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THE DETERMINANTS OF CREDIT SPREAD CHANGES OF INVESTMENT GRADE CORPORATE BONDS IN THAILAND BETWEEN JUNE 2006 AND FEBRUARY 2012: AN APPLICATION OF THE REGIME SWITCHING MODEL

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Abstract

Most empirical studies on credit spread change precluding idiosyncratic and systematic risk factors are failed to explain the credit spread puzzle. In practice, credit spread change varies in response to the credit cycle which is different from the business cycle. This study proposes an empirical model with two-state switching regime model of low and high variance regimes which are extracted by Markov switching model to explain the variation of credit spread change in Thailand. The results suggest that the model can explain the variation of credit spread change more efficient than the single-regime model. The sensitivities of interest rate, macroeconomic, and liquidity factors are consistent with associated theories and the credit spread change are more sensitive to these factors in high regime across credit rating and time-to-maturity groups. The low rating group is not sensitive to the liquidity risk.

JEL Classification: G12

Keywords: credit spread, corporate bond, Markov switching model

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Content

Chapter1 Introduction

The corporate bond market in Thailand is growing dramatically due to the need for diversification in portfolio risk. However, the secondary market is relatively inefficient in comparison to the equity market. The transaction data and frequency are at lower levels due to the emerging stage of the market. Most studies suggest that the credit spread change is affected by the credit risk including interest rate risk, macroeconomic risk, and liquidity risk, assuming the default risk is controlled by the credit rating of the corporate bond (Collin-Dufresne, Goldstein & Martin, 2001; Huang & Huang, 2003). This leads to the problem so called credit spread puzzle. It cannot be solved by either theoretical models or ordinary empirical models of idiosyncratic or systematic risk factors.

Studies on the regime-switching model in economic literature have been widely applied in explaining the unusual macroeconomic events for the dependent variable. For credit spread literature, the method is implemented to explain the credit spread puzzle. The credit cycle effect showed that the sensitivity of credit spread change to its determinant was partially different under low and high regimes (Davies, 2008; Maalaoui, Dionne & François, 2008). The credit cycle is related to the recovery rate of the firm as in the theoretical model of Merton (1973).

The empirical studies that focused on the determinants of corporate bond yield spread in Thailand are limited to the credit spread level (Mongkonkiattichai & Pattarathammas, 2010). Although, the explanatory power of the model was up to 80% in low credit rating corporate bonds with specific month dummy variables, the study was a cross-sectional study at an individual-level using traditional bond characteristic as explanatory variables, which cannot explain the dynamics of the credit spread process in different credit cycles.

This study focuses on explaining the factors affecting the aggregate credit spread change of corporate bonds in Thailand between June 2006 and February 2012 during different credit cycles while controlling the time-to-maturity and credit rating. It highlights the use of a regime-switching model in explaining credit spread in different credit cycles. The research questions are: What are the determinants of credit spread change in Thailand in overall and in two-regimes of credit cycle i.e. low and high regime?

The results find that the equity market return, the change of interest rate, and the change of market liquidity are key determinants of credit spread change across rating and time-to-maturity group. However, the low rating group does not have a relationship with liquidity factors. The credit spread change is more sensitive to the factors in the high regime and more robust in the low regime. It suggests that the individual investors should enter the bond market when the market equity market return, the change of interest, and the liquidity are low. The consequence is the high credit spread change, in particular in the high regime. When the credit cycle is in the low regime, the investors should sell their corporate bonds, in particular in the low regime, when the equity market return, the change of interest rate, and liquidity are high. On the supply side the corporate bond issuers should make decisions about capital structure optimization to maximize shareholder profit through callable bonds before the maturity of bonds. For the noncallable option, it is important for the issuer to know the optimal credit spread as indicated by the market rate. The credit spread change dynamic supports the issuer in setting the IPO price of the corporate bonds. For financial institutions, a good understanding in explaining credit spread change can affect the measurement of the probability of default due to the change in independent variables. For the regulator side, though it is not clear which factor makes credit cycle switch, the regulator should be aware of the monetary policy to appropriately regulate the interest rate. Moreover, the increase of liquidity in the market can reduce the cost of funding to the investor. The authority should provide more information to stimulate higher trading in the secondary market.

Research Objective:

The first objective is to find the statistically significant factors affecting the change of credit spread. The determinants of the credit spread are related to the risk affected on the value of corporate bonds, which include interest rate risk, macroeconomic risk, and liquidity risk. It is interesting to affirm the credit spread puzzle for the corporate bond market in Thailand.

The second objective is to study the effect of the latent variables of the credit cycle on the switch of the sensitivities of the explanatory factors of the credit spread. The determinants of the credit spread in low and high regimes of credit cycle are tested. The focus is on the switch of the sensitivities during low and high regimes of credit spread. The credit spread puzzle can be affirmed after using switching-regime models.

Expected outcomes:

The results from the multiple-regime model can determine the drivers of credit spread of corporate bond in Thailand in the low and the high regimes. The sign on both regimes can be either similar or different, due to the regime switches.

The rest of the paper is organized as follows. In Section II the review of literature on credit risk model and related risks on corporate bond are examined. In Section III, the data and methodology are discussed. In Section IV, the results are provided and the discussion of the results is presented in Section V. Lastly the conclusion can be drawn in Section VI.

Definition:

Corporate Bond	A debt instrument that obligates the issuer to pay a specified percentage of the bond's par value on designated dates and to repay the bond's par or principal value at maturity" (Fabozzi, Mann & Wilson, 2005, pp. 305).
Credit Risk	The distribution of financial losses owing to unexpected changes in the credit quality of the counterparty in a financial agreement" (Backshall et al., 2005, pp. 779). "It includes credit default risk and credit spread risk" (Fabozzi et al., 2005, pp. 327).
Credit Spread	The difference between a corporate bond's yield and the yield on a comparable-maturity benchmark Treasury security. Credit spreads are driven by both macroeconomic forces and issue-specific factors" (Fabozzi et al., 2005, pp. 329).
Credit Spread Puzzle	The puzzle that such factors [implied by the theory] explain little [explanatory power] of these spreads [credit spread]" (Tsuji, 2005, pp. 1)
Markov State Switching Model	A type of specification which allows for the transition of states as an intrinsic property of the econometric model. Such type of statistical representations are well known and utilized in different problems in the field of economics and finance" (Perlin, 2010, pp. 1).

