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Determinants of Euro Term Structure of Credit Spreads

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Abstract

In this paper, we analyze wether the sensitivity of credit spread changes to financial and macroeconomic variables depends on bond characteristics such as rating and maturity. First, we estimate the term structure of credit spreads for different rating categories by applying an extension of the Nelson-Siegel method. Then, we analyse the determinants of credit spread changes. According to the structural models and empirical evidence on credit spreads, our results indicate that changes in the level and the slope of the default-free term structure, the market return, implied volatility, and liquidity risk significantly influence credit spread changes. The effect of these factors strongly depends on bond characteristics, especially the rating and to a lesser extent the maturity.

JEL-code : C22, E45, G15

Keywords: Credit risk, Structural models, Nelson-Siegel

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1 Introduction

While many studies concentrate on theoretical models for the pricing of corporate bonds and credit risk, there has been much less empirical testing of these models. Yet, there are several reasons for investigating the determinants and behavior of credit spreads. First, the Euro corporate bond market, which lags its US counterpart, has become broader and more liquid. The number and the market value of Euro corporate bonds have more than doubled over the last decade. The development of the A and BBB rated market segment has been particularly impressive, coming from virtual non-existence in early 1998, to account for almost half the individual rated bond issues outstanding in late 2003. Second, the credit derivatives market, including structured finance products such as collateralized debt obligations (CDO) and asset-backed securities (ABS), has experienced considerable growth over the last two decades and is expected to grow strongly in the coming years. Some structured products such as collateralized bond obligations (CBO) are backed by a large pool of corporate bonds. This implies that the cash flows (coupon and principal) of the underlying bonds determine the profitability of these structured products. Therefore, the creditworthiness of corporate bonds is important for the analysis of these products. Third, according to the Basel II Accord, credit risk models can be used as a basis for calculating a bank's regulatory capital. To develop and use these models, one needs to make assumptions about what variables to include and the relation between credit risk and financial and macroeconomic variables such as, for example, the risk-free rate. Finally, central bankers use credit spreads to assess (extract) default probabilities of firms and to assess the general functioning of financial markets (credit rationing and sectoral versus macroeconomic effects). In addition, the credit spread is often used as a business cycle indicator. Having a better understanding of credit spreads will help central bankers to extract more precise information from bond prices/spreads.

The contributions of this article are twofold. First, we analyze the determinants of credit spread changes using a data set of euro corporate bonds between 1997 and 2002. As the US has a large and mature corporate bond market, most empirical studies on the determinants of credit spreads concentrate on US data (see, for example, Longstaff and Schwartz (1995), Duffee (1998), Collin-Dufresne et al. (2001), Cossin and Hricko (2001), Elton et al. (2001), and Perraudin and Taylor (2003)). Empirical studies on the determinants of European credit spreads are rather limited (see, for example, Boss and Scheicher (2002)) and mainly focus on time series properties of bond indices. Second, we analyze the determinants of credit spread changes for bonds with different ratings and maturities. We test whether the sensitivity of credit spread changes to financial and macroeconomic variables significantly depends on bond characteristics such as rating and maturity. Furthermore, we analyze whether our empirical results are in line with the predictions of structural credit risk models, initiated by Black and Scholes (1973) and Merton (1974), and comparable with other studies on US corporate bonds. To our knowledge, this is the first paper to empirically test whether bond characteristics influence the relation between credit spread changes and macroeconomic and financial variables.

Our analysis is most closely related to that of Collin-Dufresne et al. (2001) on US credit spreads. While the latter investigates a panel data set of credit spreads on individual US corporate bonds, this study focuses on the euro term structure of credit spreads for different rating categories. The term structure of credit spreads is estimated as the difference of the term structure of spot rates on euro corporate and government bonds. Spot rates, which are estimated by applying an extension of the Nelson-Siegel method on a data set of individual bond yields, have the advantage that they are not affected by the coupon rate and much easier to compare than yields to maturity. The disadvantage of using the term structure of credit spreads is that we solely focus on systematic factors and not firm-specific factors. However, Collin-Dufresne et al. (2001) conclude that aggregate factors are much more important than firm-specific factors in explaining credit spread changes. While Collin-Dufresne et al. (2001) make a distinction between credit spreads for different rating categories and two maturity classes, we distinguish between credit spreads for different rating categories and a broad range of maturities. Furthermore, we test whether the results are significantly different.

The data set consists of weekly observations of prices and yields on 1577 euro corporate bonds and 260 AAA government bonds from January 1998 until December 2002. The bonds in question are those included in euro bond indices constructed by Merrill Lynch. The corporate bonds are used to estimate the risky term structure of spot rates, whereas the government bonds are used to estimated the risk-free term structure of spot rates. Our results on the estimation of the term structure of credit spreads are as follows: It is important to take into account the effect of the liquidity risk, the coupon rate, and the subrating category. The results show that an extension of the NS model, which includes these additional factors, produces better estimates of the term structure compared to the original NS model.

Our results on the determinants of credit spread changes are as follows: According to the structural credit risk models, we find that changes in the level and the slope of the default-free term structure, the stock return, and implied volatility of the stock price, significantly influence credit spread changes. Furthermore, we find that liquidity risk causes credit spreads to widen. An important conclusion that can be drawn from the empirical analysis is that the effect of those factors significantly depends on bonds characteristics, especially the rating and to a lesser extent the maturity. Bonds with a lower rating are often more affected by financial and macroeconomic news. The maturity of the bond mainly influences the relation between financial and macroeconomic news and credit spread changes on higher rated bonds (AAA and AA). Finally, we find evidence for mean reversion of credit spreads for all ratings and maturities.

Our models explains on average 22% of the variation in credit spreads as measured by the adjusted R^2. This is comparable with the results of Collin-Dufresne et al. (2001) for US corporate bonds. Although the US and the European corporate bond markets differ significantly in terms of market value and number of bonds, empirical results for bond markets in both regions are very similar, that is, the impact of financial and macroeconomic news on credit spread changes is very similar. Our results suggest that the effect of news on credit spread changes strongly depends more on bond characteristics, especially the rating.

The paper is organized as follows. Section 2 presents the main determinants of credit spreads. Some determinants are implied by structural credit risk models, others are deduced from empirical studies. Section 3 gives an overview of the methodology to extract spot rates (extended Nelson-Siegel model) and four measures of fit. In Section 4, we first present the data and the estimation results of the term structure of credit spreads. Then, we empirically analyze the main determinants of credit spread changes for different (sub)rating categories and maturities. Finally, Section 5 concludes.

2 Determinants of Credit Spreads

Structural or contingent-claim models, which relate the credit event to the firm's asset value and the firm's capital structure, provides an intuitive framework to assess the main determinants of credit spreads.[1] Since the Merton model is one of the first structural credit risk models, the literature often refers to it as the representative of the structural models. Over the last two decades, the model has been extended in several ways by relaxing some of its restrictive assumptions (see, for example, Geske (1977), Black and Cox (1976), Cox et al. (1980), Turnbull (1979), Leland (1994, 1998), Longstaff and Schwartz (1995), and Leland and Toft (1996)). However, the main factors such as the risk-free rate, the asset value, and the asset volatility and their effect on credit spreads are common to all of these models. In what follows, we will briefly describe the Merton model and the relation between credit spreads and factors that are derived from the

[1] The theoretical literature on credit risk pricing can be divided in two broad categories: (1) structural credit risk models and (2) reduced-form models. The latter do not attempt to model the asset value and the capital structure of the firm. Instead they specify the credit event as an unpredictable event governed by a hazard-rate process. Mathematically, these models are more tractable and therefore more suitable for credit derivatives pricing. For the purpose of this paper, however, we will concentrate on the structural models.

Merton model. In accordance with the empirical evidence on the determinants of credit spreads, we also discuss liquidity risk as a possible determinant.

In the Merton (1974) model, default occurs when the firm's asset value, $V_{T,}$ falls below a specified critical value at maturity T. The latter is given by the face value of the firm's zerobond debt, L, which is by assumption the only source of debt. The firm's asset value process, V, follows an Îto process

$$\frac{dV_t}{V_t} = \mu dt + \sigma_V \, dW_t \ , \tag{1}$$

with μ the drift parameter, σ_V the constant volatility, and W a standard Brownian motion.[2] In case of default, debt holders receive the amount V_T. The value of a default-risky zero-coupon bond at time T can be written as

$$D(T) = \min(L, V_T) = L - \max(0, L - V_T) \tag{2}$$

The value of a default-risky zero-coupon bond equals the difference of the value of a default-free zero-coupon bond with face value L and the value of European put option written on the firm's asset value, with strike price L and exercise date T. The bondholders have written a put option to the equity holders, agreeing to accept the assets in settlement of the payment if the value of the firm falls below the face value of the debt. The payoff, $L - V_T$, is often called the *put-to-default.* Since V is the sum of the firm's debt and equity, the value of the equity can thus be seen as the value of a call option on the firm's asset value. Issuing debt is similar to selling the firm's assets to the bondholders while the equity holders keep a call option to buy back the assets. Using the put-call parity, this is equivalent to saying that the equity holders own the firm's assets and buy a put option from the bond holders.

Merton (1974) derived a closed-form solution for the price of a defaultable zero-coupon bond by combining equation (2) with the Black and Scholes formula for the arbitrage price of a European put option. Having an analytical expression for the price of a defaultable bond, we can deduce the related credit spread (CR) on a defaultable bond as the difference between the yield on a defaultable bond, Y^d, and the yield on a risk-free bond, Y,

$$CR(t,T) = Y^d(t,T) - Y(t,T) = -\frac{\ln(l_t^{-1} N(-h_1) + N(h_2))}{T-t}, \tag{3}$$

with

[2] For simplicity, we assume that the payout or dividend ratio equals zero.

$$h_{1,2}\left(l_t, t-T\right) = \frac{-\ln l_t \ \pm \ \frac{1}{2}\sigma_V^2 \ (T-t)}{\sigma_V\sqrt{T-t}},$$

and

$$l_t = \frac{LB(t,T)}{V_t} = \frac{L\exp^{-r(T-t)}}{V_t}.$$

N denotes the cumulative probability distribution function of a standard normal. $L_t = LB(t,T)$ is the present value of the promised claim (the face value) at the maturity of the bond (T) and $B(t,T)$ represents the value of a unit default-free zero-coupon bond. l is the leverage ratio, r the continuously compounded risk-free rate, and σ_V the volatility of the firm's asset value. Equation (3) shows that the credit spread is affected by the risk-free rate, the asset value, and volatility of the asset value. These factors will be discussed in more detail below. In addition, we also discuss the slope of the default-free term structure, as this variable is implied by the structural models because it is closely related to the risk-free interest rate, and liquidity risk. Finally, we discuss how the leverage and the maturity of the debt value influences the relation between the credit spread and its determinants.

2.1 Risk-free Interest Rate

We expect a negative relation between the (instantaneous) risk-free rate and the credit spread. The drift of the risk-neutral process of the value of the assets (see equation (1)), which is the expected growth of the firm's asset value, equals the risk-free interest rate. An increase in the interest rate implies an increase in the expected growth rate of the firm's asset value. This will in turn reduce the probability of default and the credit spread (see Longstaff and Schwartz (1995)). Furthermore, lower interest rates are usually associated with a weakening economy and thus higher credit spreads.

Simulations based on structural credit risk models show that for firms with moderate debt levels (l significantly larger than one), the effect of an interest rate change first increases with the time to maturity (only for short maturities) and then remains constant (for medium and long maturities). For firm at the brink of default (l close to one), the effect first decreases with the term to maturity (only for short maturities) and then remains constant (for medium and long maturities). In general, the effect of an interest rate change is always stronger for bonds with a higher leverage. Since firms with a higher debt level often have a lower rating, we expect that the interest rate effect is stronger for bonds with a lower rating.

2.2 Slope of the Term Structure

The expectations hypothesis of the term structure implies that the slope of the default-free term structure, which is often measured as the spread between the long-term and the short-term rate, is an optimal predictor of future changes in short-term rates over the life of the long-term bond. As such, an increase in the slope implies an increase in the expected short-term interest rates. As in the case of the motivation for the risk-free interest rate above, we expect a negative dependence between changes in the slope of the default-free term structure and credit spread changes. Litterman and Scheinkman (1991) and Chen and Scott (1993) document that most of the variations in the term structure can be explained by changes in the level and the slope.

Furthermore, the slope of the term structure is often related to future business cycle conditions (see, for example, Estrella and Hardouvelis (1991), Bernard and Gerlach (1998), and Estrella and Mishkin (1995, 1998)). A decrease in the slope is considered to be indicators of a weakening economy. A positively sloped yield curve is associated with improving economic activity, which might in turn increase a firm's growth rate and reduce its default probability. This strengthens our expectations of a negative relation between the slope and the credit spread.

2.3 Asset Value

We expect a negative relation between the credit spread and the firm's asset value, V. Firms where the asset value can easily cover the debt value (with a low leverage ratio) are unlikely to default. An increase in the firm's asset value (for a given debt value) reduces the leverage ratio and the value of the put option. As a result, the credit spread will decrease. Therefore, we expect a negative relation between the firm's asset value and the credit spread. According to the Merton type models, the effect of an increase in V on credit spreads is stronger for bonds with a short term to maturity and for firms with a high leverage ratio. For bonds with a medium to long term to maturity, the effect is more or less constant.

