
A 3-5Y	0.9233***	-0.8781***	2.2086***	0.9345***	-1.6891***	2.0564***	2.1246***	-1.0316***	2.1115***	0.992
BBB 3-5Y	0.6493***	1.2438***	0.3789	1.3525***	-0.7666***	-0.1891	5.4841***	-1.6975***	0.4392	0.981
AA 5-7Y	0.2729***	0.4950***	2.0433***	0.4044***	-0.5013***	1.7257***	2.6451***	-2.1806***	2.3071***	0.988
A 5-7Y	0.9296***	-0.2088**	2.3197***	0.8456***	-1.4776***	2.0121***	2.8893***	-2.6160***	2.7278***	0.994
BBB 5-7Y	1.1203***	0.8939***	1.9579***	1.3306***	-1.8039***	1.3424***	3.7229***	0.1043	1.1699***	0.986
AA 7-10Y	0.3404***	1.3769***	1.8548***	0.5044***	-0.5531***	1.4242***	2.9252***	-1.6855***	2.2322***	0.987
A 7-10Y	1.0606***	0.0103	2.8507***	1.0529***	-1.5228***	2.7438***	2.8219***	-1.7433***	2.8125***	0.993
BBB 7-10Y	1.3731***	1.4188***	1.3481***	1.3027***	-1.6641***	1.3334***	3.8628***	-0.3649	0.7946***	0.989
AA 10Y+	0.5025***	2.8068***	1.3541***	0.6261***	-0.0244	0.5032***	3.0097***	-1.2105***	1.4142***	0.977
A 10Y+	0.8541***	2.8150***	0.3855***	0.7933***	-0.1585***	-0.0754	3.4654***	-0.6262***	0.5487***	0.992
BBB 10Y+	1.6144***	3.6155***	-0.4321*	1.6607***	-0.6069***	-0.7110***	3.5154***	0.9287***	-1.0735***	0.979
AA	0.4647***	0.9244***	1.4079***	0.5143***	-0.4703***	1.0044***	2.6389***	-1.9921***	1.6236***	0.987
A	1.0533***	0.0562	1.9649***	0.9908***	-1.3564***	1.7803***	2.5435***	-1.6812***	2.0104***	0.993
BBB	1.2121***	1.1532***	0.8773***	1.3815***	-1.3772***	0.6715***	4.0247***	-0.2751	0.4208**	0.993
1-3Y	0.8031***	0.0555***	0.0411**	0.9911***	-1.3896***	0.0131	3.0978***	-1.4141***	0.0535***	1.000
3-5Y	0.6273***	0.4168***	1.0047***	0.9304***	-1.0087***	0.8620***	3.3162***	-1.2041***	1.1255***	0.998
5-7Y	0.8014***	0.5841***	1.7102***	0.9930***	-1.2987***	1.5524***	3.1105***	-1.1535***	1.7034***	0.998
7-10Y	0.9071***	1.2354***	1.5462***	1.0073***	-1.1662***	1.6641***	3.0678***	-0.9175***	1.5443***	0.998
10Y+	0.8457***	3.2634***	0.1749**	0.9942***	-0.0660**	-0.1258**	3.3527***	-0.0881	0.1712**	0.997
									Average	0.989
									Max	1.000
									Min	0.972