Chapter2 Review of Literature

In this section the link between the theories and credit spread, including the main variables is demonstrated. The theories are classified according to the risks affecting the credit spread, i.e. default risk, interest rate risk, macroeconomic risk, liquidity risk, and time-to-maturity risk.

A) Default Risk - The structural model, developed from option pricing theory of Black and Scholes (1973) is used to value the credit spread. The model explains relationship between credit spread and the default probability, such that the increase in firm default probability increases the credit spread. When the firm value increases, the default probability is low. The firm value is proxied by firm equity return (Kwan, 1996; Campbell & Taksler, 2003; Anramov, Jostova & Philipov, 2007; Chen & Kou, 2009; Mongkonkiattichai & Pattarathammas, 2010) or inversely measured through the leverage ratio (Collin-Dufresne et al., 2001).

B) Interest Rate Risk - While in the structural model, the riskfree rate were assumed to be constant, the reduced-form model allowed the factors to be a stochastic process. The model can fit the empirical data better than the structural model, but still cannot explain the determinants of credit spread variation (Jarrow & Turnbull, 1995; Lesseig & Stock, 1998; Elton, Gruber, Agrawal & Mann, 2004; Longstaff, Mithal & Neis, 2005). The negative relationship between the change of interest rate level and credit spread is expected, due to the fact that the increase in risk free rate increases the drift of the risk-neutral process of firm value, and therefore the probability of default decreases and the credit spread narrows (Longstaff & Schwartz, 1995). Moreover, if the firm values are correlated with the interest rate, the firm value volatility is related with both equity volatility and interest rate volatility. Increasing interest rate volatility increases the firm volatility and therefore the credit spread increases (Huang & Kong, 2003). Pure expectation theory explains that the relationship between forward rate and future rate, that they are equal (Cox, Ingersoll & Ross, 1981). Therefore the slope of the term structure can imply the future interest rate. The steeper the slope of the term-structure, the higher the future interest rate. The future probability of default decreases, when the expectation of future interest rate increases; therefore the credit spread narrows (Collin-Dufresne et al., 2001).

C) Macroeconomic Risk - Since the structural model cannot explain credit spread change efficiently, the systematic risk factors are widely selected as the choice of determinants of credit spread change (Collin-Dufresne et al., 2001). The financial instability hypothesis from Minsky (1992) explained the credit crisis of the debt market caused by the accumulation of the debt from three imbalance number of three groups of borrowers, i.e. hedge borrowers, speculative borrowers, and Ponzi borrowers. The credit cycle is different from the business cycle since the assumption of the theory is based on different economy structure.

The efficient markets hypothesis shows that there is a relationship between the equity and bond markets through non-synchronized perceptions of private information. Therefore the equity market with low transaction cost reacts to the information before the bond market, and therefore the relationship between the lagged return of equity market can explain the bond market return (Kwan, 1996).

D) Liquidity Risk - Analogous to the stock market, the aggregate liquidity factors can explain the stock returns, such that the stocks with higher liquidity give higher expected return to the investors (dos Santos Paiva & Savoiac, 2009). Liquidity theory explains why the investors require higher premium on investing on the slow-cash-converted securities, such as corporate bonds, than the fast-cash-converted securities, such as Treasury bonds (Nakashima & Saitob, 2009). The credit spread puzzle of the Merton model may cause this by not including the liquidity factor in the model, especially in very short-term corporate bonds (Covitz & Downing, 2007). The higher the liquidity, the lower the credit spread (Lo, Mamaysky & Wang, 2004).

E) Time-To-Maturity Risk - Since the volatility of the yield of corporate bonds is related to the time-to-maturity, the credit spread is affected by the time-to-maturity. This relationship is called term-structure, which can be increasing, decreasing or hump shaped. The main theory related to the increasing shape is liquidation theory, which explains that the investor demands higher premiums on longer maturity bonds in order to hold a longer one. Therefore, the yield to maturity increases with the time-to-maturity (Fabozzi, 2005).

In explaining credit spread change there are three major conceptual models, i) single-regime model, ii) simulation model, and iii) multiple-regime model. For the single-regime model, the determinants of credit spread are based on default factors, interest rate factors, macroeconomic factors, and liquidity factors. The main part of the credit spread variable remains unexplainable (Collin-Dufresne et al., 2001; Campbell & Taksler, 2003; Huang & Kong, 2003; Nakashima & Saitob, 2009; Chebbi & Hellara, 2010).

The bond pricing models from Merton (1974), Geske (1977), Longstaff and Schwartz (1995), Leland and Toft (1996), and Collin-Dufresne and Goldstein (2001) were compared as in the work of Eom, Helwege and Huang (2004) in predicting bond price. They are based on related theories, however, the predicted error of all the models were sensitive to the systematic risk.

The last type of the framework is the use of multiple-regime model to explain the credit spread in low and high regimes. The measurement of credit cycle was based on the Markov switching model (MS model) from Hamilton (1990). The framework of Davies (2008) and Maalaoui et al. (2008) used time-dummy variable based on the regime extraction from credit spread change. Alternatively, the business cycle can be observed by macroeconomic indicators as follows. Davies (2008) used the SETAR model (Self Extracting Threshold) based on annual CPI inflation, while Maalaoui et al. (2008) used the recession announcement from NBER and set the time-dummy variable accordingly. Mongkonkiattichai and Pattarathammas (2010) set the time-dummy variable as one when the month is associated with a bear period of the equity market. The credit cycle can improve explanatory of the model better than the business cycle (Maalaoui et al., 2008). The model can explain credit spread better than the single-regime model based on the minimize AIC (Akaike Information Criteria).

In the next section the measurement of dependent and independent variables and the methodology are explained.

Chapter 3 Methodology

The regression model of single- and multiple-regime models can be demonstrated as follows.