Structural models typically assume that the assets of the firm are tradable securities. In practice, however, the asset value has to be deduced from the balance sheet and is updated only on an infrequent basis. Therefore, the asset value is usually replaced by the equity return of publicly traded companies or the return on a stock index. Collin-Dufresne et al. (2001) conclude that the sensitivity of credit spreads to the S&P 500 return is several times larger than the sensitivity to firm's own equity return. Therefore, we mainly focus on the return on a stock index instead of the return of individual stocks. Similar to the asset value and in accordance with the empirical findings Ramaswami (1991), Shane (1994), and Kwan (1996), we expect a negative relation between the return of a stock index and the credit spread. Furthermore, the return on a stock index gives an indication of the overall state of the economy. Several studies (see, for example, Chen (1991), Fama and French (1989), Friedman and Kuttner (1992), and Guha and Hiris (2002)) show that credit spreads behave counter-cyclically, that is, credit spreads tend to increase during recessions and narrow during expansions. This strengthens our expectation of negative relation between credit spreads and equity (index) returns. It is very likely that firms with a high leverage ratio or a smaller capital buffer are more affected by a deterioration of economic growth. Therefore, we expect that the effect of the return on a stock index is larger for lower rated bonds.

2.4 Asset Volatility

Equation (3) shows that credit spreads are affected by the volatility of the firm's asset value. High asset volatility corresponds with a high probability that the firm's asset value will fall below the value of its debt. In that case, it is more likely that the put option will be exercised and thus, credit spreads will be higher. The effect of a volatility increase is larger for bonds with a high leverage ratio compared to bonds with a debt value far below the asset value. For firms with moderate debt levels (l significantly larger than one), the effect of a change in the volatility first increases with the time to maturity (only for short maturities) and then remains constant (for medium and long maturities). For firm at the brink of default (l close to one), the effect first decreases with the term to maturity (only for short maturities) and then remains constant (for medium and long maturities).

Since the asset value, and thus asset volatility, is only updated on an infrequent basis, asset volatility is often replaced by equity volatility. As with asset volatility, an increase in equity volatility increases the probability that the put option will be exercised and therefore credit spreads will increase (see, for example, Ronn and Verma (1986) and Jones et al. (1984)). Studies that analyze portfolios of bonds often use the (implied) volatility of a stock index that is related to the portfolios.[3] Campbell and Taksler (2002) find that equity volatility explains as much variation in corporate credit spreads as do credit ratings.

2.5 Measure of Liquidity

Option models typically used in the structural approach assume perfect and complete markets where trading takes place continuously. This implies that liquidity risk does not affect credit spreads. However, Collin-Dufresne et al. (2001), Houweling et al. (2002), and Perraudin and

[3] A basic approach to measure equity volatility is to calculate implied volatility from current option prices in the market (see, for example, Day and Lewis (1990) and Lamoureux and Lastrapes (1993)).

Taylor (2003) find evidence that liquidity significantly influences credit spreads (changes). Investors are only willing to invest in less liquid assets compared to similar liquid assets at a higher premium. If the liquidity risk were similar for government and corporate bonds, the liquidity premium should be cancelled out when taking the difference between the two yields. However, government bond markets are larger and more liquid than corporate bond markets. Therefore, an investor may expect some reward for the lower liquidity in corporate bond markets.

Amihud and Mendelson (1986) and Easley et al. (2002) argue that liquidity is priced because investors maximize expected returns net of transactions (or liquidity) costs. Amihud and Mendelson (1986) state that the bid-ask is a natural measure of illiquidity. The quoted ask price includes a premium for the immediate buying, while the quoted bid price reflects a concession for immediate sale. Hence, the bid-ask spread measures the cost of immediate execution. In this paper, we proxy liquidity risk by the bid-ask spread. Narrowing bid-ask spreads indicate greater liquidity and thus lower credit spreads.

It is not clear whether the effect of liquidity risk should be different for bonds with different ratings and/or maturities. Houweling et al. (2002) find that the effect of liquidity risk is stronger for bonds with a lower rating and longer maturities. Perraudin and Taylor (2003) present similar results for bonds with different maturities.

3 Modeling the Term Structure of Credit Spreads

In accordance with the structural credit risk models, we expect that the relation between credit spreads changes and macroeconomic and financial variables depends on the leverage ratio (creditworthiness) of the issuer and the maturity of the bonds. Similar to the leverage ratio, the rating provides an indication of a firm's creditworthiness. If a firm's debt-to-assets ratio becomes one, default will occur. At the same time, its rating should move to the default category.[4] Therefore, we use the rating as a proxy for the firm's leverage ratio.

In order to obtain and easily compare credit spreads on bonds with different ratings and maturities, we estimate the term structure of credit spreads for AAA, AA, A, and BBB rated bonds. Moreover, making a distinction between different rating categories also allows us to more accurately estimate the term structure of credit spreads. The latter is calculated as the difference between the term structure of spot rates on corporate and government bonds. There are a number of reasons for using the spot rates instead of yields to maturity. The yield to maturity depends on the coupon rate. The yield to maturity of bonds with the same maturity

[4]Note that in this paper, we focus on investment grade bonds. This means that our sample does not include firms which are at the brink of default or have a leverage ratio near one.

but different coupons may vary considerably. As a results, the credit spread will depend on the coupon rate. Furthermore, by using yields to maturity, one compares bonds with different duration and convexity. On the other hand, spot rates are not observable. Therefore, we use an extension of the parametric model introduced by Nelson and Siegel (1987) to extract the spot rates.

3.1 Extended Nelson-Siegel Approach

The Nelson-Siegel (NS) model offers a conceptually simple and parsimonious description of the term structure of interest rates. It avoids over-parametrization while it allows for monotonically increasing or decreasing yield curves and hump shaped yield curves. Diebold and Li (2002) conclude that the NS method produces one-year-ahead forecasts that are strikingly more accurate than standard benchmarks. Furthermore, it avoids the problem in spline-based models to choose the best knot point specification.[5]

The idea of the NS method is to fit the empirical form of the yield curve with a pre-specified functional form for the spot rates, which is a function of the time to maturity of the bonds.

$$
\begin{aligned}
i_t(m, \boldsymbol{\theta}) &= \beta_{0,t} + \beta_{1,t} \frac{1 - \exp\left(-m_t / \tau_t\right)}{\left(-m_t / \tau_t\right)} \\
&\quad + \beta_{2,t} \left(\frac{1 - \exp\left(-m_t / \tau_t\right)}{\left(-m_t / \tau_t\right)} - \exp\left(-m_t / \tau_t\right) \right) + \varepsilon_t, \\
\text{with } \varepsilon &\sim N\left(0, \sigma^2\right),
\end{aligned}
\tag{4}
$$

i and m are N_tx1 matrices of spot rates and years to maturity, respectively, with N_t the number of bonds at time t. $\boldsymbol{\theta}_t = (\beta_{0,t}, \beta_{1,t}, \beta_{2,t}, \tau_t)$ is the parameter vector. β_0 represents the long-run level of interest rates, β_1 the short-run component, and β_2 the medium-term component. If the time to maturity goes to infinity, the spot rate converges to β_0. If the time to maturity goes to zero, the spot rate converges to $\beta_0 + \beta_1$. To avoid negative interest rates, β_0 and $\beta_0 + \beta_1$ should be positive. β_0 can be interpreted as the long-run interest rate and $\beta_0 + \beta_1$ as the instantaneous interest rate. This implies that $-\beta_1$ can be interpreted as the slope of the yield curve. The curve will have a negative slope if β_1 is positive and vice versa. β_1 also indicates the speed with which the curve evolves towards its long-run trend. β_2 determines the magnitude and the direction of the hump or through in the yield curve. The parameter τ_1 is a time constant that should be

[5] For comparison with other methods, see Green and Odegaard (1997).

positive in order to assure convergence to the long-term value β_0. This parameter specifies the position of the hump or trough on the yield curve.[6] The specification in equation (4) is estimated on a weekly basis on a cross-section of N_t bonds at time t. The sample is divided into four rating categories j, with $j = \{AAA,\ AA,\ A, \text{ and } BBB\}$.

In accordance with Elton et al. (2004), we find that the NS method results in systematic errors. Therefore, we use an extension of the NS model, which is comparable with Elton et al. (2004) but not exactly the same, by adding four additional factors to the NS model, namely liquidity risk, taxation, and plus and minus subrating classifications. First, to capture differences in liquidity, we add the bid-ask spread as an additional factor (Liq). If liquidity decreases, bid-ask spreads tend to widen and hence spot rates might go up. A second reason why spot rates in the same rating category might be different is because of tax effects. Therefore, we include the difference between the coupon of a bond and the average coupon rate of the sample $\left(C - \overline{C}\right)$. The underlying idea is that low coupon bonds have a more favorable tax treatment compared to high coupon bonds. Finally, another reason why spot rates on bonds within a rating category might differ, is that bonds are not viewed as equally risky. Moody's and Standard and Poor's (S&P) both introduced subcategories within a rating category. While S&P add a plus (+) or a minus (-) sign, Moody's adds a number (1,2 or 3) to show the standing within the major rating categories. Bonds that are rated with a plus (1) or a minus (3) might be considered as having a different probability of default compared to the flat letter rating (2). Therefore, we include a dummy for the plus subcategory (D_pl) and a dummy for the minus subcategory (D_mi). For simplicity, we assume that the additional factors only affect the level of the term structure and not the slope. Adding four additional factors to the NS model gives

$$
\begin{aligned}
i_t(m, \widetilde{\boldsymbol{\theta}}) \quad &= \quad \beta_{0,t} + \beta_{1,t} \frac{1 - \exp\left(-m_t\ /\tau_t\right)}{\left(-m_t\ /\tau_t\right)} + \beta_{2,t} \left(\frac{1 - \exp\left(-m_t\ /\tau_t\right)}{\left(-m_t\ /\tau_t\right)} - \exp\left(-m_t\ /\tau_t\right) \right) \\
&\quad + \beta_{3,t}\ Liq_t + \ \beta_{4,t}\left(C_t - \overline{C}_t\right) + \ \beta_{5,t}\ D\_pl_t + \ \beta_{6,t}\ D\_mi_t + \widetilde{\varepsilon}_t, \qquad (5)
\end{aligned}
$$

$$
\text{with } \widetilde{\varepsilon} \quad \sim \quad N\left(0, \sigma^2\right),
$$

$\beta_0, \beta_1, \beta_2, \tau_1$ represent the parameters in the original NS model, whereas β_3, β_4, β_5, and β_6

[6] Svensson (1994) extended the NS model with an additional exponential term that allows for a second possible hump or trough. However, Geyer and Mader (1999) find that the Svensson method does not perform better in the form of smaller yield errors in the objective function compared to the NS method. Furthermore, Bolder and Streliski (1999) conclude that the Svensson model requires approximately four times as much time in estimation.

represent the sensitivities of the spot rates to the additional factors.

Every set of parameters $(\widetilde{\boldsymbol{\theta}})$ translates in different spot rates and bond prices. Therefore, we estimate the parameters as such as to minimize the sum of squared errors between the estimated yields, y^{NS}, and observed yields to maturity, y, at time t.[7]

$$\widehat{\boldsymbol{\theta}}_t = \arg\min_{\boldsymbol{\theta}_t} \sum_{i=1}^{N_t} \left(y_t^{NS} - y_t\right)^2$$

with N_t the number of bonds at time t. We apply maximum likelihood to estimate the parameters, $\widehat{\boldsymbol{\theta}}$.

3.2 Goodness of Fit Statistics

In order to compare the extended model with the original NS method and to test how well the (extended) NS model describes the underlying data, we estimate three in-sample measures: (1) the *average absolute yield errors* (AAE), (2) the percentage of bonds that have a yield outside a 95% confidence interval (*hit ratio*), and (3) the *conditional and unconditional frequency of pricing errors.* Finally, we examine the out-of-sample *forecasting performance.* For each measure, we compare the results of the NS model with those of the extended NS model.

1. The first measure of goodness of fit is the average absolute yield errors (AAE).

$$AAE_{j,t} = \sqrt{\frac{\left|(y_{j,t}^{NS} - y_{j,t})\right|}{N_t}} = \sqrt{\frac{|\varepsilon_{j,t}|}{N_t}}$$

   y_t and y_t^{NS} are the observed and estimated yields to maturity at time t in rating category j. N_t is the number of bonds at time t. The higher the $AAE_{j,t}$ the less good the quality of the fit.

