Interest Rates and Credit Spread Dynamics

Robert Neal

Indiana University

Douglas Rolph[*]

Nanyang Technological University

Nanyang Business School

Brice Dupoyet

Florida International University

College of Business Administration

Xiaoquan Jiang

Florida International University

College of Business Administration

February 23, 2015

Interest Rates and Credit Spread Dynamics

This version: February 23, 2015

Abstract

This paper revisits the relation between callable credit spreads and interest rates. We use cointegration to model the time-series of corporate and government bond rates, and draw inference about how credit spreads evolve after a shock to government rates using a bootstrapped standard error methodology. We find little evidence that unexpected changes to government rates lead to a significant change in future credit spreads. These results hold for both large positive and negative shocks, as well as after conditioning on the prevailing interest rate environment.

Credit spreads are negatively correlated with interest rates through the impact of changes in interest rates on the credit conditions of corporations. Most theoretical studies consider these correlations in the context of risk-neutral valuation models of corporate debt, and focus on the effect that interest rates have on the growth in firm value. These models specify how firm value evolves over time and assume that default is triggered when the firm value falls below some default threshold. The default threshold is a function of the amount of debt outstanding.[1] Since the (risk-neutral) growth of the firm increases with the instantaneous risk-free rate, the likelihood that the firm value falls below the default threshold decreases and the credit risk premium declines. This effect induces a negative correlation between credit spreads and interest rates.

A number of empirical studies provide evidence of a strong negative relation between changes in credit spreads and interest rates. The negative correlation between interest rates and credit spreads persists after controlling for firm and market-level determinants of default risk (Longstaff and Schwartz [1995], Collin-Dufresne, Goldstein, and Martin [2001], Avramov, Jostova and Philipov [2007], Campbell and Taksler [2003]). While the general consensus in the literature points to a negative link between credit spreads and government rates, the call feature of corporate debt has the potential to induce a source of common variation in credit spreads and interest rates that is unrelated to default risk (Jacoby, Liao, and Batten [2009])). For callable bonds, higher interest rates imply a lower chance that the issuer will exercise the call option. Thus bondholders will accept a lower yield for these call provisions, which will result in an overall decrease in the bond yield spread. While the negative relation between credit spreads and interest rates weakens for non-callable bonds, there remains a statistically significant decrease in credit

spreads for several months following a positive shock to short term government rates (Duffee [1998]).

A common approach in the literature is to regress contemporaneous credit spreads or changes in credit spreads on contemporaneous levels or changes in treasury rates. Interest rates and credit spreads, however, have a high degree of persistence. The error term of the regression is thus autocorrelated, correlated with the independent variable (interest rates) and contains information about contemporaneous interest rates. The estimates of the regression coefficients can then be inefficient and the significance tests on the estimated coefficients invalid, as shown in Granger and Newbold [1974]. Our approach is to let the data be our guide by explicitly incorporating the influence of persistence through the modeling of the joint evolution of corporate and government interest rates using a cointegration framework.

We revisit the relation between credit spreads and interest rates using an improved methodology that combines cointegration with bootstrapped standard errors. Two variables are cointegrated when both are driven by the same unit root process. If corporate rates can be modeled as the sum of the nonstationary Treasury rate and a risk premium, it is clear that both the Treasury and the corporate rates share a common process. Since the two rates are driven by the same stochastic trend, they cannot evolve independently and the levels of the variables will be linked together.[2]

Using the cointegration estimates, we examine how credit spreads evolve after an unexpected change in government rates by taking advantage of the Generalized Impulse Response Function (GIRF) methodology (Koop et al. [1996]). This econometric technique uses

bootstrapped standard errors to infer how credit spreads evolve after a shock to government rates. In contrast, many previous empirical studies rely on an assumed distribution of the residuals. Thus, our approach provides a more robust testing framework and accounts for possible fat tails of the empirical distribution of residuals.

Additionally, this approach allows the path of credit spreads to depend on recent levels and changes in government rates. Numerous studies document that government rates and credit spreads contain information about the current and future state of the macro economy.[3] However, most previous studies focus on the unconditional relation between credit spreads and government rates. Our approach conditions on current interest rates, and allows for asymmetric responses to positive and negative interest rate shocks.

We find no statistically significant change in credit spreads after large shocks to either short-term or long-term Treasury yields, either contemporaneously or up to three years after a shock. The results hold for shocks to short, intermediate and long maturity government rates, and credit spreads constructed with intermediate and long maturity corporate bond indices. This contrasts with earlier empirical studies which find yields and spreads to be negatively correlated. Our results suggest that how interest rates evolve over time matter for our understanding of the relation between interest rate shocks and credit spreads.