The Single-Regime Multiple Regression Model

The model is simply an ordinary multiple regression analysis with a general form expressed as

$$\Delta CS_t^j = \alpha_0^j + \sum_{i=1}^{N} \alpha_i^j X_{t,i}^{(j)} + \varepsilon_t^j \tag{1}$$

where ΔCS_t^j is the credit spread change of credit ratings and time-to-maturity portfolio j, α_0^j is a constant, α_i^j are estimated sensitivities of the observed independent variables $X_{t,i}$, including the risk free rate (r_t^{2y}), the slope of term structure ($slope_t^{10y-2y}$) and the interest rate volatility ($\sigma_t^{r_t^{10y}}$), lag of the equity market return (set_{t-2}), lag of the historical equity market return (σ_{t-2}^{set}), missing price ratios of each credit rating group j (mis_t^j) and turnover ratio ($turn_t$), and ε_t^j is unexplained part.

The models are controlled by four rating groups (e.g. AAA, AA, A, and BBB) and three time-to-maturity groups (e.g. short, medium, and long time-to-maturity) for the default and time-to-maturity risk (Collin-Dufresne et al., 2001; Maalaoui et al., 2008). The sensitivities should be compared within the rating and time-to-maturity groups, whether they are changed monotonically with rating and time-to-maturity changes.

The Multiple-Regime Multiple Regression Model

The multiple-regime multiple regressions focus on the regime change of the credit cycle by adding additional interaction terms (Davies, 2008; Maalaoui et al., 2008). The general term of the multiple regime model is as follows

$$\Delta CS_t^j = \beta_0^j + \sum_{i=1}^{N} \beta_i^j X_{t,i}^{(j)} + \gamma_0^j \times inter_t^j + \sum_{i=1}^{N} \gamma_i^j X_{t,i}^{(j)} \times inter_t^j + \varepsilon_t^j \quad (2)$$

$$\Delta CS_t^{j,L} = \beta_0^j + \sum_{i=1}^{N} \beta_i^j X_{t,i}^{(j)} + \varepsilon_t^j \ \ when\, inter_t^j = 0 \quad (3)$$

$$\Delta CS_t^{j,H} = (\beta_0^j + \gamma_0^j) + \sum_{i=1}^{N} (\beta_i^j + \gamma_i^j) X_{t,i}^{(j)} + \varepsilon_t^j \ \ when\, inter_t^j = 1 \quad (4)$$

where β_0^j and β_i^j are parameters of the low regime, γ_0^j and γ_i^j are parameters of the marginal effect terms. The dummy variables $inter_t^j$ are equal to zero when the credit cycle regime of portfolio j is in the low regime, otherwise one (Davies, 2008; Maalaoui et al., 2008). β_i^j and $\beta_i^j + \gamma_i^j$ can be interpreted as sensitivities of explanatory variables in low and high regimes respectively.

The proxies of dependent and independent variables are discussed as follows.

A) Credit Spreads - The individual corporate bond data are obtained from the mark-to-market of the fixed-incomes prepared by the ThaiBMA via the iBond database, including static credit spread[1], time-to-maturity, and credit rating. To ensure that the portfolios have no additional risk, the corporate bonds with an embedded option and a floating coupon type are filtered out. Moreover, they are discarded whenever a bond has less than one year time-to-

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[1] The individual static spread, CS_t^i, for bond i at month t, is calculates from the price of the corporate bond and the spot rate of the government yield curve as follows,

$$P_t^i = \frac{c}{[1+(zc_1 + CS_t^i)]^{t_1}} + \frac{c}{[1+(zc_2 + CS_t^i)]^{t_2}} + \ldots + \frac{c + Par}{[1+(zc_n + CS_t^i)]^{t_n}}$$

where P_t is a price of the corporate bond at time t, c is a coupon payment, Par is a par value of the corporate bond, zc_k spot rate for the coupon payment time t_k, where k is the coupon payment period from t_1 to t_n. CS_t^i was the static spread is assumed to be constant across all the coupon payment period, t_k. The calculation of the static spread can be found from SOLVER and GOALSEEK from Microsoft Excel (Siwamogsathem, 2010).

maturity (Collin-Dufresne et al., 2001; Maalaoui et al., 2008). The corporate bonds without a credit rating either TRIS or FITCH are also filtered out. The non-investment bonds, i.e. with a credit rating lower than BBB, are filtered out.

The aggregate static spread curves, CS_t^j, are constructed for each credit rating, j, e.g. AAA, AA, A, BBB[2], through the lognormal function as in equation 5.

$$CS_t^j(T) = a_0 \ln(1+T) + a_1 \quad (5)$$

where CS_t^j is the static spread curve of portfolio j at month t. It is a function of time-to-maturity T, and a_0 and a_1 are the parameters from the OLS of $CS_t^i(T)$ and its related time-to-maturity T (Siwamogsathem, 2010). The lognormal function gives an increasing function which is reasonable for the credit spread of corporate bonds that is increasing with the time-to-maturity. The $CS_t^j(t,T)$ is a series of credit spread at time-to-maturity T can be calculated from the parameter of obtained from the OLS.

B) Interest Rate Factors The interest rate risk is captured by the interest rate level, the slope of the yield curve, and the interest rate volatility. The interest rate level (r_t^{2y}) is obtained from the yield of two-year Treasury yield ThaiBMA zero coupon yield curve. The proxy of the slope of the yield curve ($slope_t^{10y-2y}$) is the spread between 10-year and 2-year maturity Treasury bonds. The historical interest volatility ($\sigma_t^{r^{10y}}$) is calculated from the one-year historical interest rate volatility using the daily spot rate of ten-year-maturity Treasury bond yield from the ThaiBMA zero coupon yield curve.

C) Macroeconomic Factors Macroeconomic risk includes equity market return and historical volatility of equity market return. The equity market index is obtained from the Bloomberg database via Stock Exchange of Thailand (SET). The return of the stock market (

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[2] To form a portfolio of corporate bond in credit ratings, the credit ratings from TRIS or FITCH are consolidated by the one with the lower rate. Since TRIS and FITCH use the same terminology of credit symbols, a rating conversion is not required. Secondly, the ratings with + and − are grouped to the middle rating which are AA, A, and BBB (Maalaoui et al., 2008).

set_t) is the percentage change of the stock index. The historical volatility of equity market return (σ_t^{set}) is calculated from the standard deviation of daily return back for 180 days from the Bloomberg database.

D) Liquidity Factors Liquidity factors are measured by the missing price, the ratio of non-trading days to the number of days in the month of each bond. and the turnover ratio ($turn_t$) is a ratio between the total trading volume in the month to the number of outstanding bonds (Maalaoui et al., 2008). The higher the ratio, the more frequent trades are in the secondary market. The trading volume data is from the pricing data from the ThaiBMA website. The outstanding volume is calculated by using value of the outstanding at the end of the month divided by par value of 1,000 THB.