Table 4 Cross-sectional regressions

This table reports the results of the cross-sectional regression tests of 23 rating and maturity class corporate bond portfolios. The tests are based on Fama–MacBeth regressions, in which betas are estimated using five-year rolling periods for each portfolio. The sample period is from January 2003 to August 2015. The dependent variable is a portfolio's monthly yield spread. β_{ir_s}, β_{ir_c}, β_{crd_l}, β_{crd_s}, β_{crd_c}, β_{illiq_l}, β_{illiq_s}, β_{illiq_c}, and β_{neo} are the betas of the steepness of the interest rate, the concavity of the interest rate, the level of credit, the steepness of credit, the concavity of credit, the level of illiquidity, the steepness of illiquidity, the concavity of illiquidity, and *NEO*. To examine whether the yield spreads have linear relationships with the betas as realized returns, we use the regression models that include squared betas. The *t*-values are given in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Variables	Model 1	Model 2	Model 3-1	Model 3-2
Constant	-0.1785	0.6509***	-0.0507	-0.3568**
	(-1.209)	(5.546)	(-0.389)	(-2.099)
β_{ir_s}	2.6220***	2.4730***	0.6024***	0.5567***
	(18.469)	(21.724)	(25.749)	(23.271)
β_{ir_c}			0.0897	0.0546
			(1.363)	(1.088)
β_{crd_l}	1.1625***	0.4201**	1.6167***	0.5743***
	(6.901)	(2.267)	(13.015)	(3.074)
β_{crd_s}			-0.6280***	-0.5297***
			(-9.790)	(-8.772)
β_{crd_c}			0.3669***	0.4120***
			(9.768)	(9.780)
β_{illiq_l}			0.1206	0.5493***
			(1.358)	(6.148)
β_{illiq_s}			0.0584	0.0277
			(1.198)	(0.615)
β_{illiq_c}			-0.0059	0.0307
			(-0.102)	(0.571)
β_{neo}		0.8140***		
		(10.990)		
$\beta^2_{ir\_s}$	-0.2104**	-0.2124***	0.0151**	0.0256***
	(-2.557)	(-3.403)	(2.189)	(3.933)
$\beta^2_{ir\_c}$			0.0186	-0.0050
			(1.315)	(-0.413)
$\beta^2_{crd\_l}$	-0.1818***	0.1807**	-0.4180***	-0.1941***
	(-3.362)	(2.568)	(-11.856)	(-3.348)
$\beta^2_{crd\_s}$			-0.1108***	-0.0497**
			(-4.587)	(-2.157)
$\beta^2_{crd\_c}$			0.0054	0.0022
			(0.467)	(0.175)
$\beta^2_{illiq\_l}$			0.0679**	-0.0360***
			(2.341)	(-3.601)
$\beta^2_{illiq\_s}$			0.0598***	0.0338**
			(3.131)	(2.114)
$\beta^2_{illiq\_c}$			-0.0119	0.0013
			(-0.965)	(0.113)
β^2_{neo}		0.1146***		
		(4.919)		
R-squared	0.729	0.917	0.994	0.994

Table 5 Risk prices

This table reports the results of the risk prices of the cross-sectional regression tests of 23 rating and maturity class corporate bond portfolios. The sample period is from January 2003 to August 2015. Panel A shows the results for the Fama and French (1993) model. Panel B shows the new variable, *NEO*, which was not considered in the Fama–French two-factor model. Panel C shows the results for Model 3-1, in which the non-orthogonal credit level is used as the net credit factor. Panel D shows the results for Model 3-2, in which the orthogonal credit level is used as the net credit factor. Risk prices are calculated by partial differentiation (e.g., $\partial YS_{p,t}/\partial\beta_p = \widehat{\gamma_1} + 2\widehat{\gamma_2}\beta_p$), considering the non-linear relationship between yield spreads and betas (e.g., $YS_{p,t} = \widehat{\gamma_1}\beta_p + \widehat{\gamma_2}\beta_p^2$). Here, β_p is calculated as the average of the rolling betas for each factor. The contribution ratios are given in parentheses and expressed as percentages.