Our results are interesting for several reasons. First, cointegration has implications for models of pricing corporate debt and credit derivatives. Cointegration supports the intuition that corporate and treasury rates are closely linked and cannot evolve in arbitrary ways. This linkage, however, is not captured in the parameterization of reduced form bond pricing models, structural

models, and credit spread option-pricing models. The omission is important because Duan and Pliska [2004] show that, under reasonable conditions, ignoring cointegration will significantly bias the calculated price of spread options. Second, our finding that higher Treasury rates do not have a statistically significant impact on credit spreads has implications for models that analyze credit spread dynamics. For example, the comparative statics of the capital structure models of Leland and Toft [1996] and Collin-Dufresne and Goldstein [2001], and the bond pricing models of Longstaff and Schwartz [1995], Kim, Ramaswamy, and Sundaresan [1993], and Merton [1974] all predict that higher rates will lower credit spreads. Our results suggest that there is little empirical support for this relation.

DATA AND SUMMARY STATISTICS

Data Description

We obtain monthly corporate bond yields from the Lehman Brothers U.S. Corporate Index and monthly constant-maturity government rates from the Federal Reserve's H.15 release. The Lehman Brothers U.S. Corporate database begins in 1973 and our study therefore spans from February 1973 to December 2007. The Lehman Brothers Corporate Indices include all publicly traded U.S. corporate debentures and secured notes that meet prescribed maturity, liquidity, and quality guidelines. Securities with calls, puts and sinking fund provisions are included. We consider the effects of interest rate shocks on the credit spreads for bond indices that differ by credit rating (Aaa, Aa, A, and Baa) and maturity (below ten years for intermediate maturity bonds, and above ten years for long maturity bonds).

Summary Statistics

Exhibit 1 contains summary statistics for corporate rates, Treasury rates, changes in corporate rates and changes in Treasury rates for both long-term and intermediate-term maturities. Over the 1973-2007 period, the 10-year government rate averaged 7.59%, while long-term corporate rates ranged between 8.52% and 9.62%. During the same period, the 3-year government rate averaged 7.07%, while intermediate-term corporate rates ranged between 7.81% and 8.99%. The mean monthly changes in rates are close to zero for all series.

Panel A of Exhibit 2 presents autocorrelation coefficients for both levels and changes of the 10-year Treasury and long-term corporate rates, while Panel B covers the 3-year Treasury and intermediate-term corporate rates. For long-term corporate rates levels, the autocorrelation coefficients for the first four lags exceed 0.95, while for intermediate-term rates, the autocorrelation coefficients for the first four lags exceed 0.93, with highly statistically significant (unreported) Box-Ljung Q-Statistics. Correlations in *changes* range from -0.13 to 0.16, and again there is strong statistical significance for all lags. Exhibit 3 reports the augmented Dickey-Fuller and Phillips-Perron unit root tests. Using between one and six lags, these two tests fail to reject at the 5% level the presence of a unit root for both long-term and intermediate-term corporate and government rates. In addition, the Dickey-Fuller and Phillips-Perron tests for the first differences (not reported) are significant at the 1% level, a result consistent with the previously obtained correlations in changes. Thus, the levels of the interest rates appear nonstationary while the

changes appear stationary. Overall, these results are consistent with the conclusions of a number of studies on unit roots in nominal interest rates.[4]

COINTEGRATION AND THE UNCONDITIONAL RELATION BETWEEN CORPORATE AND TREASURY RATES

The Cointegration Model

In this section we provide a cointegration framework to analyze the relation between corporate and Treasury bond yields. Cointegration is based on the idea that while a set of variables are individually nonstationary, a linear combination of the variables might be stationary due to a long-run statistical relationship linking the cointegrated variables together. Cointegration also implies that the short-term movements of the variables will be affected by the lagged deviation from the long-run relationship between the variables, inducing mean reversion around the long-run relationship. An alternative view of cointegration is that two variables are cointegrated when both are driven by the same unit root process. If corporate rates can be modeled as the sum of the nonstationary Treasury rate and a risk premium, it is clear that both the Treasury and the corporate rates share a common process. Since the two rates are driven by the same stochastic trend, they cannot evolve independently and the levels of the variables will be linked together.[5]