E) Interaction Terms The interaction terms of each portfolio $inter_t^j$ are obtained from the Markov Switching Model using the time-series data of credit spread of each portfolio as an input of the analysis. The credit spread of each portfolio is assumed to have the following process

$$\ln CS_t^j = \mu_{S_t}^j + \varepsilon_{S_t}^j \quad (6)$$

where $S_t = 1,2$, $\mu_{S_t}^j$ is the mean of $\ln CS_t^j$ at state S_t, and $\varepsilon_{S_t}^j$ follows a normal distribution with zero mean and variance $\sigma_{S_t}^{2^j}$. The means and variances in regime 1 and 2 are different. The transition of the state is assumed stochastic or it is uncertain whether the state will change or not. Since the switching process is assumed to be known, a transition matrix that controls the probability of making a switch from one to another state is represented by the probability of a switch from state n to state m between time t and $t+1$ (p_{mn}).

The estimation of the parameters in the Markov Switching model is based on the maximum likelihood using Hamilton's filter[3]. The calculation of the *smoothed probabilities* can

[3] The model follows the Bayesian prior for two regimes setting and the generalization of the Maximum Likelihood Estimation objective function is

$$\zeta(\theta) = \log p(y1,\ldots,y_T;\theta) - (\nu\mu_1^2)/(2\sigma_1^2) - \ldots$$

be obtained from an iterative process. The smoothed probability is then used to weight y_t. The OLS calculation of the weighted y_t is performed to generate the new estimate parameter. The process is repeated again until the value of the likelihood function is maximum and the fixed parameter of θ is found (Maalaoui et al., 2008)..

$$(\nu\mu_2^2)/(2\sigma_2^2) - \alpha\log\sigma_1^2 - \alpha\log\sigma_2^2 - \cdots$$
$$\beta/\sigma_1^2 - \beta/\sigma_2^2$$

where α , β , ν are specific Bayesian prior. The parameters $\hat{\theta}$ including $\hat{\mu}_n$, $\hat{\sigma}_n^2$, $\hat{p}_{11}$, $\hat{p}_{22}$ are calculated from the iterative algorithms (Hamilton, 1990) as

$$\hat{\mu}_n = \frac{\sum_{t=1}^{T} y_t p(S_t = n \mid y_1, \ldots, y_T; \hat{\theta})}{\nu + \sum_{t=1}^{T} p(S_t = n \mid y_1, \ldots, y_T; \hat{\theta})}$$

$$\hat{\sigma}_n^2 = \frac{1}{\alpha + 1/2\sum_{t=1}^{T} p(S_t = n \mid y_1, \ldots, y_T; \hat{\theta})} \times \cdots$$
$$[\beta + 1/2\sum_{t=1}^{T}(y_t - \hat{\mu}_n)^2 p(S_t = n \mid y_1, \ldots, y_T; \hat{\theta}) + \ldots$$
$$1/2\nu\hat{\mu}_n^2]$$

$$\hat{p}_{11} = [\sum_{t=2}^{T} p(S_t = 1, S_{t-1} = 1 \mid y_1, \ldots, y_T; \hat{\theta})]/$$
$$[\sum_{t=2}^{T} p(S_{t-1} = 1 \mid y_1, \ldots, y_T; \hat{\theta}) + \hat{\rho} - \ldots$$
$$p(S_t = 1 \mid y_1, \ldots, y_T; \hat{\theta})]$$

$$\hat{p}_{22} = [\sum_{t=2}^{T} p(S_t = 2, S_{t-1} = 2 \mid y_1, \ldots, y_T; \hat{\theta})]/$$
$$[\sum_{t=2}^{T} p(S_{t-1} = 2 \mid y_1, \ldots, y_T; \hat{\theta}) - \hat{\rho} + \ldots$$
$$p(S_t = 1 \mid y_1, \ldots, y_T; \hat{\theta})]$$

where

$$\hat{\rho} = \frac{1 - \hat{p}_{22}}{(1 - \hat{p}_{11}) + (1 - \hat{p}_{22})}$$

The calculation process is to estimate the parameters by employing Expectation-Maximization (EM) algorithm, the iterative process to find the maximum likelihood of the model with a latent variable (Dempster, Laird & Rubin, 1977).

For this study, the calculation of smoothed probability and parameter θ is performed by MATLAB package MS_Regress written by Perlin (2010). Whenever the smoothed probability is lower than 0.5, the credit spread is in the low regime and vice versa. The smooth probability is converted to dummy variable, $inter_t^j$, using this criteria (Maalaoui et al.,. 2008).

Chapter 4 Findings

The data are groups to four credit rating groups and the lognormal function fits the credit spread and time-to-maturity. After running the algorithm in MATLAB under the assumptions of two regimes with different means and variances and fixed conditional probability of p_{11} and p_{22}, the model cannot distinguish between two different regimes. One of the reasons that two different regimes cannot be found is that the data range is relative small (only 69 observations). During the sample period, there is only one credit cycle. However, with an alternative assumptions of one common mean with two different variances and fixed conditional probability of p_{11} and p_{22}, most of the credit spreads can be determined in two different regimes, i.e. low and high variance regimes.

The summary of estimated parameters from Markov regime switching model is in Table 4.1 Across all portfolios, mean of credit spread increase with longer time-to-maturity and lower credit rating. The volatilities of credit spread in state 1 is lower than state 2. The conditional probabilities p_{11} is higher than p_{22} within the range of 0.67 to 0.98. They are more persistent and reluctant to switch between different regimes. To construct interaction term ($inter_t^j$), whenever the continuous probability is lower than 0.5, the credit spread is in the low regime, otherwise it is in the high regime.