2. The second measure is the percentage of bonds that have an observed yield to maturity outside a 95% confidence interval around the estimated term structure of yields to maturity. We use the delta method and the maximum likelihood results to obtain a 95% confidence interval for the term structure of estimated yields to maturity.

$$\Pr\left(\mathbf{f}(\widehat{\boldsymbol{\theta}}) - \mathbf{2} * \sqrt{\mathbf{diag}\,(\mathbf{H})} \leq \mathbf{f}(\boldsymbol{\theta}) \leq \mathbf{f}(\widehat{\boldsymbol{\theta}}) + \mathbf{2} * \sqrt{\mathbf{diag}\,(\mathbf{H})}\right) = 95\%$$

[7] Alternatively, bond prices could be approximated and price errors could be minimized. Deacon and Derry (1994), however, find that minimizing yields improves the fit of the yield curve because greater weight is given to bonds with maturities up to about ten years.

with $H = \frac{\vartheta \, \mathbf{f}(\boldsymbol{\theta})}{\vartheta \, \boldsymbol{\theta}}' \Sigma \frac{\vartheta \, \mathbf{f}(\boldsymbol{\theta})}{\vartheta \boldsymbol{\theta}}$ where Σ denotes the variance-covariance matrix of the estimated parameters $\widehat{\boldsymbol{\theta}}$. $\mathbf{f}(\widehat{\boldsymbol{\theta}})$ denote the estimated yields to maturity according to the (extended) NS method.

3. As a third measure, we report the conditional frequency of pricing errors. We examine the pricing errors of individual bonds at time t and classify them in three categories: positive, zero, or negative. Errors are assumed to be zero if the absolute value of the yield error is below the bid-ask spread. We then look at pricing errors of these bonds at time $t+1$ and report the changes (transition matrix). If pricing errors are white noise, there should be no clear pattern in the transition matrices. Bliss (1997) and Diebold and Li (2002) find that regardless of the term structure estimation method, there is a persistent difference between estimated and actual bond prices.

4. The previous measures are all in-sample goodness of fit measures. Bliss (1997), however, concludes that in-sample results may give a distorted view of a method's performance. Therefore, we also examine the out-of-sample forecasting performance. Based on the estimation of the parameters, $\boldsymbol{\theta}$ at time t, we forecast the term structure of the yields to maturity at time $t+k$, $\widetilde{y}_{t+k} = f(m, \widehat{\boldsymbol{\theta}}_t)$ with $k = \{1, 2, 4\}$. We estimate the AAE for the forecasted yields resulting from the (extended) NS model.

4 Empirical Analysis

4.1 Data Description

The data set consists of weekly prices and yields to maturity of individual corporate and government bonds between January 1998 and December 2002. The corporate and government bonds in question are included in the EMU Corporate and Government Broad Market indices, respectively. The latter are based on secondary market prices of bonds issued in the eurobond market or in EMU-zone domestic markets and denominated in euro or one of the currencies that joined the EMU. Besides bond prices, the data set contains data on the coupon rate, the time to maturity, the rating, the industry classification, and the amount issued. Ratings are composite Moody's and Standard & Poors ratings. The Merrill Lynch Corporate Broad Market index covers investment-grade firms. Hence the analysis is restricted to corporate bonds rated BBB and higher. Further, all bonds have a fixed rate coupon and pay annual coupons. To be included in the Merrill Lynch indices, corporate bonds should have a minimum size of 100 million euro and government bonds of 1 billion euro. Because the EMU Broad Market indices have relatively low minimum size requirements, they provide a broad coverage of the underlying markets.

Several filters are imposed to construct the sample of bonds. First, we exclude unrated bonds. Second, to minimize the effect of liquidity risk, we exclude all bonds which have less than one price quote a week on average. Third, to ensure that we consider corporate bonds backed solely by the creditworthiness of the issuer, we eliminate such bonds as securitized bonds, quasi & foreign government bonds, and Pfandbriefe. Fourth, as in Duffee (1999), the data set only includes bonds with at least one year remaining to maturity. These filters leave us with a data set of 1577 corporate bonds issued by 448 firms. We have 260 AAA rated government bonds.[8]

We make a distinction between four rating categories: AAA, AA, A, and BBB. From the 1577 corporate bonds that enter the Merrill Lynch index between January 1998 and December 2002, 408 bonds have an AAA rating, 509 an AA rating, 484 an A rating, and 176 a BBB rating. If a bond is downgraded to a speculative grade rating (below BBB) or matured, it is removed from the index. Figure 1 shows the number of bonds in each rating category over the sample period. While the number of AAA and AA rated bonds has been stable over the sample period, the number of A and BBB rated bonds has increased substantially. Between January 1998 and April 2000, the Merrill Lynch included less than 50 BBB rated bonds on average. Moreover, less than half of the BBB rated bonds included were quoted during that period. Figure 2 presents, for each rating category, the number of bonds that are not quoted in percentage of the total number of bonds in that rating category. The results show that before January 2000 less than 50% of the BBB rated bonds were quoted on a weekly basis. From June 2000, the indicator for BBB rated bonds has sharply decreased below 20% and converged to a level comparable to higher rated bonds. Therefore, we will restrict the analysis of BBB rated bonds to the period June 2000-December 2002.

Panel C of Table 2 presents the average yearly rating transition matrix from 1998 to 2002. Each row corresponds to the initial rating and each column corresponds to the rating after one year. The probability that a bond has the same rating after one year is 86.5% for BBB and 98.2% for AAA. These results are comparable to the one-year transition matrices presented by Moody's Investors Services and Standard and Poor's for a data set of predominantly US-based firms (see CreditMetrics, Technical document). Some probabilities in Panel C are equal to zero. For BBB rated bonds, for example, the probability of being upgraded to AAA or AA within one year is negligible. The last column gives the probability that a bond is removed from the index although it has more than one year to maturity.[9] For example, when a bond is downgraded to speculative grade, it is removed from the index and its rating becomes NA (Not Available). The

[8] The sample of 260 AAA bonds consists of 101 German, 55 Austrian, 53 French, 37 Dutch, 7 Irish, 4 Spanish and 3 Finish bonds.

[9] Bonds are normally removed from the Merrill Lynch Broad EMU index one year before maturity.

first column gives the average number of bonds with an initial AAA, AA, A, or BBB rating.

Panel A of Table 1 presents the average number of corporate bonds in maturity buckets of 2 or 3 years and for different rating categories. The results show that only few bonds have a maturity beyond 10 years to maturity. Panel B and C of Table 1 show that the majority of the AAA and AA rated bonds are financials, 96% and 81% respectively, whereas the majority of the BBB rated bonds are industrials, 84%. A rated bonds are issued by industrials and financials, 54% and 39% respectively. Utilities issue only few bonds compared to financials and industrials. Panel A of Table 2 shows that the maturity of BBB rated bonds varies between 1 and 10 years and between 1 and 22 for A rated bonds. Although higher rated bonds have on average longer maturities, the number of bonds beyond 10 years to maturity is limited. The average number of weeks that a bond is included in the index is 145 weeks.

4.2 Estimating the Term Structure of Credit Spreads

For each rating category, we estimate the term structure of credit spreads by using the NS and the extended NS model with four additional factors. To motivate the choice of these four factors, we perform a pooled times series and cross-section analysis of the yield errors from the NS model

$$\begin{aligned} \boldsymbol{\varepsilon}_j &= \gamma_0 + \gamma_1 \mathbf{D\_pl}_j + \gamma_2 \mathbf{D\_mi}_j + \gamma_3 (\mathbf{C}_j - \overline{\mathbf{C}}) + \gamma_4 \mathbf{Liq}_{,j} + \boldsymbol{\eta}_j, \\ j &= \{\text{AAA, AA, A and BBB}\} \end{aligned}$$

where $\boldsymbol{\varepsilon}$, $\mathbf{D\_pl}$, $\mathbf{D\_mi}$, $\mathbf{C}-\overline{\mathbf{C}}$, $\mathbf{Liq}$, and $\boldsymbol{\eta}$ are K_jxT matrices representing yield errors, dummies for a plus rating, dummies for a minus rating, deviations from the sample average coupon rate, and bid-ask spreads. K_j is the number of bonds in rating category j and γ_0, γ_1, γ_2, γ_3, and γ_4 are the parameters. For each rating category, we use an unbalanced data set of weekly data from January 1998 until December 2002 ($T = 260$) , except for BBB rated bonds ($T = 134$). The model is estimated using seemingly unrelated regressions (SUR). Table 3 provides evidence for using four additional factors to the original NS model. The estimation results confirm that the yield errors from the original NS model are influenced by the subrating categories (plus, flat or minus), the coupon rate, and liquidity. All sensitivity coefficients have the expected sign and are significant at the 1% level, except for the sensitivity of the yield errors of AAA rated bonds to the bid-ask spreads. Furthermore, the sensitivity of the yield errors to the factors becomes more important for lower rated bonds.

4.2.1 Measures of Fit

Before discussing the results of the term structure estimation, we present the results of foure measures of fit. Figure 7 presents the average yield errors (AAE) for AAA, AA, A, and BBB rated bonds using the NS model (solid lines) and the extended NS model (dotted lines). The results indicate that the NS model results in smaller AAE for all rating categories. Until the first half of 2000, yield errors are similar across rating categories (except for BBB). From October 2000, yield errors as well as credit spreads in all rating categories start to diverge. The results indicate that periods of higher credit spreads coincide with periods of high volatility of yields. This means that the dispersion of credit spreads within rating category increases during periods of high credit spreads. The latter are often associated with economic downturns. Panel A of Table 4 present the summary statistics (mean and standard deviation) of the average yield errors (AAE) from the (extended) NS method and the results of the t-tests (p-values are given between brackets). The null hypothesis of equal yield errors of the original and extended NS model is rejected at 5% level for all rating categories. Panel B of Table 4 shows that, except for AA, yield errors that result from the extended NS method are on average higher for bonds with a short to medium term to maturity compared to bonds with a long time to maturity. Although the difference between yield errors is small, the results indicate that it is easier to estimate the term structure at the shorter maturity end.

A second measure of fit is the hit ratio, that is, the percentage of bonds that have an observed yield to maturity outside a 95% confidence interval around the estimated term structure of yields to maturity (see Panel C of Table 4). Between 2% and 3% of the bonds have a yield outside a 95% confidence interval if the NS model is applied. The extended NS model results in much lower hit ratios, between 0.5% and 1.3%. For AA, A, and BBB rated bonds, most yields outside the confidence interval are above the interval.

The third measure of fit is the transition matrix of the fitted yield errors (see Table 5). For each rating category, fitted yield errors of the NS model (panel A) and extended NS model (panel B) are classified in three groups: negative, zero, or positive. Column 3 of Table 5 gives the percentage of fitted yield errors in a certain category (unconditional frequency). Columns 4 to 6 present the percentage of fitted yield errors in a category at time t conditional on the category at time $t+1$ (conditional frequency). If errors are random, the classification at time t should have no effect on the classification at time $t+1$. This means that the unconditional and conditional frequency of being positive should be similar. However, Table 5 shows that the probability of being positive at time $t+1$ if the yield errors are positive at time t is above 50% for all rating categories. Although the difference is very small, the persistence of the yield errors is smaller for the extended NS model. Furthermore, for AAA rated bonds there is a higher probability that the yield errors fall within the interval between the bid and the ask yield, 29% for AAA rated bond compared to 7% for BBB rated bonds. If we use the extended NS model even more AAA rated bonds have yield errors within the bid-ask spread (33% compared to 9%).

Finally, we test the out-of-sample forecasting performance of both the NS and the extended NS model. We estimate one-week, two-week, and one-month ahead forecasts of the yields. Table 6 presents the AAE of the original model and the forecasts, for both the NS and the extended NS model. The AAE of a one-month ahead forecast of AAA and AA rated bonds are more than double the in sample AAE of the original (extended) NS model. A one-week ahead forecast results in yield errors that are only slightly higher than the original model. The forecast yield errors resulting from the extended NS model are always smaller than those from the NS model.

In general, our results show that the extended Nelson-Siegel model performs better than the original. Therefore, we will use the latter to estimate the term structure of credit spreads. However, notice that even for the extended NS model, the dispersion of yields within a rating category can be substantial, especially for lower rating categories.

4.2.2 Term Structure of Credit Spreads: Extended NS model

Figures 3, 4, 5, and 6 present the credit spreads on AAA, AA, A, and BBB rated bonds with 3, 5, 7, and 10 years to maturity. The spreads on AA, A, and BBB rated bonds are a weighted average of the spreads in the subrating categories (plus, flat, and minus). The weights at time t are the number of bonds in the corresponding subrating category as a fraction of the total number of bonds in that rating category at time t. Because the data set includes only few BBB minus rated bonds, we only make a distinction between two subcategories, namely BBB plus and BBB flat and minus (see Panel B of Table 2). The disadvantage of having only few bonds in a subrating category is that a single outlier can significantly influence the results.

In accordance with Jones et al. (1984), Sarig and Warga (1989), Fons (1994), and Jarrow et al. (1997), we find an upward sloping term structure of credit spreads, except for the beginning of 1998. From the beginning of 2000 until the beginning of 2001, credit spreads of all rating categories increased. This coincides with a period of zero or negative growth rate of the OECD leading indicator for the EMU area. In the first quarter of 2001, credit spreads decline as investors believe that the downturn in growth and the rise in default rates have been priced in bond yields. After September 11, 2001 credit spreads on AA, A, and BBB rated bond sharply increase. From January 2002, credit spreads slowly decrease to their level before September 11. At the same time, the growth rate of the OECD leading indicator become positive, with a peak growth rate in December 2001. From mid 2002, credit spreads in virtually all rating categories widen again.