Panel A: Model 1

	IR	CRD	Total
Level		0.61	0.61
		(21.1)	(21.1)
Steepness	2.29		2.29
	(78.9)		(78.9)
Total	2.29	0.61	2.90
	(78.9)	(21.1)	(100.0)

Panel B: Model 2

	IR	CRD	Mixed	Total
Level		0.80		0.80
		(23.2)		(23.2)
Steepness	2.04			2.04
	(59.7)			(59.7)
Mixed			0.59	0.59
			(17.1)	(17.1)
Total	2.04	0.80	0.59	3.43
	(59.7)	(23.2)	(17.1)	(100.0)

Panel C: Model 3-1

	IR	CRD	ILLIQ	Total
Level		0.76	0.29	1.05
		(45.5)	(17.3)	(62.8)
Steepness	0.63	-0.42	-0.07	0.14
	(38.0)	(-25.1)	(-4.4)	(8.6)
Concavity	0.13	0.38	-0.03	0.48
	(7.9)	(22.7)	(-1.9)	(28.6)
Total	0.76	0.72	0.19	1.67
	(45.9)	(43.1)	(11.0)	(100.0)

Panel D: Model 3-2

	IR	CRD	ILLIQ	Total
Level		0.17	0.31	0.48
		(15.8)	(28.1)	(43.9)
Steepness	0.61	-0.43	-0.05	0.13
	(55.0)	(-39.5)	(-4.2)	(11.3)
Concavity	0.04	0.42	0.03	0.49
	(4.0)	(37.8)	(3.0)	(44.8)
Total	0.65	0.16	0.29	1.10
	(59.0)	(14.1)	(26.9)	(100.0)

Table 6 Risk premium

This table reports the risk premiums for each risk factor and their contribution to the total risk premium when the extended Fama–French eight-factor model is applied. The risk premium is calculated by multiplying the average betas of the 23 rating and maturity class corporate bond portfolios by the risk prices estimated using the Fama–MacBeth regressions. The betas of each corporate bond portfolio are estimated using the data of the whole sample from January 2003 to August 2015. Panel A shows the results for Model 3-1, in which the non-orthogonal credit level is used as the net credit factor. Panel B shows the results for Model 3-2, in which the orthogonal credit level is used as the net credit factor. The contribution ratios are given in parentheses and expressed as percentages.

Panel A: Model 3-1

	IR	CRD	ILLIQ	Total
Level		1.11	1.10	2.21
		(28.8)	(28.5)	(57.4)
Steepness	0.55	0.50	0.06	1.11
	(14.2)	(13.0)	(1.6)	(28.8)
Concavity	0.16	0.41	-0.04	0.53
	(4.1)	(10.6)	(-1.0)	(13.8)
Total	0.71	2.02	1.12	3.85
	(18.3)	(52.4)	(29.2)	(100)

Panel B: Model 3-2

	IR	CRD	ILLIQ	Total
Level		0.35	1.36	1.71
		(10.6)	(41.8)	(52.4)
Steepness	0.53	0.48	0.04	1.05
	(16.3)	(14.8)	(1.3)	(32.4)
Concavity	0.06	0.40	0.04	0.50
	(1.8)	(12.2)	(1.3)	(15.2)
Total	0.59	1.23	1.44	3.26
	(18.1)	(37.6)	(44.3)	(100)

Table 7 Relation between illiquidity premium and credit premium

This table shows the results of following model: $ILLIQ_t = \alpha + \beta \cdot CRD_t + \varepsilon_t$,

where $ILLIQ$ is the illiquidity premium and CRD is the credit premium.

This table shows the results of the time-series regressions on the relationship between the illiquidity premium and the credit premium. The sample period is from January 2003 to August 2015. The sample period is divided into four periods: before the global financial crisis (2003.1~2007.5), during the global financial crisis (2007.6~2010.4), during the European national debt crisis (2010.5~2012.9), and after the European national debt crisis (2012.10~2015.8). The average betas of the portfolio are calculated by averaging the estimated betas using at least 60 months of data from the start of January 2003 so that the risk premiums are generated from January 2008. The risk premium is calculated by multiplying the average betas of the 23 rating and maturity class corporate bond portfolios by the risk prices estimated using the Fama–MacBeth regressions. The extended Fama–French eight-factor model is applied, and the orthogonal credit level is used as net credit factor. The *t*-values are given in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	Constant	β	N	*Adj. R-Squared*
Global Financial Crisis	0.8705***	0.2954**	28	0.119
	(3.930)	(2.158)		
European National Debt Crisis	6.6105***	-3.0985***	29	0.499
	(5.928)	(-5.377)		
After the European National Debt Crisis	3.2132***	-1.4596***	35	0.980
	(56.934)	(-40.454)		
Full Period	1.9536***	-0.5905***	92	0.195
	(9.305)	(-4.796)		