The Augmented Duckey Fuller test is performed to all dependent and independent variables to avoid the non-stationary problem. Most of the variable are failed to reject the null hypothesis that there is a unit root. Therefore they are non-stationary data, excepted for the volatility of long-term interest rate and the equity market return, which can reject the null hypothesis at 1% significance level. To solve the non-stationary problem, the first difference is applied to the non-stationary series and retested with ADF. The result shows that the null

Table 1: Estimated Parameters from Markov Regime Switching Model

This table presents the parameters of the switching regime model for AAA, AA, A, and BBB Thai corporate bonds credit rating groups maturing in 2, 5, and 10 years. The natural logarithm of credit spreads have a common mean and two different standard deviation in the first and the second regime, i.e. $\ln CS_t^j = \mu^j + \epsilon_{S_t}^j$, where $\epsilon_{S_t}^j$ follows a normal distribution with zero mean and variance $\sigma_{S_t}^{2j}$. The parameters include μ, σ_1, σ_2, p_{11}, and p_{22} stand for mean, standard variation of regime 1 and 2, conditional probabilities of the process being in state 1 and 2, respectively. The values in parentheses are the p value from the estimation.

Var. (p)	AAA 2 yrs	AAA 5 yrs	AAA 10 yrs	AA 2 yrs	AA 5 yrs	AA 10 yrs	A 2 yrs	A 5 yrs	A 10 yrs	BBB 2 yrs	BBB 5 yrs	BBB 10 yrs
μ	3.45	3.93	4.22	3.89	4.56	4.72	4.12	4.66	4.96	5.05	5.54	5.83
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
σ_1	0.01	0.01	0.01	0.05	0.01	0.10	0.08	0.01	0.01	0.02	0.02	0.02
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.017)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
σ_2	0.60	0.58	0.57	0.54	0.21	0.17	0.34	0.57	0.54	0.29	0.29	0.29
	(0.005)	(0.005)	(0.005)	(0.025)	(0.000)	(0.000)	(0.000)	(0.007)	(0.007)	(0.01)	(0.01)	(0.01)
p_{11}	0.98	0.98	0.98	0.98	1.00	0.90	0.93	0.98	0.98	0.98	0.98	0.98
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
p_{22}	0.94	0.94	0.94	0.91	0.98	0.90	0.67	0.93	0.93	0.93	0.93	0.93
	(0.000)	(0.000)	(0.000)	(0.013)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)	(0.002)

Source: created for this study

hypotheses are rejected for all the first difference of the non-stationary data with significance level at 1%. The results of the test is not shown here.

Table 2 presents the descriptive statistics of the dependent and independent variables including their mean, median, maximum and minimum values, standard deviations, skewness, Kurtosis, Jacqc-Bera and its p-value.

Since the bond market has much less liquidity than the stock market, the information flowing to the bond market is much slower than the stock market. The appropriate lags of independent variables should be in consideration. The univariate linear regressions are performed between each independent variable with different lags and twelve credit spread changes. The criteria to select the appropriate lag is using the minimum Akaike Criterion. The results are not shown here. Most of the independent variables do not need lag terms, except for the return of the equity market and its historical volatility, whose lag terms of two months can minimize the AIC.

The last preliminary result is to check whether the independent variables having correlation between each other. If the correlation between pair of independent variable are higher than 0.80 or lower than -0.80, including of both variables in the analysis would lead to multicollinearity problem (Gujarati, 2003).. The correlation matrix, not showing here, shows no pair of independent variables with high correlation.

Table 2: Descriptive Statistics

This table shows the descriptive statistic of each variables as grouped in four panels including A. interest factors, B. macroeconomic factors, and C. liquidity factor. The statistic results include mean, median, max. and min., standard deviation, skewness, Kurtosis, Jarque-Bera and its p-value. For the normality test, skewness and Kurtosis of normally distributed residual is at 0 and 3.0. When the p-value (p) of Jarque-Bera (JB) is sufficiently low, the null hypothesis that the residual is normally distributed is rejected. The notation on the first column are, r_t^{2y} is the interest rate level, $slope_t^{10y-2y}$ is the slope of term-structure, $\sigma^{r_t^{10y}}$ is the long-term interest rate volatility, set_t is equity market return, σ_t^{set} is the historical volatility of equity market return, hml_t is High-Minus-Low of Fama French, smb_t is Small-Minus-Big of Fama French, and mis_t^k is the missing price ratio of credit rating portfolio k, where k is AAA, AA, A, or BBB. The subscript t notes the data are time-seiries. σ, S and K stand for standard deviation, skewness and Kurtosis, respectively.

Variable	Mean	Median	Max	Min	σ	S	K	JB	p	Obs.
Panel A. Credit Spread Change										
ΔCS_t^{AAA02Y}	0.05	-0.05	20.86	-17.38	4.92	0.64	8.66	95.52	0.000	68
ΔCS_t^{AAA05Y}	0.08	-0.12	31.77	-26.19	7.72	0.63	8.01	75.67	0.000	68
ΔCS_t^{AAA10Y}	0.10	-0.18	41.32	-33.89	10.16	0.62	7.76	68.44	0.000	68
ΔCS_t^{AA02Y}	0.32	0.10	48.18	-23.74	7.91	2.84	21.99	1113.18	0.000	68
ΔCS_t^{AA05Y}	0.54	0.08	77.14	-37.98	12.72	2.80	21.63	1072.14	0.000	68
ΔCS_t^{AA10Y}	0.73	-0.01	102.46	-50.43	16.93	2.79	21.47	1054.67	0.000	68
ΔCS_t^{A02Y}	-0.19	-0.79	82.09	-28.17	12.29	4.30	31.20	2462.29	0.000	68
ΔCS_t^{A05Y}	-0.14	-1.25	125.86	-46.68	18.71	4.35	32.03	2602.62	0.000	68
ΔCS_t^{A10Y}	-0.10	-1.89	164.13	-62.87	24.37	4.35	32.20	2630.48	0.000	68
ΔCS_t^{BBB02Y}	0.68	0.03	93.39	-57.46	17.73	1.76	13.98	376.67	0.000	68
ΔCS_t^{BBB05Y}	1.09	-0.05	152.11	-96.01	29.00	1.70	13.93	371.29	0.000	68
ΔCS_t^{BBB10Y}	1.46	-0.14	203.45	-129.72	38.87	1.67	13.91	369.19	0.000	68
Panel B. Interest Rate Factors										
Δr_t^{2y}	-0.03	-0.06	0.83	-1.22	0.32	-0.51	5.05	14.80	0.001	68
$\Delta slope_t^{10y-2y}$	0.0018	-0.01	1.10	-0.61	0.27	0.99	5.71	31.93	0.000	68
$\sigma_t^{r^{10y}}$	0.73	0.80	1.13	0.22	0.25	-0.11	2.27	1.65	0.438	68
Panel C. Macroeconomic Factors										
set_t	0.01	0.02	0.14	-0.30	0.07	-1.26	6.75	57.88	0.000	68
$\Delta\sigma_t^{set}$	0.11	0.09	11.98	-12.06	3.01	0.00	12.63	262.76	0.000	68
Panel D. Liquidity Factors										
$\Delta turn_t$	0.00007	-0.00019	0.0099	-0.0044	0.00	0.99	5.45	28.02	0.000	68
Δmis_t^{AAA}	-0.00178	0.00000	0.0968	-0.0968	0.04	0.12	3.89	2.39	0.302	68
Δmis_t^{AA}	-0.00028	-0.00085	0.0444	-0.0461	0.01	-0.21	4.80	9.71	0.008	68
Δmis_t^{A}	-0.00024	-0.00029	0.0237	-0.0294	0.01	-0.37	4.32	6.46	0.040	68
Δmis_t^{BBB}	-0.00021	0.00000	0.0226	-0.0233	0.01	-0.14	4.98	11.35	0.003	68