These evolutions seem to indicate that credit spreads behave counter-cyclically, that is, credit spreads tend to widen during recessions and narrow during expansions.

Table 7 presents the average and the standard deviation of credit spreads in subrating categories of bonds with 2 to 10 years to maturity. Bonds with an AA-plus rating have a credit spread that is on average fifteen basis points lower compared to the AA-minus rating category. For the A rating category, the difference between the plus and minus subcategory is even more pronounced. The credit spread on A-minus rated bonds is on average double the spread on A-plus rated bonds. For the BBB rated bonds, there is a difference of fifty basis points between the plus rating and the flat and the minus rating. Credit spreads on AAA and AA rated bonds with 2 years to maturity are on average a few basis points higher compared to bonds with 3 years to maturity. A possible explanation is that bonds with 2 years to maturity pay a higher liquidity premium and thus a higher spread.

4.3 Determinants of Credit Spread Changes

4.3.1 Model Specification and Data

We investigate the determinants of credit spread changes for different types of bonds based on rating and maturity. We make a distinction between four rating categories, namely AAA, AA, A, and BBB rated bonds, and nine maturity categories, namely 2 to 10 years to maturity. For AA and A, we make a distinction between three subrating categories, namely plus, flat, and minus rating, whereas for BBB, we make a distinction between two subrating categories, namely plus and flat together with minus. The reason is that we find substantial differences between their credit spreads (see Table 7). Beyond 10 years to maturity there are not enough bonds to estimate the term structure properly (see Table 1). Therefore, we focus on the term structure of credit spreads up till 10 years to maturity.

The underlying data set consists of weekly data from January 1998 until December 2002. Notice that results for BBB bonds are not directly comparable with the results for other rating categories since the analysis of the former covers a shorter period (June 2000 until December 2002). In order to analyze the main determinants of credit spread changes of bonds in rating category j and with years to maturity m, we estimate the following equation

$$\triangle CR_{t,j,m} = \alpha_0 + \alpha_1 \triangle i_{3,t} + \alpha_2 \triangle i_{slope,t} + \alpha_3 R^m_{t-1,j} + \alpha_4 \triangle volp_t + \alpha_5 \triangle vol\text{n}_t$$

$$+\alpha_6 Liq_{t-1,j} + \alpha_7 \Delta Liq_{t,j} + \alpha_8 (CR_{t-1,j,m} - \overline{CR}) + \nu_{t,j,m}, \quad (6)$$

$$\text{with } \nu_{t,j,m} \sim N\left(0, \sigma^2\right)$$

where $\Phi = (\alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7, \alpha_8)$ is the vector of parameters, and $j =$(AAA, AA plus, AA flat, AA minus, A plus, A flat, A minus, and BBB) the rating category.

i_3 and i_{slope} are the level and the slope of the default-free term structure. As in Duffee (1998), we define the slope as the spread between the 10-year constant maturity EMU government bond yield minus the 3 month euro rate. The level is defined as the 3 month euro rate.[10]

R^m_j is a weighted average of the return on the DJ Euro Stoxx Financials and the DJ Euro Stoxx Industrials. The weights are the number of bonds in rating category j that are issued in the financial sector, respectively industrial sector, as a fraction of the total number of financial and industrial bonds in rating category j. The idea is to mimic the stock price that corresponds to a particular rating category as good as possible. Since the AAA rating category mainly consists of financials, R^m_{AAA} almost coincides with the return on the DJ Euro Stoxx Financials. For the BBB rating category, R^m_{BBB} is mainly driven by the return on the DJ Euro Stoxx Industrials. We include a one-period lag of R^m_j. This is in accordance with the findings of Kwan (1996) that stocks lead bonds in firm-specific information, that is, lagged stock returns have explanatory power for current bond yield changes, while current stock returns are unrelated to lagged bond yield changes.

vol is the implied volatility on the DJ Euro Stoxx. The implied volatility is the average of the put and the call implied volatility. In accordance with Bekaert and Wu (2000) and Collin-Dufresne et al. (2001), we test whether the impact of volatility is asymmetric by making a distinction between positive and negative changes in the implied volatility, $\triangle volp$ and $\triangle vol$n.

Liq_j is the average bid-ask spread of the bonds in rating category j. Thus, the average bid-ask spread is a function of the rating category. The bid-ask spread of BBB rated bonds is more than double the spread of AAA rated bonds.

Finally, $CR_{t-1,j,m} - \overline{CR} = MR$ is the level of the lagged credit spread minus the average in rating category j and maturity range m. This factor should capture the mean-reversion of credit

[10] Before January 1999, we define the slope as the spread between the 10-year constant maturity ecu government bond yield minus the 3 month ecu rate. The level is defined as the 3 month ecu rate.

spreads, which was first introduced by Longstaff and Schwartz (1995). If credit spreads evolve around a long-term equilibrium, the sensitivity to the lagged credit spread should be negative. This means that if credit spreads are high, the changes are smaller or even negative compared to low credit spread levels.

Weekly data of the explanatory variables are obtained from Datastream and Bloomberg. We estimate the credit spread model using seemingly unrelated regression (SUR) methodology. The latter has the advantage that it accounts for heteroskedasticity, and contemporaneous correlation in the errors across equations. Furthermore, it allows us to test whether the sensitivity coefficients for different ratings and maturities are significantly different.

4.3.2 Estimation Results

We will concentrate on the estimation results for different rating categories (AAA, AA, A, and BBB) and not subrating categories (plus, flat, and minus). The reason is that the sensitivity coefficients, Φ, of credit spread changes on bonds with different subratings are very similar.[11] Moreover, we cannot reject the null hypothesis that credit spread changes on bonds with different subratings, for example, AA+ and AA-, react differently to changes in the explanatory variables. Therefore, we focus on the average credit spreads on bonds with different rating categories. Panel A to H of Table 8 present the estimation results for different rating categories and different years to maturity ranging from 2 to 10 years.

We perform Wald tests to analyze whether bonds with different maturities and/or ratings react in significantly different ways to changes in financial and macroeconomic variables. Panel A to H of Table 9 present the results of the Wald tests of the following two null hypotheses

$$\begin{aligned} H1 &: \alpha_{s,2yr} = \alpha_{s,3yr} = ... = \alpha_{s,10y} = 0, \text{ with } s = 0, 1, ..., 8, \\ H2 &: \alpha_{s,2yr} = \alpha_{s,3yr} = ... = \alpha_{s,10y}, \text{ with } s = 0, 1, ..., 8. \end{aligned}$$

Hypothesis 1 ($H1$) is that the sensitivities of credit spread changes on bonds with 2 to 10 years to maturity to a specific factor s equal zero. If $H1$ cannot be rejected at the 5% level, this would mean that a particular factor s does not influence credit spread changes on bonds with 2 to 10 years to maturity. Hypothesis 2 ($H2$) is that the sensitivities of credit spread changes on bonds with 2 to 10 years to maturity to a specific factor s are the same. If $H2$ cannot be rejected at the 5% level, this would mean that the maturity does not influence the effect of financial and

[11] The estimation results for different subrating categories are not presented but are available upon request.

macroeconomic news on credit spreads changes. Table 10 presents the results of the Wald tests of the following hypothesis

$$H3 : \alpha_{s,2yr,AAA} = \alpha_{s,2yr,AA}, ..., \text{ and } \alpha_{s,10yr,AAA} = \alpha_{s,10yr,AA}, \text{ with } s = 0, 1, ..., 8.$$

Hypothesis 3 ($H3$) is that the sensitivity of credit spread changes to a particular factor s is similar for two rating categories, for example, AAA and AA. If $H3$ is rejected at the 5% level, this would mean that the rating category does not influence the effect of financial and macroeconomic news on credit spreads changes.

Our first observation is that changes in the level ($\triangle i_3$) and the slope ($\triangle i_{slope}$) of the default-free term structure are two important determinants of credit spread changes. In accordance with Longstaff and Schwartz (1995), Duffee (1998), and Collin-Dufresne et al. (2001) and the Merton type of models, we find a negative relationship between changes in the level and the slope and credit spread changes. Our results are best comparable with Collin-Dufresne et al. (2001) as the latter also takes into account other factors besides the default-free term structure. The sensitivity coefficients α_1 and α_2 are combarable with those in Longstaff and Schwartz (1995) and Duffee (1998) but higher than those in Collin-Dufresne et al. (2001). The null hypothesis that the sensitivities to changes in the level, α_1, equal zero for the different maturities ($H1$) is rejected at the 5% level for AAA and AA and at the 10% level for A. The null hypothesis that the sensitivities to changes in the slope, α_2, equal zero for the different maturities ($H1$) is rejected at the 5% level for all rating categories. For the higher rating categories (AAA and AA), the effect of changes in the level and the slope depend on the maturity of the bonds, that is, the effect first increases and then decreases with the time to maturity. For the other rating categories, the effect of the level and the slope are similar for different maturities. This is in accordance with our expectations. For low-leveraged firms, the merton type models predict that the effect first increases for very short maturities and then remains constant. However, we mainly focus on bonds with 2 to 10 years to maturity and not on very short maturities.

We find that the sensitivities to changes in the level and the slope are larger for lower rated bonds. For example, a 100 basis point increase in $\triangle i_3$ causes a 6 basis point decrease in the credit spread changes on AAA rated bonds with 7 years to maturity and a 33 basis point decrease in the credit spread changes on BBB rated bonds with 7 years to maturity. This is in accordance with the Merton model. However, the Wald tests cannot reject the null hypothesis ($H3$) that the effect is the same for all rating categories (see Table 10).

In all regressions, the sensitivity to the lagged equity return $\left(R^m_{t-1}\right)$ has the expected negative sign. If we include R^m_{t-1}, we find that the null hypothesis ($H1$) that the sensitivities to the lagged market return are simultaneously equal to zero for all maturities is strongly rejected for all rating categories. However, if we include the current market return (R_t^m), $H1$ is only rejected for A and BBB rated bonds. This result seems to favor the results of Kwan (1996) who finds that stocks lead bonds in firm-specific information. Lagged stock returns have explanatory power for current credit spread changes. The null hypothesis that all sensitivities to the lagged market return are similar for all maturities, can not be rejected at the 5% level for all rating categories. This is in accordance with our expectations. Furthermore, the results show that the effect of the market return is larger for bonds with a higher leverage, which is also in accordance with the Merton type models. A 100 basis point increase of the weekly market return reduces the credit spread changes on AAA and BBB rated bonds with 7 years to maturity by 0.08 and 0.7 basis points, respectively. Similar to Longstaff and Schwartz (1995) and Collin-Dufresne et al. (2001), we find that the effect of R_{t-1}^m is economically less important than the effect of changes in the level and the slope of the default-free term structure.

Changes in the implied volatility of the DJ Euro Stoxx ($\triangle vol$) have the expected positive sign, which is in accordance with the findings of Campbell and Taksler (2002). An increase in the implied volatility increases the probability of default and hence causes a widening of credit spreads. The effect of volatility changes is clearly asymmetric. Collin-Dufresne et al. (2001) find similar results for credit spreads on US corporate bonds. For AA, A, and BBB rated bonds, positive changes in the volatility significantly influence credit spread changes, whereas negative changes do not. For AAA, the results are less clear. Wald tests show that the effect of the volatility changes does not depend on the maturity of the bonds. However, the rating is important. In accordance with the Merton type models, the results show that higher rated bonds are less affected.

As in Collin-Dufresne et al. (2001), Houweling et al. (2002), and Perraudin and Taylor (2003), liquidity risk, which is measured as the average bid-ask spread, significantly influences credit spread changes on all bonds. The level of the bid-ask spread is significant at the 5% level in all cases, whereas the changes in the bid-ask spread are only significant for BBB rated bonds. This shows that credit spread changes are more affected by the level of liquidity risk than the changes in liquidity risk. This might be due to the fact that higher rated bonds are more liquid than BBB rated bonds and are not immediately affected by a change. The bid-ask spread is indeed higher for BBB rated bonds compared to AAA rated bonds, which shows that BBB rated bonds are less liquid compared to AAA rated bonds.

In general, the effect of the bid-ask spread becomes stronger for bonds with a lower rating. An increase of 100 basis points in the bid-ask spread increases the credit spread on AAA and BBB rated corporate bond with 7 years to maturity by 23 and 164 basis points. For AAA and AA rated bonds, the effect of the bid-ask spread becomes stronger for bonds with longer maturities.

The credit spread lagged one period significantly influences credit spread changes. $H1$ is rejected for all rating categories at the 5% level. As expected, we find that a higher level of the lagged credit spread causes a smaller increase of the credit spread or even an decrease compared to a lower level. This results provides some evidence for the mean reversion of credit spreads. The effect does not depend on the maturity of the bonds. The null hypothesis that all sensitivities are similar across maturities could not be rejected at the 5% level for all (sub)rating categories ($H2$).