Table 8 Relation between risk premium and economic situations

This table shows the risk premium for each factor and its contribution to the total risk premium in three economic situations. Each risk premium is the arithmetic average of the risk premium calculated monthly. The sample period is from January 2003 to August 2015. The sample period is divided into four periods: before the global financial crisis (2003.1~2007.5), during the global financial crisis (2007.6~2010.4), during the European national debt crisis (2010.5~2012.9), and after the European national debt crisis (2012.10~2015.8). The average betas of the portfolio are calculated by averaging the estimated betas using at least 60 months of data from the start of January 2003 so that the risk premiums are generated from January 2008. The risk premiums are calculated by multiplying the average betas of the 23 rating and maturity class corporate bond portfolios by the risk prices estimated using the Fama–MacBeth regressions. The extended Fama–French eight-factor model is applied and the orthogonal credit level is used as the net credit factor. The t-values are given in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Global Financial Crisis				
	IR	CRD	ILLIQ	Total
Level		0.69	1.41	2.11
		(20.7)	(42.2)	(62.8)
Steepness	0.38	0.29	0.05	0.72
	(11.4)	(8.6)	(1.5)	(21.5)
Concavity	0.07	0.58	-0.13	0.52
	(2.2)	(17.3)	(-3.9)	(15.6)
Total	0.46	1.56	1.33	3.35
	(13.6)	(46.6)	(39.7)	(100.0)
Panel B: European National Debt Crisis				
	IR	CRD	ILLIQ	Total
Level		0.97	0.76	1.72
		(28.7)	(22.3)	(51.0)
Steepness	0.56	0.50	-0.03	1.03
	(16.5)	(14.9)	(-1.0)	(30.4)
Concavity	0.27	0.46	-0.10	0.63
	(8.1)	(13.6)	(-3.1)	(18.6)
Total	0.83	1.93	0.62	3.38
	(24.6)	(57.2)	(18.3)	(100.0)
Panel C: After the European National Debt Crisis				
	IR	CRD	ILLIQ	Total
Level		0.62	1.01	1.63
		(19.6)	(31.7)	(51.3)
Steepness	0.52	0.48	0.00	1.00
	(16.5)	(15.0)	(-0.1)	(31.4)
Concavity	0.15	0.45	-0.05	0.55
	(4.7)	(14.0)	(-1.4)	(17.3)
Total	0.68	1.54	0.96	3.18
	(21.2)	(48.6)	(30.2)	(100.0)

Table 9 Risk premiums between high quality bonds and low quality bonds

This table shows the changes in the term structures of the risk premiums and the differences in the risk premiums between high-quality bonds and low-quality bonds, depending on the economic situation. We estimate the differences in risk premiums between an AA rating portfolio and a BBB rating portfolio in economic situations and using the remaining maturities. The remaining maturities are classified as short term (1~3 years), medium term (5~7 years), or long term (7~10 years). The differences in the risk premiums between the AA rating portfolio and the BBB portfolio are calculated by averaging the differences in the risk premiums of the portfolio, estimated monthly. The differences in the risk premiums of the two portfolios are calculated monthly by multiplying the differences of the factor betas of the AA and BBB rating portfolios across each maturity, estimated using time-series regressions with the risk prices of each factor estimated using Fama–MacBeth cross-section regressions. The extended Fama–French eight-factor model is applied and the orthogonal credit level is used as the net credit factor. The monthly betas of the rating and maturity class corporate bond portfolios are estimated using data from January 2003 until the previous month when the betas are estimated.