Source: interest rate factors and liquidity factor from ThaiBMA, macroeconomic factors from Bloomberg Database

The Empirical Results

A. Single Regime Model - The results of the OLS analysis of a single regime model are presented in panel A in Table 4.3. The constant terms are not statistically significant for all portfolios. The change of interest rate is statistically significant across all portfolios. The sensitivity to the change of short-term interest rate increases across credit rating groups, but decreases across time-to-maturity. Only the AAA rating group, the change of slope of the term structure is slightly positively related with the credit spread change. The coefficient value increases with the time-to-maturity.

The lag of return of the equity market is negatively correlated with credit spread change both economically and statistically. Moreover, the sensitivities increase consistently across credit rating and time-to-maturity groups. However, the change of the historical volatility of return of equity market is not statistically significant.

The turnover ratio is statistically significant in AA and A rating groups. The sensitivities increase with the time-to-maturity. The missing price ratio is only statistically significant in AAA rating group. The sign of both liquidity factors are as expected. Surprisingly, the BBB rating group is the only group that is not related with liquidity factor.

B. Multiple Regime Model Panel B in Table 4.3 shows the results from the regression of multiple-regime model. For the low regime, most of the explanatory variables are not statistically significant, except for the change of interest rate level in AA and A rating groups, the return of equity market and its historical volatility in short-term AA rating group, the turnover ratio in AAA rating group, and the missing price ratio in AA and A rating groups. Most of the signs are as expected from the theories, except for the return of equity market and turnover ratio.

Table 3: Determinants of Credit Spread Changes in Thailand by Ratings and Time-to-Maturity Groups

The results of the regression analysis of single- and multiple-regime model are presented in panel A and B, respectively. The single-regime model is: $\Delta CS_t^j = \beta_0^j + \beta_1^j \Delta r_t^{2y} + \beta_2^j \Delta slope_t^{10y-2y} + \beta_3^j \sigma_t^{r_t^{10y}} + \beta_4^j set_{t-2} + \beta_5^j \Delta\sigma_{t-2}^{set} + \beta_6^j \Delta turn + \beta_7^j \Delta mis_t^j + \epsilon_t^j$. The multiple-regime model is: $\Delta CS_t^j = \beta_0^j + \beta_1^j \Delta r_t^{2y} + \beta_2^j \Delta slope_t^{10y-2y} + \beta_3^j \sigma_t^{r_t^{10y}} + \beta_4^j set_{t-2} + \beta_5^j \Delta\sigma_{t-2}^{set} + \beta_6^j \Delta turn + \beta_7^j \Delta mis_t^j + inter_t^j + \gamma_1^j \Delta r_t^{2y} \times inter_t^j + \gamma_2^j \Delta slope_t^{10y-2y} \times inter_t^j + \gamma_3^j \sigma_t^{r_t^{10y}} \times inter_t^j + \gamma_4^j set_{t-2} \times inter_t^j + \gamma_5^j \Delta\sigma_{t-2}^{set} \times inter_t^j + \gamma_6^j \Delta turn_t \times inter_t^j + \gamma_7^j mis_t^j \times inter_t^j + \epsilon_t^j$. In each panel, the coefficients of explanatory variables and their t-statistics, adjusted R-square, Akaike criterion, and the adjusted standard error methodology are presented. The values in parentheses are t-statistics. The asterisk sign of ***, **, * indicate the significance level at 1%, 5%, and 10% respectively. The critical t-value at significance level at 1%, 5%, and 10% are 2.663, 2.002, and 1.296 for the single regime model, and 2.678, 2.009, and 1.299 for the multiple regime model, respectively. The adjusted standard methodology is noted with N and W in row adj. Med. for Newey West and White Heteroscedasticity respectively.