Finally, the adjusted R^2 (last row of each panel) shows that our model explains between 10% and 39% of the variation in credit spreads depending on the rating and time to maturity. The average adjusted R^2 is 23% for AAA rated bonds, 19% for AA rated bonds, 15% for A rated bonds, and 28% for BBB rated bonds. Our model explains the most of the variation of credit spreads on bonds with medium maturities. The adjusted R^2 is on average 19% for bonds with 3 and 10 years to maturity and 24% for bonds with 5 and 7 years to maturity.

Although 22% (on average) of the variation of credit spreads can be explained by factors suggested by the structural credit risk models and empirical studies on the determinants of credit spreads, a large part remains unexplained. In that respect, our results resembles those of Collin-Dufresne et al. (2001), which find that their model explains on average 25% of US credit spread changes. Furthermore, they find that the same factors affect credit spread changes. This seems to indicate that although the US corporate bond market is broader and more liquid credit spread changes are affected by the same factors. Furthermore, our results indicate that the effect of financial and macroeconomic news depends more on the bond characteristics, especially the rating.

4.3.3 Robustness

So far, the level and the slope of the default-free term structure are proxied by the three-month euro rate and the difference between the 10-year EMU government bond yield and the three-month euro rate. In the NS model, however, the $\beta_0 + \beta_1$ and the $-\beta_1$ (see equation (4)) are assumed to be the level and the slope of the default-free term structure. These parameters are estimated on a weekly basis for a sample of 260 AAA rated government bonds. To check the robustness of our results, we reestimate the credit spread model (6) and include changes in $\beta_0+\beta_1$ and $-\beta_1$ to proxy for changes in the level and the slope of the default-free term structure. The correlation between $\triangle(\beta_0 + \beta_1)$ and the changes in the three month euro rate is 0.5 while the correlation between $\triangle(-\beta_1)$ and changes in the difference between the 10-year EMU government bond yield and the three-month euro rate is 0.4. Although the adjusted R^2 slightly decreases, the results (not show here) are similar to the previous results. Changes in the level and the slope of the default-free have the expected negative sign. The null hypothesis that the sensitivities to changes in the level of the default-free term structure are simultaneously equal to zero for different maturities is rejected at the 1% level for all ratings. The same holds for the slope effect, except for A minus rated bonds. Including the $\beta_0 + \beta_1$ and the $-\beta_1$ slightly increases the coefficients and the significance of the stock return and the changes in the volatility of the stock return. The coefficients and the p-values of the bid-ask spread and the lagged credit spread are not altered.

5 Conclusion

In this paper, we analyze whether the sensitivity of credit spread changes to financial and macroeconomic variables significantly depends on bond characteristics such rating and maturity. Using a data set of 1577 investment grade corporate and 260 AAA rated government bonds, we first estimate the term structure of credit spreads for different (sub)rating categories by applying an extension of the Nelson-Siegel (NS) method. The extension includes four additional factors in order to capture differences in liquidity, taxation, and subrating categories.

Then, we analyze changes in the term structure of credit spreads for different (sub)rating categories. Our results indicate that changes in the level and the slope of the default-free term structure are two important determinants. An increase in the level and/or the slope significantly reduces credit spread changes. For the higher rating categories (AAA and AA), the effect of changes in the level and the slope depend on the maturity of the bonds, that is, the effect first increases and then slightly decreases with the time to maturity. We find a significant negative relation between the DJ Euro Stoxx returns and credit spread changes and a significant positive relation between increasing implied volatility of the DJ Euro Stoxx and credit spread changes. Although the effects are statistically significant, the economic importance is much smaller compared to the effect of changes in the default-free term structure. The effect of the market return strongly depends on the rating but not on the maturity of the bonds. Lower rated bonds are much more affected by the market return. We find evidence for the asymmetric influence of the implied volatility on credit spread changes, that is, only positive changes in the implied volatility have a significant impact. Furthermore, the effect of positive changes in the implied volatility becomes stronger for lower rated bonds but does not depend on the maturity of the bonds. Liquidity risk, measured as the bid-ask spread, significantly affects all rating categories and becomes more important for lower rating categories. While credit spreads on AAA, AA, and

A rated bonds are mainly influenced by the level of the bid-ask spread, credit spreads on BBB rated bonds are influenced by the level and changes in the bid-ask spread. This result seems to indicate that liquidity risk itself is more important than changes in liquidity risk. For AAA and AA rated bonds, the effect increases with maturity. Finally, we find evidence for mean reversion of credit spreads for all ratings and maturities.

In accordance with Collin-Dufresne et al. (2001), we find that on average 22% of the variation in credit spread can be explained by the variables suggested by the structural models and empirical studies. Although the euro corporate bond market is a relatively new and expanding market, the results are in line with those for the US corporate bond market.

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Table 1: Average Number of Corporate Bonds in Different Rating Categories, Sectors, and Maturity Ranges

Panel A: Average number of bonds based on rating and maturity

	AAA		AA		A		BBB*	
Total	193	(18)	259	(20)	236	(103)	115	(53)
1-3 years	65	(9)	72	(7)	50	(23)	24	(21)
3-5 years	52	(6)	67	(11)	63	(30)	42	(21)
5-7 years	30	(5)	40	(11)	45	(22)	32	(7)
7-10 years	32	(4)	67	(14)	69	(32)	17	(5)
+10 years	15	(4)	14	(3)	8	(3)	-	

Panel B: Average number of bonds based on rating and sector

	AAA		AA		A		BBB*	
Total	235	(9)	318	(28)	265	(112)	131	(63)
Financials	225	(10)	258	(17)	142	(47)	8	(7)
Industrials	4	(1)	32	(9)	103	(53)	111	(51)
Utilities	1	(2)	19	(5)	16	(13)	8	(3)

Panel C: Average percentage of bonds based on rating and sector

	AAA	AA	A	BBB*
Financials	96%	81%	54%	6%
Industrials	2%	10%	39%	84%
Utilities	1%	6%	6%	6%

Note: This table presents the average number of corporate bonds based on rating and time to maturity (Panel A) and rating and sector (Panel B). Standard deviations are given between brackets. The average percentage of bonds based on rating and sector are presented in Panel C. The data set consists of weekly data from January 1998 until December 2002. *For BBB, the data starts from June 2000.

Table 2: Characteristics of the Sample of Bonds

Panel A: Summary statistics of years to maturity and number of weeks

		Mean	Stdev	Min	Max
Years to Maturity					
	AAA	4.9	3.2	1.0	19.9
	AA	5.3	3.0	1.0	15.0
	A	5.6	2.8	1.0	21.9
	BBB*	5.1	2.0	1.0	10.2
Number of weeks					
	Total	145	75		

Panel B: % of bonds in subrating categories and sectors

	Subrating categories		
	Plus	Flat	Minus
AA	24.6%	33.2%	42.2%
A	39.9%	33.9%	26.2%
BBB*	54.5%	34.1%	11.4%

Panel C: One year transition matrix

	Initial rating	**AAA**	**AA**	**A**	**BBB**	NA
AAA	202	98.2	1.6	0.2	0	0.1
AA	279	0.3	88.9	10.2	0	0.6
A	214	1.3	2.8	89.9	4.5	1.6
BBB*	90	0	0	8.3	86.5	5.3

Note: Panel A presents the summary statistics (mean, standard deviation, minimum, and maximum) of the time to maturity and the number of weeks that a corporate bond is included in the index between January 1998 and December 2002. Panel B presents the percentage of corporate bonds in the AA, A, and BBB rating category that have a plus, flat, or minus rating. Panel C presents the probability that a corporate bond has the same rating or has been up- or downgraded after one year. The latter presents the average of five yearly transition matrices. *For BBB rated bonds, the analysis covers the period June 2000 until December 2002.

Table 3: Pooled Times Series and Cross-section Analysis of Yield Errors

$$\boldsymbol{\varepsilon}_j = \gamma_0 + \gamma_{1j}\mathbf{D\_pl}_j + \gamma_2\mathbf{D\_mi}_j + \gamma_3(\mathbf{C}_j - \overline{\mathbf{C}}) + \gamma_4\mathbf{Liq}_{,j} + \boldsymbol{\eta}_j,$$
$$j = \{\text{AAA, AA, A and BBB}\},$$

where ε, D_pl, D_mi, $(C - \overline{\mathbf{C}})$, Liq, and η are $K_j \mathrm{x} T$ matrices representing respectively yield errors, dummies for a plus rating, dummies for a minus rating, deviations from the sample average coupon rate, bid-ask spreads (liquidity), and errors. K_j represents the number of corporate bonds in each rating category j. The model is estimated using seemingly unrelated regressions (SUR).

	AAA	AA	A	BBB*
Constant	-0.01	0.02	-0.03	-0.05
	[0.00]	[0.00]	[0.00]	[0.00]
Plus rating		0.03	0.16	0.40
		[0.00]	[0.00]	[0.00]
Minus rating		-0.06	-0.10	-0.38
		[0.00]	[0.00]	[0.00]
Coupon	-0.02	-0.02	-0.03	-0.09
	[0.27]	[0.00]	[0.00]	[0.00]
Liquidity	-0.01	-0.09	-0.31	-2.12
	[0.00]	[0.00]	[0.00]	[0.00]
R^2	0.10	0.08	0.14	0.17
T (times series)	260	260	260	134
K (cross-section)	395	606	643	202

Note: This table presents the pooled cross-section and times series analysis of yield errors resulting from the Nelson-Siegel term structure estimations. The analysis covers the period January 1998 until December 2002. p-values are given between brackets. *For BBB rated bonds, the analysis covers the period June 2000 until December 2002.

Table 4: Average Absolute Yield Errors

Panel A: Average absolute errors: NS versus extended NS (exNS) model

	AAA		AA		A		BBB	
	NS	exNS	NS	exNS	NS	exNS	NS	exNS
Mean	8.9	8.0	11.1	10.5	18.0	16.1	51.8	45.0
Stdev	(2.4)	(2.3)	(1.7)	(1.5)	(8.7)	(7.8)	(27.2)	(25.2)
t-test								
Value	3.93		4.38		2.72		2.1	
Prob	[0.00]		[0.00]		[0.01]		[0.04]	

Panel B: Average absolute errors of the extended NS Model

	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr	10 yr
AAA	8.1	8.8	9.1	9.6	7.4	6.5	5.9	7.8	5.9	5.5
AA	9.8	9.9	10.3	9.4	10.1	11.8	13.8	11.0	10.3	10.5
A	16.2	17.0	15.5	15.4	16.6	17.4	15.1	15.1	15.5	13.7
BBB	67.1	45.2	49.5	45.8	38.4	38.8	54.3	47.2	33.1	31.5

Panel C: % of yields outside a 95% confidence interval (Hit ratio)

	NS mode			Extended NS model		
	Total	Above	Below	Total	Above	Below
AAA	2.36	0.88	1.47	1.22	0.50	0.72
AA	2.12	1.49	0.63	1.04	0.61	0.44
A	2.85	2.62	0.23	0.98	0.86	0.13
BBB	2.78	2.52	0.26	0.56	0.56	0.00

Note: Panel A presents the averages and the standard deviations of the absolute yield errors (AAE_{yield}) resulting from the term structure estimations using the Nelson-Siegel (NS) and the extended NS model. For each rating category, we test for equality of the means (AAE_{yield}) with a t-test. The latter are presented in the bottom lines of Panel A. Panel B presents the AAE_{yield} for different maturity ranges. Panel C presents the percentage of bonds that have a yield outside (above and/or below) a 95% confidence interval around the estimated term structure. The results in Panel A and C are presented in basis points.

Table 5: Transition Matrices of the Fitted Yield Errors

Panel A: Results of the original NS model

		Unconditional frequency (ε_t)	Conditional frequency ($\varepsilon_{t+1}\vert\varepsilon_t$)		
			$\varepsilon_{t+1} < 0$	$\varepsilon_{t+1} = 0$	$\varepsilon_{t+1} > 0$
AAA	$\varepsilon_t < 0$	33.7	87.0	5.4	7.6
	$\varepsilon_t = 0$	29.2	5.9	85.0	9.1
	$\varepsilon_t > 0$	37.1	7.1	7.0	85.9
AA	$\varepsilon_t < 0$	43.9	89.8	4.4	5.8
	$\varepsilon_t = 0$	24.2	7.7	86.6	5.7
	$\varepsilon_t > 0$	31.9	7.7	4.4	87.9
A	$\varepsilon_t < 0$	50.4	93.9	2.6	3.5
	$\varepsilon_t = 0$	13.7	10.3	81.5	8.2
	$\varepsilon_t > 0$	36.0	4.6	3.3	92.1
BBB	$\varepsilon_t < 0$	60.3	96.7	2.1	1.2
	$\varepsilon_t = 0$	7.1	20.7	64.2	15.1
	$\varepsilon_t > 0$	32.5	2.0	3.7	94.4

Panel B: Results of the extended NS model

		Unconditional frequency (ε_t)	Conditional frequency ($\varepsilon_{t+1}\vert\varepsilon_t$)		
			$\varepsilon_{t+1} < 0$	$\varepsilon_{t+1} = 0$	$\varepsilon_{t+1} > 0$
AAA	$\varepsilon_t < 0$	31.6	85.6	6.0	8.3
	$\varepsilon_t = 0$	32.6	5.8	86.0	8.2
	$\varepsilon_t > 0$	35.8	7.5	7.7	84.8
AA	$\varepsilon_t < 0$	41.3	89.2	5.1	5.7
	$\varepsilon_t = 0$	26.0	7.9	86.0	6.1
	$\varepsilon_t > 0$	32.7	7.1	5.1	87.8
A	$\varepsilon_t < 0$	51.7	93.0	3.2	3.8
	$\varepsilon_t = 0$	15.1	11.1	78.9	9.9
	$\varepsilon_t > 0$	33.2	5.7	4.6	89.6
BBB	$\varepsilon_t < 0$	54.0	92.8	3.4	3.8
	$\varepsilon_t = 0$	9.3	24.1	54.9	21.0
	$\varepsilon_t > 0$	36.6	5.1	6.0	88.8

Note: The underlying data are the fitted yield errors from the Nelson-Siegel model (panel A) and the extended NS model (panel B). For each rating category, fitted yield errors are classified in three groups (pos., zero, neg.) at time t and t+1. The percentages of yield errors in a certain category (unconditional frequency) are presented in column 3. The percentages of yield errors in a category at time t+1 conditional on the classification at time t (conditional frequency) are presented in column 4 to 6 in panel A and B.