Assuming stationarity in the changes, the short-term dynamics of two cointegrated variables X_{1t} and X_{2t} can be captured in the following error-correction model:

$$\Delta X_{1,t} = a_{10} + \gamma_1(X_{1,t-1} - \lambda X_{2,t-1}) + \sum_{i=1}^{p} a_{i,11}\Delta X_{1,t-i} + \sum_{i=1}^{p} a_{i,12}\Delta X_{2,t-i} + \varepsilon_{1,t} \tag{1}$$

$$\Delta X_{2,t} = a_{20} + \gamma_2(X_{1,t-1} - \lambda X_{2,t-1}) + \sum_{i=1}^{p} a_{i,21}\Delta X_{1,t-i} + \sum_{i=1}^{p} a_{i,22}\Delta X_{2,t-i} + \varepsilon_{2,t} \tag{2}$$

In this model, ε_{1t} and ε_{2t} represent two i.i.d. error terms, the cointegration vector is said to be $(1,-\lambda)$, and the linear combination $X_{1,t} - \lambda X_{2,t}$ is stationary. The economic interpretation of $X_{1,t} - \lambda X_{2,t}$ is that it represents the deviation from the long-run relationship between X_1 and X_2. This deviation affects the short-term dynamics, with the error-correction coefficients γ_1 and γ_2 describing how quickly X_1 and X_2 respond to the deviation. It is well known that the presence of cointegration between X_1 and X_2 causes the time series behavior of X to differ from that of a conventional vector autoregression.[6]

Equations (1) and (2) can also be written in matrix form as

$$\Delta X_t = A_0 + \Pi X_{t-1} + A_1\Delta X_{t-1} + ... + A_k\Delta X_{t-p} + \varepsilon_t \tag{3}$$

where A_0 is a (1×2) vector of intercepts and $A_1 \dots A_k$ are (2×2) matrices of coefficients on lagged ΔX.[7] The important characteristic distinguishing cointegration models from VAR models is whether $\Pi = 0$. If this restriction holds, then ΔX_t can be represented by a conventional VAR in differences. However, if the rank of Π exceeds zero, the elements of Π are non-zero. We test for cointegration by estimating the rank of Π using Johansen [1988]'s likelihood ratio tests, namely, the maximal eigenvalue test and the trace statistic test.

Vector Error Correction Model Estimates

The first set of trace statistics in Exhibit 4 examines whether long-term corporate rates (Panel A) and intermediate-term rates (Panel B) share a common unit root with the corresponding government rates. All tests are statistically significant at the 5% level. Thus, we reject the null hypothesis that corporate and government yields are not cointegrated in favor of the alternative hypothesis that there is at least one cointegrating vector. The second trace statistics, however, do not support the existence of two cointegrating vectors for either the Intermediate-Term Bond series or the Long-Term Bond series as one cannot reject the null hypothesis of one cointegrating vector or less for any of the series. The results for all series are based on using two lags of the levels of interest rates, with the lag length determined by the Schwartz Criterion.

Exhibit 5 reports the estimated cointegrating vectors, with λ ranging from 1.1054 to 1.2508 for long maturity bonds, and from 1.0852 to 1.2480 for intermediate maturities. The p-values for both panels are less than 1%. The results in Exhibit 5 have two interesting implications. First, since all λ values exceed one, a 1% increase in Treasury rates ultimately generates increases in corporate rates of more than 1%. Thus, as interest rates rise, credit spreads will eventually widen. Second, the lower quality bonds exhibit a greater long-run sensitivity to interest rate movements than higher quality bonds. This is inconsistent with a commonly held view that increased credit risk will make corporate bonds less interest rate sensitive.

An alternative way to interpret the cointegrating relationship is to estimate the error-correction regressions found in equations (1) and (2). Cointegration implies that the coefficient on the error-correction term will be negative and significant, with the size of the coefficient

measuring the sensitivity of corporate rates to the error-correction term. The negative sign

indicates that credit spreads subsequently adjust to restore the long-run equilibrium when a

deviation occurs. Using the estimated cointegrating vectors from Exhibit 5, Exhibit 6 provides

estimates of the error-correction model. The error-correction coefficients are significantly

negative, ranging from -0.0653 to -0.0511 and from -0.1042 to -0.0619 for long and intermediate

maturities respectively.