	AAA02Y	AAA05Y	AAA10Y	AA02Y	AA05Y	AA10Y	A02Y	A05Y	A10Y	BBB02Y	BBB05Y	BBB10Y
Panel A. Single Regime Model												
$constant$	-0.18	-0.38	-0.56	0.98	1.58	2.1	0.99	2.58	3.96	0.12	0.3	0.46
	(-0.12)	(-0.16)	(-0.177)	(0.418)	(0.418)	(0.418)	(0.345)	(0.531)	(0.681)	(0.026)	(0.037)	(0.037)
Δr_t^{2y}	-4.95***	-7.63***	-9.97**	-9.98***	-15.85***	-20.98***	-16.78***	-25.33**	-32.82**	-9.66	-15.91	-21.37*
	(-2.769)	(-2.678)	(-2.639)	(-3.563)	(-3.51)	(-3.487)	(-2.704)	(-2.341)	(-2.652)	(-1.281)	(-1.218)	(-1.447)
$\Delta slope_t^{10y-2y}$	3.32*	5.15*	6.75*	2.4	3.81	5.04	2.34	2.96	3.5	8.81*	14.61	19.68
	(1.805)	(1.756)	(1.734)	(0.832)	(0.818)	(0.813)	(0.623)	(0.67)	(0.452)	(1.341)	(1.048)	(1.294)
$\sigma_t^{r_t^{10y}}$	0.59	1.09	1.53	-1.18	-1.84	-2.41	-2.62	-5.64	-8.27	2.18	3.32	4.32
	(0.21)	(0.244)	(0.258)	(-0.268)	(-0.259)	(-0.256)	(-0.469)	(-0.597)	(-0.73)	(0.287)	(0.211)	(0.186)
set_{t-2}	-25.05***	-36.87***	-47.2***	-44.19***	-71.34***	-95.09***	-60.12*	-96.44**	-128.2**	-109.46**	-178.82**	-239.47***
	(-3.022)	(-2.789)	(-2.691)	(-3.404)	(-3.409)	(-3.411)	(-1.925)	(-2.089)	(-2.043)	(-2.28)	(-2.643)	(-3.514)
$\Delta\sigma_{t-2}^{set}$	0.08	0.14	0.2	0.06	0.09	0.13	0.54	0.74	0.92	0.36	0.57	0.75
	(0.41)	(0.462)	(0.482)	(0.189)	(0.192)	(0.193)	(0.687)	(0.665)	(0.617)	(0.454)	(0.416)	(0.472)
$\Delta turn$	-13.72	-1	10.13	-539.29*	-851.1*	-1123.78*	-1060.68**	-1581.21**	-2036.4**	-982.57	-1615.25	-2168.52
	(-0.062)	(-0.003)	(0.022)	(-1.448)	(-1.418)	(-1.405)	(-2.519)	(-2.113)	(-2.335)	(-1.198)	(-1.275)	(-1.21)
Δmis_t^j	28.65**	43.91**	57.25*	27.6	46.64	63.29	-39.9	-57.55	-72.98	306.79	501.75	672.24
	(2.112)	(2.03)	(1.994)	(0.474)	(0.497)	(0.506)	(-0.353)	(-0.368)	(-0.325)	(1.202)	(1.144)	(1.112)
$\overline{R}^2$	0.35	0.33	0.32	0.39	0.38	0.38	0.45	0.45	0.45	0.29	0.29	0.29
aic	5.73	6.66	7.23	6.63	7.59	8.16	7.40	8.24	8.77	8.38	9.37	9.96
adj. Med.							W	N	W	N	W	

Continued on next page

Table 3: Continued

	AAA02Y	AAA05Y	AAA10Y	AA02Y	AA05Y	AA10Y	A02Y	A05Y	A10Y	BBB02Y	BBB05Y	BBB10Y
Panel B. Multiple Regime Model												
$constant$	-0.47	-0.75	-1	-0.79	-1.04	-1.72	-0.51	0.61	1.2	-2.61	-4.35	-5.87
	(-0.516)	(-0.394)	(-0.507)	(-0.503)	(-0.161)	(-0.511)	(-0.305)	(0.193)	(0.384)	(-0.58)	(-0.738)	(-0.592)
Δr_t^{2y}	-0.91	-1.49	-1.99	-3.45*	-19.02***	-5.84	-5.86**	-8.13*	-10.45**	-3.45	-5.51	-7.31
	(-0.782)	(-0.586)	(-0.789)	(-1.672)	(-3.625)	(-1.275)	(-2.111)	(-1.964)	(-2.042)	(-0.595)	(-0.577)	(-0.573)
$\Delta slope_t^{10y-2y}$	-1.67	-2.63	-3.47	-1.61	-9.7	-4.13	-0.38	-3.45	-4.66	-3.73	-6.06	-8.09
	(-0.96)	(-0.853)	(-0.908)	(-0.629)	(-1.291)	(-0.752)	(-0.126)	(-0.67)	(-0.877)	(-0.511)	(-0.488)	(-0.502)
$\sigma_t^{r^{10y}}$	0.68	1.05	1.38	1.59	-0.24	3.27	-0.93	-3.3	-4.93	5.05	8.4	11.33
	(0.437)	(0.303)	(0.405)	(0.546)	(-0.011)	(0.526)	(-0.323)	(-0.572)	(-0.898)	(0.613)	(0.726)	(0.625)
set_{t-2}	2.24	4.8	7.04	5.71	34.56*	10.52	8.4	22.22	29.67	27.98	45.89	61.55
	(0.301)	(0.335)	(0.44)	(0.501)	(1.37)	(0.431)	(0.556)	(0.952)	(1.06)	(0.86)	(0.802)	(0.858)
$\Delta\sigma_{t-2}^{set}$	-0.04	-0.05	-0.06	-0.14	1.44*	-0.27	-0.09	-0.03	-0.02	0.06	0.11	0.14
	(-0.431)	(-0.178)	(-0.32)	(-0.605)	(1.677)	(-0.545)	(-0.349)	(-0.07)	(-0.036)	(0.096)	(0.122)	(0.099)
$\Delta turn$	217.73*	336.38	440.14*	62.76	240.33	210.51	78.33	222.6	348.33	-101.43	-144.74	-182.61
	(1.696)	(1.147)	(1.566)	(0.234)	(0.527)	(0.365)	(0.289)	(0.402)	(0.675)	(-0.145)	(-0.11)	(-0.119)
Δmis_t^j	11.23	17	22.05	52.38*	81.91	123.94*	123.29*	191.31	252.97*	196.54	319.93	427.83
	(1.137)	(0.905)	(1.022)	(1.325)	(1.214)	(1.46)	(1.528)	(1.269)	(1.664)	(0.894)	(1.128)	(0.883)
$inter_t^j$	-6.7*	-11.51*	-15.72*	15.13*	4.65	34.71*	-0.33	1.45	4.58	14.44	25.88	35.88
	(-1.425)	(-1.777)	(-1.458)	(1.56)	(0.374)	(1.841)	(-0.023)	(0.124)	(0.216)	(0.878)	(0.908)	(0.99)
$\Delta r_t^{2y} \times inter_t^j$	-10.47***	-15.78***	-20.42**	-17.97***	4.97	-38.01***	-29.77***	-45.72***	-59.09***	2.2	2.88	3.48
	(-2.874)	(-3.2)	(-2.465)	(-3.706)	(0.508)	(-4.085)	(-3.845)	(-5.155)	(-3.774)	(0.171)	(0.147)	(0.122)
$\Delta slope_t^{10y-2y} \times inter_t^j$	8.89***	13.72***	17.95***	9.06**	16.53*	20.71**	3.92	8.74	10.98	24.86**	41.2***	55.49**
	(3.202)	(3.076)	(2.907)	(2.371)	(1.846)	(2.539)	(0.553)	(1.081)	(0.821)	(2.298)	(2.769)	(2.328)
$\sigma_t^{r^{10y}} \times inter_t^j$	11.18	19.86*	27.46	-31.42*	-4.7	-71.71**	-1.78	-7.04	-14.19	-24.46	-44.98	-62.91
	(1.171)	(1.555)	(1.259)	(-1.739)	(-0.173)	(-2.063)	(-0.062)	(-0.3)	(-0.33)	(-0.742)	(-0.81)	(-0.866)
$set_{t-2} \times inter_t^j$	-32.38*	-49.26**	-64.02*	-79.98***	-149.44***	-172.7***	-78.48***	-144.04***	-196.97***	-256.71***	-419.52***	-561.89***
	(-1.899)	(-2.351)	(-1.656)	(-4.366)	(-3.287)	(-4.524)	(-3.12)	(-4.128)	(-3.805)	(-5.241)	(-4.311)	(-5.206)
$\Delta\sigma_{t-2}^{set} \times inter_t^j$	0.01	0.01	0.02	0.37	-1.67*	0.89	1.38**	1.73*	2.11*	1.17	1.9*	2.54
	(0.017)	(0.028)	(0.03)	(0.744)	(-1.545)	(0.882)	(2.259)	(1.897)	(1.828)	(0.902)	(1.368)	(0.892)
$\Delta turn \times inter_t^j$	-285.95	-308.81	-328.8	-475.06	-1829.42*	-1133.91	-1436.42	-2287.61*	-3159.66*	-89.31	-381.09	-636.24
	(-0.442)	(-0.411)	(-0.223)	(-0.643)	(-1.686)	(-0.728)	(-1.152)	(-1.444)	(-1.475)	(-0.051)	(-0.125)	(-0.164)
$\Delta mis_t^j \times inter_t^j$	15.33	24.73	32.96	-133.77	-126.57	-313.78	-169.04	-254.48	-362.55	738.43	1210.83	1623.94
	(0.686)	(0.601)	(0.675)	(-0.902)	(-0.565)	(-0.989)	(-0.452)	(-0.704)	(-0.62)	(1.064)	(1.111)	(1.062)
$\overline{R}^2$	0.67	0.63	0.62	0.75	0.44	0.75	0.80	0.83	0.83	0.61	0.61	0.61
aic	5.15	6.16	6.75	5.82	7.58	7.35	6.46	7.17	7.72	7.88	8.87	9.46
adj. Med.	W		W		W		W		W		W	