Table 6: Forecasting Performance of the NS and the extended NS model

Panel A: NS model

		Original	Forecasts		
			1 week	2 weeks	1 month
AAA	Mean	8.8	11.8	14.4	18.8
	Stdev	(2.4)	(4.5)	(6.5)	(9.7)
AA	Mean	11.0	13.7	16.0	20.0
	Stdev	(1.7)	(3.9)	(5.7)	(8.8)
A	Mean	18.2	20.0	21.8	24.7
	Stdev	(8.7)	(9.0)	(9.4)	(10.7)
BBB	Mean	52.7	53.3	53.9	55.2
	Stdev	(27.1)	(27.1)	(27.1)	(27.3)

Panel B: Extended NS model

		Original	Forecasts		
			1 week	2 weeks	1 month
AAA	Mean	8.0	11.1	13.8	18.2
	Stdev	(2.3)	(4.6)	(6.6)	(9.8)
AA	Mean	10.4	13.1	15.5	19.5
	Stdev	(1.5)	(3.9)	(5.8)	(9.0)
A	Mean	16.2	18.2	20.1	23.2
	Stdev	(7.8)	(8.2)	(8.7)	(10.4)
BBB	Mean	45.0	47.1	48.1	50.0
	Stdev	(25.2)	(25.1)	(25.2)	(25.4)

Note: This table presents the average absolute yield errors of (1) the original model, (2) one-week ahead forecasts, (3) two weeks ahead forecasts and (4) one month ahead forecasts of the spot rates. Standard deviations are given between brackets.

Table 7: Average Credit Spreads for Different Ratings and Years to Maturity

	Years to maturity								
	2 y	3 y	4 y	5 y	6 y	7 y	8 y	9 y	10 y
AAA	20.8	17.0	16.9	18.3	20.2	22.0	23.6	24.9	26.0
	(2.6)	(3.4)	(5.2)	(6.7)	(8.0)	(9.0)	(9.8)	(10.4)	(11.0)
AA+	23.3	22.6	24.4	27.2	30.1	32.8	35.1	37.1	38.6
	(4.1)	(4.3)	(5.9)	(7.7)	(9.2)	(10.2)	(10.9)	(11.4)	(11.6)
AA	27.7	27.0	28.8	31.6	34.5	37.2	39.5	41.5	43.0
	(3.6)	(4.8)	(6.8)	(8.6)	(10.1)	(11.3)	(12.1)	(12.6)	(12.9)
AA-	37.8	37.1	38.9	41.7	44.6	47.3	49.6	51.6	53.1
	(5.9)	(8.5)	(10.6)	(12.4)	(13.8)	(14.9)	(15.7)	(16.2)	(16.6)
A+	38.1	41.6	46.2	50.9	55.2	59.0	62.3	65.1	67.5
	(6.3)	(9.9)	(12.9)	(15.1)	(16.8)	(18.1)	(19.0)	(19.8)	(20.4)
A	53.9	57.4	62.1	66.8	71.1	74.9	78.1	81.0	83.4
	(12.4)	(17.6)	(20.7)	(22.8)	(24.3)	(25.4)	(26.2)	(26.9)	(27.4)
A-	77.1	80.6	85.2	89.9	94.2	98.0	101.3	104.1	106.5
	(26.9)	(32.0)	(34.9)	(36.7)	(38.0)	(38.8)	(39.5)	(40.0)	(40.5)
BBB+	102.7	104.1	109.9	117.8	126.6	135.7	144.8	153.9	162.9
	(24.1)	(27.0)	(30.1)	(31.2)	(31.0)	(30.4)	(29.8)	(29.9)	(31.1)
BBB and	152.8	154.2	160.1	167.9	176.7	185.8	195.0	204.1	213.0
BBB-	(33.9)	(38.6)	(42.0)	(43.1)	(42.9)	(42.2)	(41.6)	(41.3)	(41.9)

Note: This table presents the averages and the standard deviations (between brackets) of credit spreads for different (sub)rating categories and time to maturity. The term structure of credit spreads is estimated using an extension of the Nelson-Siegel method. The data set covers the period January 1998 until December 2002, except for BBB rated bonds (June 2000 until December 2002).

Table 8: Determinants of Credit Spread Changes: Estimation Results

$$\triangle CR_{t,j,m} = \alpha_0 + \alpha_1 \triangle i_{3,t} + \alpha_2 \triangle i_{slope,t} + \alpha_3 R^m_{t-1,j} + \alpha_4 \triangle volp_t + \alpha_5 \triangle voln_t$$
$$+\alpha_6 \, Liq_{t-1,j} + \alpha_7 \triangle Liq_{t,j} + \alpha_8 MR_{t,j} + \nu_{t,j},$$

CR is the credit spread, i_3 and i_{slope} are the level and the slope of the default-free term structure, R^m is a weighted average of the DJ Euro Stoxx financials and industrials, $volp$ $(voln)$ is the positive (negative) implied volatility of the DJ Euro Stoxx, Liq is the average bid-ask spread, and MR stands for mean reversion, that is, a one period lag of the credit spread minus the average credit spread. j stands for rating category. The model is estimated using Seemingly Unrelated Regressions (SUR). p-values are given between brackets.

Panel A: AAA rated bonds

	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr
ct	0.25	**-0.81**	**-1.21**	**-1.28**	**-1.19**	**-1.04**	**-0.87**	-0.71	-0.56
	[0.48]	[0.02]	[0.00]	[0.00]	[0.00]	[0.00]	[0.02]	[0.08]	[0.20]
$\triangle i_{3,t}$	-2.46	**-6.29**	**-8.05**	**-8.31**	**-7.51**	**-5.98**	**-4.00**	-1.78	0.53
	[0.17]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.02]	[0.34]	[0.79]
$\triangle i_{slope,t}$	**-3.93**	**-6.80**	**-8.46**	**-9.04**	**-8.83**	**-8.15**	**-7.19**	**-6.10**	**-4.99**
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
R^m_{t-1}	-0.03	-0.04	**-0.05**	**-0.06**	**-0.07**	**-0.08**	**-0.08**	**-0.09**	**-0.10**
	[0.24]	[0.13]	[0.04]	[0.01]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]
$\triangle volp_t$	0.03	0.05	0.07	**0.08**	**0.09**	0.08	0.08	0.07	0.06
	[0.49]	[0.25]	[0.10]	[0.05]	[0.04]	[0.06]	[0.10]	[0.17]	[0.29]
$\triangle voln_t$	**0.10**	0.00	-0.02	-0.02	0.00	0.04	0.07	**0.11**	**0.14**
	[0.03]	[0.91]	[0.58]	[0.66]	[0.91]	[0.41]	[0.13]	[0.04]	[0.01]
Liq_{t-1}	-0.39	**1.59**	**2.35**	**2.53**	**2.46**	**2.29**	**2.09**	**1.91**	**1.77**
	[0.55]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.03]
$\triangle Liq_t$	2.09	2.09	3.25	3.92	3.83	3.12	2.04	0.78	-0.51
	[0.58]	[0.57]	[0.34]	[0.24]	[0.26]	[0.38]	[0.58]	[0.85]	[0.91]
MR	**-0.12**	**-0.11**	**-0.10**	**-0.10**	**-0.09**	**-0.09**	**-0.09**	**-0.08**	**-0.08**
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\overline{R}^2$	17.0	24.4	31.6	33.7	30.2	24.3	18.5	14.1	11.4

Note: Panel A presents the estimation results for the AAA rated bonds with 2 to 10 years to maturity. The dependent variables are the credit spread changes on AAA rated bonds. The data set consists of weekly data from January 1998 until December 2002 $(T = 260)$. The adjusted R^2 is presented in percentage.

Panel B: AA rated bonds									
	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr
ct	**-1.40**	**-2.21**	**-2.34**	**-2.22**	**-2.04**	**-1.88**	**-1.76**	**-1.71**	**-1.72**
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\triangle i_{3,t}$	**-4.36**	**-5.86**	**-5.79**	**-5.04**	**-3.99**	-2.79	-1.48	-0.13	1.25
	[0.03]	[0.00]	[0.00]	[0.00]	[0.02]	[0.11]	[0.41]	[0.95]	[0.56]
$\triangle i_{slope,t}$	**-5.14**	**-6.11**	**-6.62**	**-6.65**	**-6.30**	**-5.68**	**-4.90**	**-4.04**	**-3.15**
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.03]
R^m_{t-1}	-0.02	-0.04	**-0.06**	**-0.09**	**-0.11**	**-0.13**	**-0.15**	**-0.17**	**-0.18**
	[0.58]	[0.24]	[0.04]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\triangle volp_t$	**0.12**	**0.13**	**0.14**	**0.15**	**0.16**	**0.16**	**0.15**	**0.14**	**0.13**
	[0.03]	[0.02]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.03]
$\triangle voln_t$	0.04	0.02	0.02	0.03	0.04	0.04	0.04	0.04	0.04
	[0.46]	[0.74]	[0.68]	[0.53]	[0.42]	[0.36]	[0.37]	[0.42]	[0.52]
Liq_{t-1}	**2.67**	**4.47**	**4.90**	**4.79**	**4.54**	**4.29**	**4.11**	**4.05**	**4.11**
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\triangle Liq_t$	6.84	**9.93**	**9.33**	7.74	6.24	5.19	4.66	4.59	4.92
	[0.17]	[0.04]	[0.04]	[0.07]	[0.13]	[0.21]	[0.28]	[0.33]	[0.35]
MR	**-0.12**	**-0.11**	**-0.10**	**-0.10**	**-0.10**	**-0.10**	**-0.10**	**-0.10**	**-0.10**
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\overline{R}^2$	19.3	21.7	24.3	25.1	23.4	20.3	16.5	12.9	10.2

Note: Panel B presents the estimation results for the AA rated bonds with 2 to 10 years to maturity. The dependent variables are the credit spread changes on AA rated bonds. The data set consists of weekly data from January 1998 until December 2002 ($T = 260$). The adjusted R^2 is presented in percentage.

Panel C: A rated bonds									
	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr
ct	**-2.5**	**-3.6**	**-3.8**	**-3.5**	**-3.2**	**-2.93**	**-2.7**	**-2.5**	**-2.3**
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\triangle i_{3,t}$	**-8.8**	**-10.6**	**-12.2**	**-12.6**	**-12.0**	**-10.7**	**-8.9**	**-6.9**	-4.9
	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.04]	[0.17]
$\triangle i_{slope,t}$	-3.5	**-5.3**	**-8.0**	**-9.6**	**-10.0**	**-9.5**	**-8.4**	**-6.9**	**-5.2**
	[0.11]	[0.03]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.03]
R^m_{t-1}	**-0.18**	**-0.14**	-0.12	-0.13	**-0.15**	**-0.19**	**-0.23**	**-0.28**	**-0.33**
	[0.00]	[0.03]	[0.07]	[0.06]	[0.02]	[0.00]	[0.00]	[0.00]	[0.00]
$\triangle volp_t$	**0.24**	**0.31**	**0.31**	**0.29**	**0.28**	**0.29**	**0.32**	**0.36**	**0.41**
	[0.01]	[0.00]	[0.00]	[0.01]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]
$\triangle voln_t$	0.04	0.07	0.09	0.10	0.09	0.07	0.05	0.04	0.02
	[0.65]	[0.47]	[0.38]	[0.37]	[0.41]	[0.48]	[0.57]	[0.70]	[0.85]
Liq_{t-1}	**6.4**	**9.1**	**9.8**	**9.5**	**8.8**	**8.0**	**7.2**	**6.5**	**5.9**
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\triangle Liq_t$	10.29	10.41	14.03	16.40	17.1	16.4	14.9	12.6	10.6
	[0.23]	[0.27]	[0.16]	[0.11]	[0.09]	[0.09]	[0.10]	[0.14]	[0.25]
MR	**-0.11**	**-0.10**	**-0.10**	**-0.09**	**-0.09**	**-0.08**	**-0.08**	**-0.07**	**-0.07**
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\overline{R}^2$	13.2	13.6	14.8	15.2	15.1	15.1	15.6	16.7	17.4

Note: This table presents the estimations results for the A rated bonds. The dependent variables are the credit spread changes on A rated bonds. The analysis covers the period January 1998 until December 2002. The adjusted R^2 is presented in percentage.