GENERALIZED IMPULSE RESPONSE FUNCTIONS AND THE CONDITIONAL RELATION BETWEEN CREDIT SPREADS AND TREASURY RATES

The above results describe the unconditional relation between credit spreads and Treasury

rates. However, conditioning on the current interest rate environment may illuminate how credit

spreads evolve following positive and negative shocks to government rates. For example, when

the economy is in recession and government rates are relatively low, a positive shock to

government rates may convey different information about future business conditions and credit

risk than if the shock occurred during an expansion, when rates are relatively high.

In order to examine the conditional relation between corporate spreads and interest rates,

we use the estimates from the second-stage regression in Exhibit 6 to implement the Generalized

Impulse response Function (GIRF) methodology of Koop et al. [1996]. When using traditional

impulse response functions, the history of the process or the sequence of observations as well as

the signs, sizes, and correlations of the shocks occurring between the initial shock and the impulse

horizon can produce misleading estimates, as demonstrated by Pesaran and Potter [1997]. The

GIRF approach, however, corrects for these issues and allows for asymmetric responses to positive and negative interest rate shocks.

In the GIRF framework, the residuals observed from VEC model are bootstrapped, and the standard errors reflect the empirical (not assumed) residual distribution. Separating the GIRF functions into positive and negative shocks – with possibly different implications regarding the business conditions and their relation to credit risk – potentially increases the power of the test to reject the null hypothesis of no response. Additionally, traditional impulse response functions' standard errors rely on a *ceteris paribus* argument which neglects the effect of the prevailing interest rate environment. In contrast, GIRF functions construct forecasts for each period during the sample using the most recent interest rates, and then average over the resulting forecast. Thus, there is more variability in the forecasted path of future credit spreads. The higher variability leads to wider and more realistic standard errors and helps guard against erroneously concluding shocks to government rates have a statistically significant impact on credit spreads.

Generalized Impulse Response Functions Methodology

The generalized impulse response functions are defined as the difference in month $t+i$ between the conditional expectation of the corporate bond spread (corporate yield – treasury yield) following a shock to Treasury yields exceeding two standard deviations at month t, and the conditional expectation across all possible shocks to Treasury yields. Both expectations condition on interest rates at $t-1$. The response function describes what might happen to credit spreads in the months following a shock to government rates after controlling for the influence of lagged government and corporate rates.

The GIRF equations can be written as:

$$GIRF(n, \varepsilon_{g,t}, \Omega_{t-1}) = E(y_{t+n} \mid \Omega_{t-1}, \varepsilon_{g,t} > 2\sigma_\varepsilon) - E(y_{t+n} \mid \Omega_{t-1}) \quad \text{when } \varepsilon_{g,t} > 0 \qquad (5)$$

and as

$$GIRF(n, \varepsilon_{g,t}, \Omega_{t-1}) = E(y_{t+n} \mid \Omega_{t-1}, |\varepsilon_{g,t}| > 2\sigma_\varepsilon) - E(y_{t+n} \mid \Omega_{t-1}) \quad \text{when } \varepsilon_{g,t} < 0 \qquad (6)$$

where y_{t+n} is the corporate credit spread at time $t+n$, Ω_{t-1} is the time t-1 information set used to produce forecasts of y_{t+n}, $\varepsilon_{g,t} > 2\sigma_\varepsilon$ represents a positive shock exceeding two standard errors, and $|\varepsilon_{g,t}| > 2\sigma_\varepsilon$ represents a negative shock exceeding two standard errors.

To explain the GIRF procedure below, we use a model which includes one corporate bond rate and one government bond rate, where

$$X_t = \begin{bmatrix} X_{1t} \\ X_{2t} \end{bmatrix} = \begin{bmatrix} \text{corporate rate at } t \\ \text{government rate at } t \end{bmatrix}, \quad \Lambda = \begin{bmatrix} 1 & -\lambda \end{bmatrix} \qquad (7)$$

$$\text{and} \quad A_2 = \begin{bmatrix} \gamma_1 \\ \gamma_2 \end{bmatrix} \quad \text{so that} \quad \Pi = A_2 \otimes \Lambda \qquad (8)$$

(where $\otimes$ represents the Kronecker product)

Models which include government rates are generalizations of the two-variable case.

1. Retrieve the fitted/realized residuals from the Vector Error Correction model for each month t using actual data. In (2×2) matrix and (2×1) vector notation, for month t, use real data at month t-1 and month t-2 and compute

$$\Delta X_t^{\text{forecasted}} = A_1 \Delta X_{t-1} + A_2 \otimes \Lambda\ X_{t-1}$$
$$\text{where } \Delta X_{t-1} = X_{t-1}\text{-}X_{t-2} \tag{9}$$

in order to retrieve the (2×1) fitted residual vector $\quad \varepsilon_t = \Delta X_t - \Delta X_t^{\text{forecasted}}$

2. For each month t, calculate "future" interest rates at month t+n (for n=$0,1,...N$) by bootstrapping the model residuals obtained in step 1.