Source: created for this study

For the high regime, the marginal parts of explanatory variable are discussed. The change of short-term interest rate of most of the portfolio is strongly statistically significant. The relationship between interest volatility is only significant in medium-term AAA, short- and long-term AA. However, the signs are mixed. Most of the portfolios have strong negative relationships between the return of equity market and the credit spread change. However, the historical volatility of the equity market is not significant. The liquidity factors only play important role for medium-term AA and A rating group and long-term A rating group with expected sign.

The adjusted R-squared for multiple-regime models are between 0.44 and 0.83, while the adjusted R-square for single-regime models are between 0.29 to 0.45. The multiple-regime models can explain the credit spread change better than the single-regime models. For all portfolios, the Akaike criterions in multiple-regime models are lower than single-regime models.

Chapter 5 Discussion

For the single regime and the high regime, the change of short-term interest for most of the portfolios are consistent with the empirical findings of Longstaff and Schwartz (1995), Duffee (1998), Collin-Dufresne et al. (2001), and Maalaoui et al. (2008), that an increase in the short-term interest rate decreases the risk-neutral probability of default. However in the low credit rating the interest factor is less sensitive. For the slope of term-structure, in the high regime, the increase of the slope widens the credit spread. This shows that the future increase of interest rate during the high credit cycle is not good news for the investors; therefore the credit spread widens. The return of equity market is sensitive across all portfolios. Between equity and bond market there is a negative relationship and the equity market reacts faster to the information faster than the bond market, as the lag of equity return can explain change of credit spread. In the high regime, the increase of the equity return, increase the firm value away from the default threshold as in Merton (1973). The liquidity factors have relationship as expected for all portfolios except for the low credit rating. These results are different from other studies that the low credit rating is more sensitive to the liquidity change (Collin-Dufresne et al., 2001; Maalaoui et al., 2008). One of the reason is that the low credit rating is traded very few in secondary market; therefore the mark-to-market value is mainly determined the value of the bonds from the interest rate and macroeconomic factors.

Chapter 6 Conclusion and Recommendations

This study investigates the use of multiple-regime models in explaining the determinants of credit spread change in Thailand. Several results are obtained. First, the multiple-regime model can explain the credit spread change in Thailand better than the single-regime model. Second, the results from multiple-regime model show that in the low regime, the credit spread change is less sensitive than in the high regime. Third, the key determinants across all portfolios are interest rate change and return of equity market. The liquidity factor can only explain for high-credit rating.

The findings suggest that during the low regime, the credit spread remain stable and it is a good time for issuers to issue the new bond with competitive cost. For the investor, the cost of the bond is less during the high regime. As the interest rate and return of equity market decreases, the value of firm is less, the credit spread increases significantly. Investing the corporate bond at high rating is recommended. In general, the higher liquidity of the securities market can reduce the credit spread.

The study suggests that the need for the further work on other technique on other regime switching model, such as SETAR, PSTAR/LSTAR for the more sophisticated model to improve the explanatory power of the model. Furthermore, the liquidity proxies have many varieties of choices. The higher frequencies of the data and more aspects of the data, e.g., price and volume of portfolio or bond market or co movement market, if available, should be included into the model (Houweling, Mentink & Vorstb, 2005; Mahantia, Nashikkarc, Subrahmanyamc, Chackod & Mallik, 2008; Acharya, Amihud & Bharath, 2010). Since the return of equity market has the strong relationship with credit spread, it is interesting to apply the event study to precisely extract the timing of credit spread changes. It should be aware of asymmetrical effect during high and low variance of equity market return as discussed in Collin-Dufresne et al. (2001), or implement the event study together with interactive term to refine the result during the transition period.

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