Panel D: BBB rated bonds									
	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr
ct	**-10.7**	**-13.6**	**-14.9**	**-14.9**	**-14.1**	**-12.8**	**-11.3**	**-9.63**	**-7.99**
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.04]
$\triangle i_{3,t}$	-12.0	-14.5	-18.4	**-23.1**	**-27.9**	**-33.1**	**-38.8**	**-45.2**	**-52.4**
	[0.52]	[0.21]	[0.08]	[0.05]	[0.03]	[0.02]	[0.02]	[0.02]	[0.02]
$\triangle i_{slope,t}$	-19.9	-14.2	**-16.2**	**-21.4**	**-27.1**	**-32.3**	**-36.8**	**-40.7**	**-44.3**
	[0.12]	[0.08]	[0.03]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
R^m_{t-1}	**-0.77**	**-0.67**	**-0.66**	**-0.67**	**-0.69**	**-0.74**	**-0.79**	**-0.84**	**-0.88**
	[0.02]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]	[0.01]	[0.02]
$\triangle volp_t$	0.40	**0.59**	**0.71**	**0.82**	**0.94**	**1.08**	**1.25**	**1.43**	**1.62**
	[0.33]	[0.02]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\triangle voln_t$	0.41	-0.22	-0.42	-0.38	-0.23	0.00	0.24	0.49	0.71
	[0.33]	[0.40]	[0.09]	[0.14]	[0.44]	[0.99]	[0.52]	[0.26]	[0.15]
Liq_{t-1}	**15.4**	**18.5**	**19.8**	**19.7**	**18.4**	**16.4**	**14.1**	**11.5**	8.88
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.02]	[0.12]
$\triangle Liq_t$	**56.7**	**43.3**	**44.6**	**55.7**	**70.1**	**84.3**	**96.9**	**107.4**	**115.7**
	[0.02]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
MR	**-0.17**	**-0.18**	**-0.18**	**-0.18**	**-0.18**	**-0.17**	**-0.17**	**-0.17**	**-0.16**
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\overline{R}^2$	20.1	17.4	16.1	20.1	26.5	32.5	36.7	38.8	38.9

Note: This table presents the estimation results for the BBB rating category. The dependent variables are the credit spread changes on BBB rated bonds. The adjusted R^2 is presented in percentage. The analysis covers the period January 1998 until December 2002. Due to unavailability of enough BBB rated bonds from the start, the analysis for BBB rated bonds covers the period June 2000 until December 2002.

Table 9: Restrictions on Coefficients: Wald tests

$$\triangle CR_{t,j,m} = \alpha_0 + \alpha_1 \triangle i_{3,t} + \alpha_2 \triangle i_{slope,t} + \alpha_3 R^m_{t-1,j} + \alpha_4 \triangle volp_t + \alpha_5 \triangle voln_t \\ +\alpha_6\ Liq_{t-1,j} + \alpha_7 \triangle Liq_{t,j} + \alpha_8 MR_{t,j} + \nu_{t,j},$$

We test the following two hypotheses for each rating category and each coefficient of the model:
Hypothesis 1 (H1): $\alpha_{s,2yr} = \alpha_{s,3yr} = ... = \alpha_{s,10y} = 0$, with $s = 1, ..., 7$
Hypothesis 2 (H2): $\alpha_{s,2yr} = \alpha_{s,3yr} = ... = \alpha_{s,10y}$, with $s = 1, ..., 7$

Panel A: AAA rated bonds								
		$\triangle i_3$	$\triangle i_{slope}$	R^m	$\triangle volp$	$\triangle voln$	Liq	$\triangle Liq$
$H1$	χ^2	**45.6**	**84.4**	**19.8**	9.2	**25.4**	**22.3**	4.2
	p-value	[0.00]	[0.00]	[0.02]	[0.42]	[0.00]	[0.01]	[0.90]
$H2$	χ^2	**38.7**	**27.5**	6.8	4.8	**17.9**	**19.1**	3.5
	p-value	[0.00]	[0.00]	[0.56]	[0.77]	[0.02]	[0.01]	[0.90]

Panel B: AA rated bonds								
		$\triangle i_{3,t}$	$\triangle i_{slope,t}$	R^m_{t-1}	$\triangle volp_t$	$\triangle voln_t$	Liq_{t-1}	$\triangle Liq_t$
$H1$	χ^2	**21.7**	**41.7**	**31.8**	**16.6**	2.6	**34.9**	7.0
	p-value	[0.01]	[0.00]	[0.00]	[0.05]	[0.98]	[0.00]	[0.64]
$H2$	χ^2	**18.0**	9.9	15.0	1.6	1.2	**20.1**	5.0
	p-value	[0.02]	[0.28]	[0.06]	[0.99]	[1.00]	[0.01]	[0.76]

Panel C: A rated bonds								
		$\triangle i_{3,t}$	$\triangle i_{slope,t}$	R^m_{t-1}	$\triangle volp_t$	$\triangle voln_t$	Liq_{t-1}	$\triangle Liq_t$
$H1$	χ^2	16.2	**22.9**	**36.1**	**23.4**	2.9	**27.3**	14.1
	p-value	[0.06]	[0.01]	[0.00]	[0.01]	[0.97]	[0.00]	[0.12]
$H2$	χ^2	6.5	12.5	12.5	7.5	2.5	10.7	10.5
	p-value	[0.59]	[0.13]	[0.13]	[0.48]	[0.96]	[0.22]	[0.23]

Panel D: BBB rated bonds								
		$\triangle i_{3,t}$	$\triangle i_{slope,t}$	R^m_{t-1}	$\triangle volp_t$	$\triangle voln_t$	Liq_{t-1}	$\triangle Liq_t$
$H1$	χ^2	10.5	**18.3**	**32.6**	**19.8**	12.7	**34.7**	**37.8**
	p-value	[0.31]	[0.03]	[0.00]	[0.02]	[0.18]	[0.00]	[0.00]
$H2$	χ^2	6.3	9.5	8.6	6.0	12.6	10.2	**15.5**
	p-value	[0.62]	[0.30]	[0.37]	[0.65]	[0.13]	[0.25]	[0.05]

Note: This table presents the results of Wald tests on two hypothesis: (1) the sensitivities to a factor are equal to zero for all maturities and (2) the sensitivities to a factor are equal for all maturities. p-values are given between brackets. Coefficients in bold are significant at the 5% level.

Table 10: Comparing different rating categories: Wald tests

$$\triangle CR_t = \alpha_0 + \alpha_1 \triangle i_{3,t} + \alpha_2 \triangle i_{slope,t} + \alpha_3 R^m_{t-1,j} + \alpha_4 \triangle voldp_t + \alpha_5 \triangle voldn_t$$
$$+\alpha_6 Liq_{t-1,j} + \alpha_7 \triangle Liq_{t,j} + \alpha_6 RM_{t-1,j} + \nu_{t,j},$$

We test the following hypothesis for each pair of rating categories:

Hypothesis: $\alpha_{s,2yr,AAA} = \alpha_{s,2yr,AA}, ...,$and $\alpha_{s,10yr,AAA} = \alpha_{s,10yr,AA}$, with $s = 1, ..., 7$

	$\triangle i_3$	$\triangle i_{slope}$	R^m	$\triangle volp$	$\triangle voln$	Liq	$\triangle Liq$
AAA versus							
AA	10.9	9.3	7.7	9.0	14.5	**33.2**	6.8
	[0.28]	[0.41]	[0.57]	[0.44]	[0.11]	[0.00]	[0.66]
A	8.5	6.3	**20.7**	**20.6**	9.5	**26.9**	5.7
	[0.49]	[0.71]	[0.01]	[0.01]	[0.39]	[0.00]	[0.77]
BBB	10.8	13.2	**26.9**	15.6	11.9	**23.7**	**41.7**
	[0.29]	[0.15]	[0.00]	[0.08]	[0.22]	[0.00]	[0.00]
AA versus							
A	11.7	9.4	14.0	**17.2**	2.6	**16.8**	13.8
	[0.23]	[0.40]	[0.12]	[0.05]	[0.98]	[0.05]	[0.13]
BBB	9.5	14.1	**29.0**	14.2	11.2	**30.8**	**39.2**
	[0.39]	[0.12]	[0.00]	[0.12]	[0.26]	[0.00]	[0.00]
A versus							
BBB	6.3	10.9	**19.6**	7.9	11.8	**40.4**	**26.9**
	[0.71]	[0.28]	[0.02]	[0.54]	[0.22]	[0.00]	[0.00]

Note: This table presents the results of Wald tests on the hypothesis that the sensitivities to a factor are for bonds with different ratings. p-values are given between brackets. Coefficients in bold are significant at the 5% level.

Figure 1: Number of Bonds in Different Rating Categories

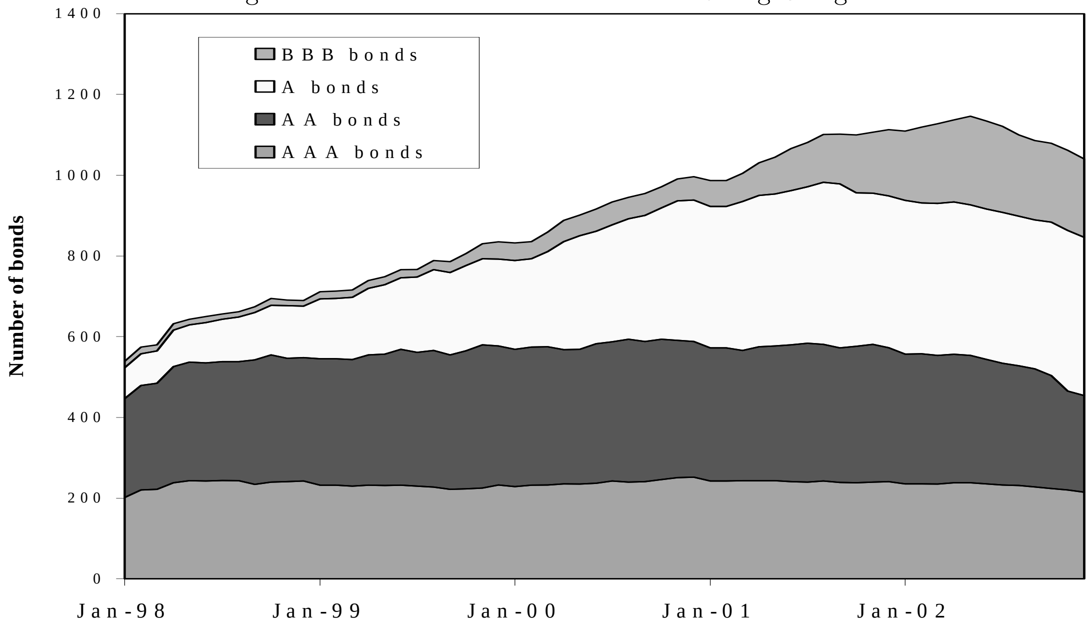


Figure 2: Liquidity, % of Index Not Quoted

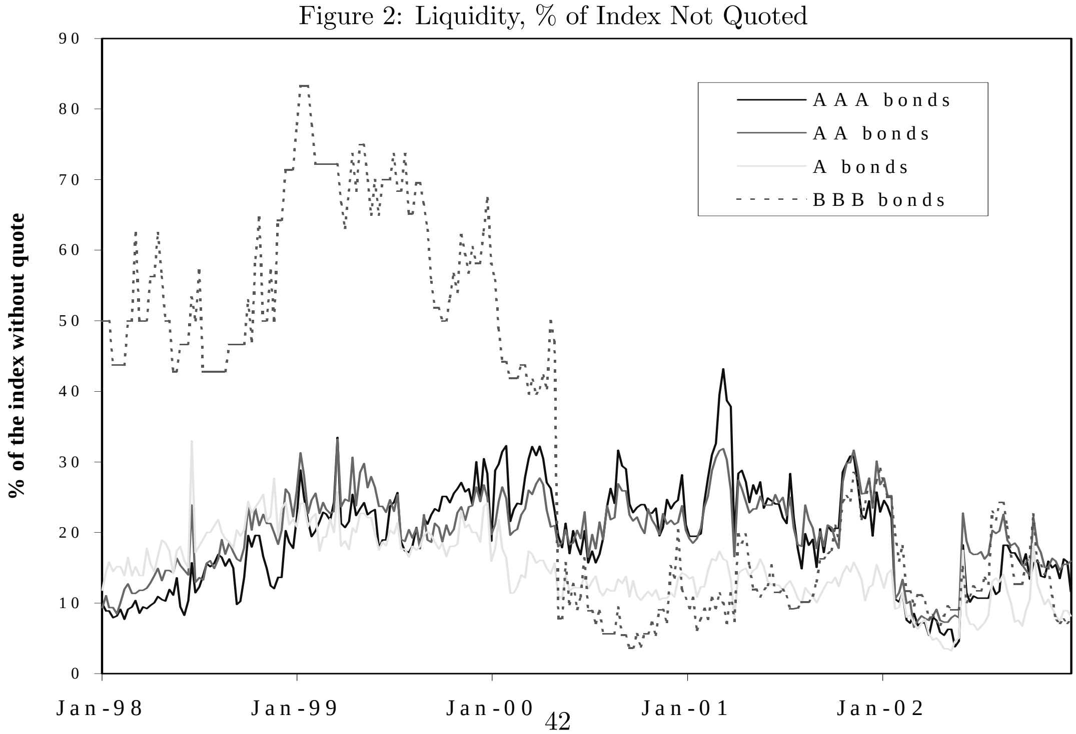


Figure 3: Credit Spreads on AAA Rated Bonds with 3, 5, 7, and 10 Years to Maturity