	Short-term				Medium-term				Long-term			
	IR	CRD	ILLIQ	Total	IR	CRD	ILLIQ	Total	IR	CRD	ILLIQ	Total
Panel A: Global Financial Crisis												
Level		0.33	0.41	0.74		0.25	0.13	0.37		0.21	0.17	0.38
		(27.5)	(34.5)	(61.9)		(15.2)	(7.8)	(23.0)		(11.2)	(8.8)	(20.0)
Steepness	0.40	0.57	-0.08	0.89	0.03	0.56	-0.01	0.58	-0.54	0.55	market0.1	0.18
	(33.2)	(48.0)	(-6.8)	(74.5)	(2.0)	(34.5)	(-0.6)	(35.9)	(-28.1)	(28.8)	(8.8)	(9.5)
Concavity	-0.19	-0.66	0.41	-0.43	0.08	0.25	0.34	0.67	0.02	0.87	0.45	1.34
	(-15.8)	(-55.1)	(34.5)	(-36.4)	(5.2)	(15.3)	(20.6)	(41.1)	(1.3)	(45.5)	(23.8)	(70.5)
Total	0.21	0.24	0.74	1.19	0.12	1.05	0.45	1.62	-0.51	1.63	0.79	1.91
	(17.4)	(20.4)	(62.2)	(100.0)	(7.2)	(65.0)	(27.8)	(100.0)	(-26.8)	(85.5)	(41.3)	(100.0)
Panel B: European National Debt Crisis												
Level		0.36	0.02	0.38		0.47	0.10	0.57		0.46	0.30	0.75
		(26.6)	(1.3)	(27.9)		(25.1)	(5.4)	(30.5)		(22.7)	(14.7)	(37.4)
Steepness	0.63	0.74	-0.01	1.36	0.00	0.68	0.09	0.78	-0.49	0.63	0.30	0.44
	(46.0)	(53.8)	(-0.5)	(99.3)	(0.2)	(36.7)	(5.0)	(42.0)	(-24.3)	(31.5)	(14.7)	(21.8)
Concavity	-0.23	-0.16	0.02	-0.37	0.28	0.18	0.05	0.51	0.33	0.36	0.13	0.82
	(-16.9)	(-11.6)	(1.3)	(-27.2)	(15.0)	(9.6)	(2.9)	(27.5)	(16.4)	(17.8)	(6.6)	(40.8)
Total	0.40	0.94	0.03	1.37	0.28	1.33	0.25	1.86	-0.16	1.45	0.73	2.02
	(29.1)	(68.7)	(2.2)	(100.0)	(15.2)	(71.4)	(13.4)	(100.0)	(-7.9)	(71.9)	(36.1)	(100.0)
Panel C: After the European National Debt Crisis												
Level		0.35	0.03	0.38		0.36	0.31	0.67		0.32	-0.01	0.31
		(27.5)	(2.6)	(30.1)		(26.6)	(22.7)	(49.3)		(43.6)	(-1.1)	(42.5)
Steepness	0.87	0.55	-0.02	1.40	0.29	0.55	-0.01	0.83	-0.02	0.48	-0.01	0.46
	(68.3)	(43.4)	(-1.9)	(109.8)	(21.2)	(40.5)	(-1.0)	(60.7)	(-2.2)	(66.1)	(-1.1)	(62.9)
Concavity	-0.23	-0.32	0.03	-0.51	-0.04	-0.16	0.06	-0.14	-0.05	-0.06	0.07	-0.04
	(-17.7)	(-24.8)	(2.6)	(-39.8)	(-2.7)	(-11.8)	(4.6)	(-10.0)	(-6.5)	(-8.7)	(9.9)	(-5.4)
Total	0.65	0.59	0.04	1.28	0.25	0.75	0.36	1.36	-0.06	0.73	0.06	0.73
	(50.6)	(46.2)	(3.3)	(100.0)	(18.4)	(55.3)	(26.3)	(100.0)	(-8.7)	(100.9)	(7.8)	(100.0)