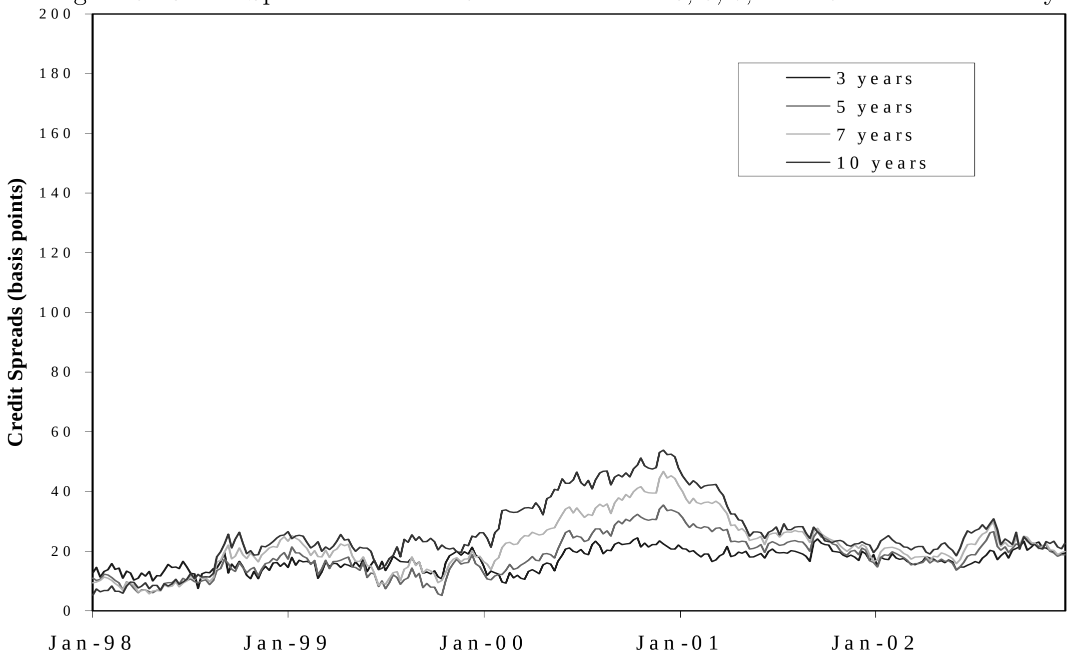


Figure 4: Credit Spreads on AA Rated Bonds with 3, 5, 7, and 10 Years to Maturity

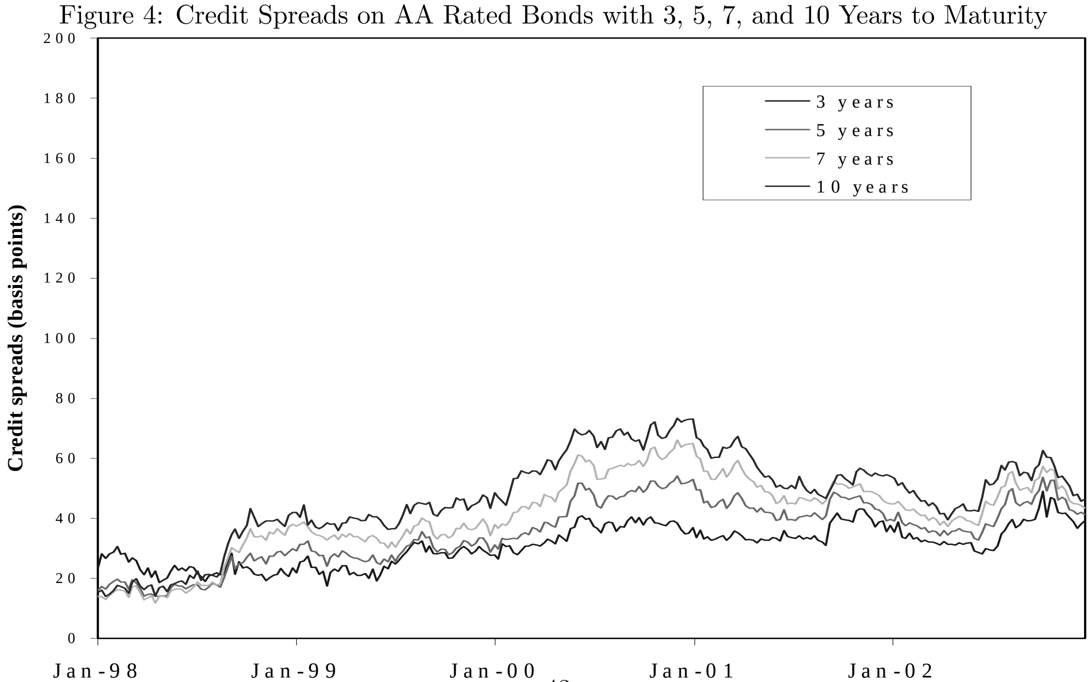


Figure 5: Credit Spreads on A Rated Bonds with 3, 5, 7, and 10 Years to Maturity

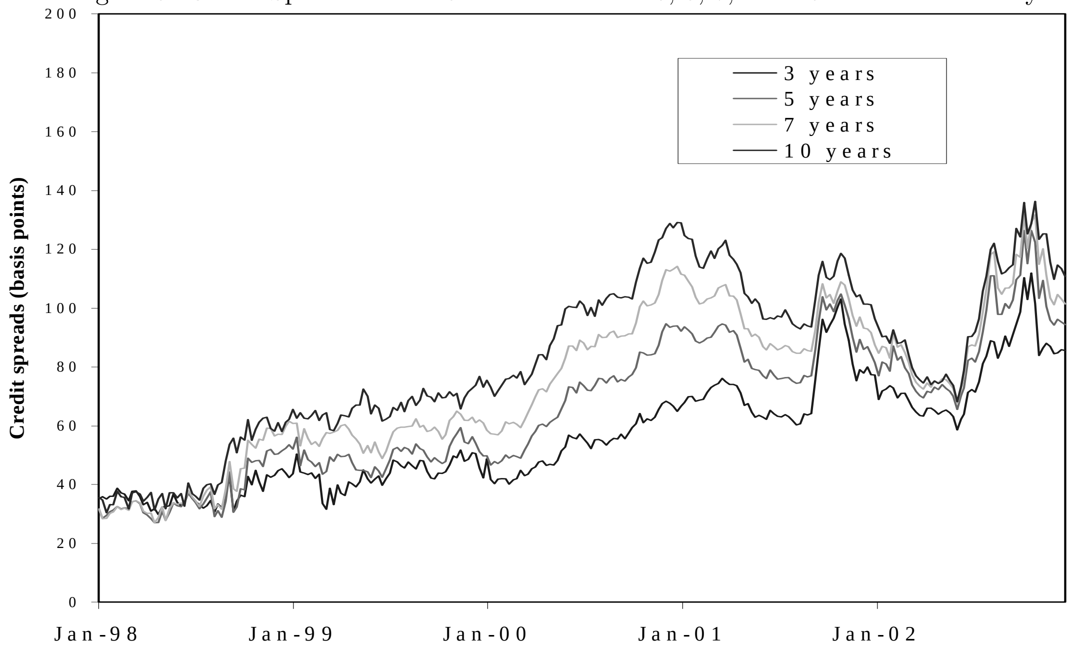


Figure 6: Credit Spreads on BBB Rated Bonds with 3, 5, 7, and 9 Years to Maturity

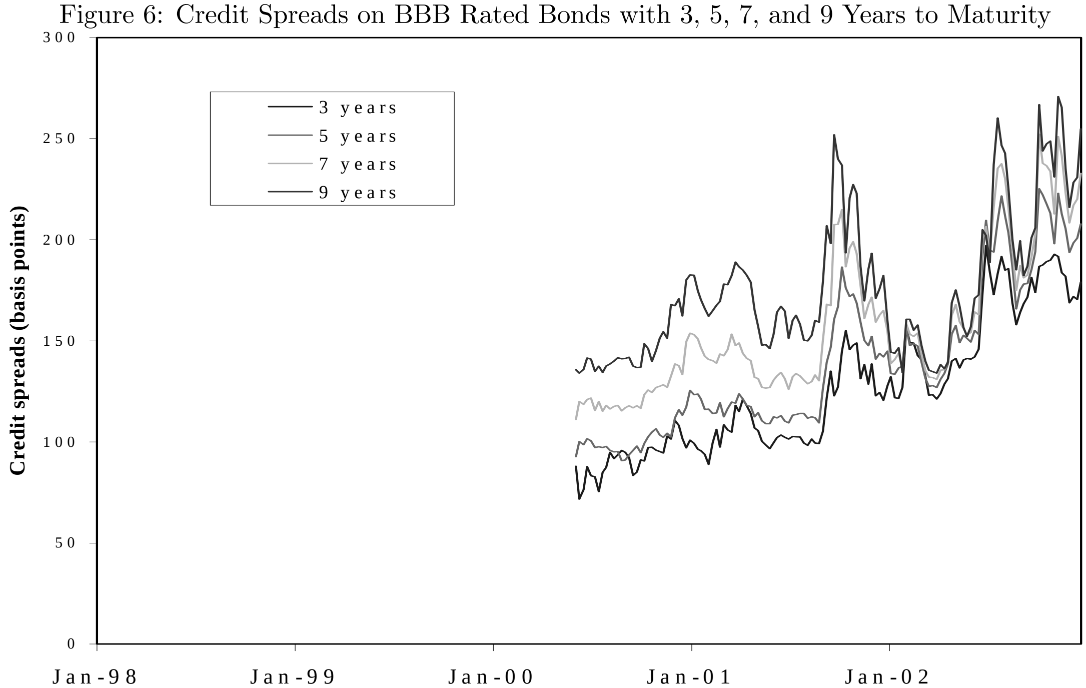
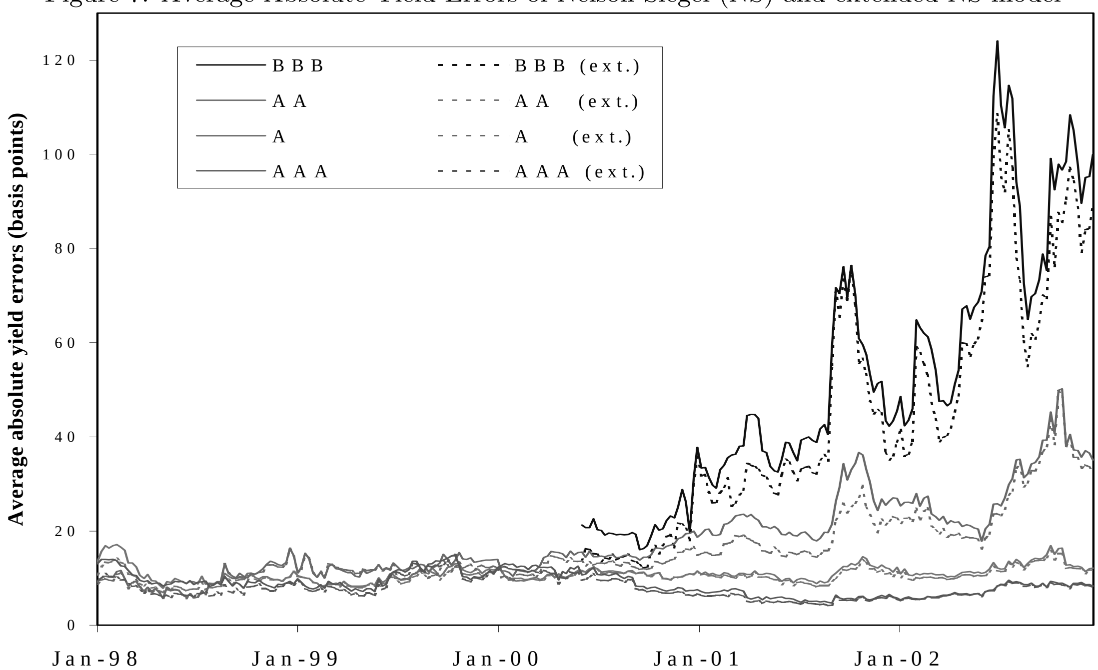


Figure 7: Average Absolute Yield Errors of Nelson-Siegel (NS) and extended NS model



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