   - For month t, use real data at month t-1 and month t-2 as well as residual ε_t, and compute

$$\Delta X_t^{\text{unconditional forecast}} = A_1 \Delta X_{t-1} + A_2 \otimes \Lambda\ X_{t-1} + \varepsilon_t \tag{10}$$

   and obtain

$$X_t^{\text{unconditional forecast}} = X_{t-1} + \Delta X_t^{\text{unconditional forecast}} \tag{11}$$

   - For month t+1, use $X_t^{\text{unconditional forecast}}$, real data at month t-1 and residual ε_{t+1}, and compute

$$\Delta X_{t+1}^{\text{unconditional forecast}} = A_1 (X_t^{\text{unconditional forecast}} - X_{t-1})$$
$$+ A_2 \otimes \Lambda\ X_t^{\text{unconditional forecast}} + \varepsilon_{t+1} \tag{12}$$

   and obtain

$$X_{t+1}^{\text{unconditional forecast}} = X_t^{\text{unconditional forecast}} + \Delta X_{t+1}^{\text{unconditional forecast}} \tag{13}$$

- For month $t+n$, $n>1$, use $X_{t+n-1}^{\text{unconditional forecast}}$, $X_{t+n-2}^{\text{unconditional forecast}}$ and residual ε_{t+n}, and compute

$$\begin{aligned} \Delta X_{t+n}^{\text{unconditional forecast}} &= A_1(X_{t+n-1}^{\text{unconditional forecast}} - X_{t+n-2}^{\text{unconditional forecast}}) \\ &\quad + A_2 \otimes \Lambda\, X_{t+n-1}^{\text{unconditional forecast}} + \varepsilon_{t+n} \end{aligned} \tag{14}$$

and obtain

$$X_{t+n}^{\text{unconditional forecast}} = X_{t+n-1}^{\text{unconditional forecast}} + \Delta X_{t+n}^{\text{unconditional forecast}} \tag{15}$$

These forecasted interest rates are used to calculate the unconditional expectation of interest rate spreads.

3. For each month t, calculate "future" interest rates at time $t+n$ for $n=0,1,...N$ by imposing that the value of the first residual at time t be larger than two standard deviations (for positive shocks). The remaining residual series is kept exactly the same as in step 2. The only difference between step 2 and step 3 is that in step 3 the first residual is drawn from the subset of residuals that are larger than two times the residuals' standard deviation.

4. Record the corporate spread for both the unconditional and the conditional simulation separately, and repeat steps 2 and 3 for the chosen number of simulations (1,000 in this case).

5. For a given number of steps ahead n, calculate the differences between these 1,000 simulated conditional and unconditional spreads and calculate their means, lower bounds and upper bounds (2.5% and 97.5% respectively).

6. For each number of steps ahead *n*, compute averages of the means, lower bounds and upper bounds across all *t* (months).

The Conditional Relation between Credit Spreads and Treasury Rates

Exhibits 7 through 10 plot the response of long-term credit spreads to a two standard deviation shock in the 10-year treasury rate. The Exhibits plot the average response of credit spreads, as well as the 2.5^{th} and 97.5^{th} percentiles of the GIRF functions. In order to examine the long-run response, we plot the path of credit spreads for the five years that follow both a positive and a negative shock to the government rate. While most empirical studies consider on the response of interest rates after a shock of one standard deviation, we focus on larger, two standard deviation shocks to government rates. Using such large shocks increases the power to reject the null hypothesis of no response to credit spreads following interest rate shocks.

As can been seen in the Exhibits, there no statistically significant short-term reaction of spreads to either positive or negative shocks to long maturity government rates. After a large positive (negative) shock, the credit spread decreases (increases) initially but subsequently reverts to near pre-shock levels. However, this temporary average deviation from initial levels is generally not statistically significantly different from zero, as shown by the width of the confidence bounds. In addition, across credit ratings, there is little difference in the response of credit spreads to interest rate shocks.

Exhibits 11 through 14 plot the response of intermediate-term corporate spreads to a two-standard-deviation shock in the 3-year treasury rate, and as in the long-term rate cases, the short run response of credit spreads to interest rate shocks are generally not statistically significantly different from zero, as shown by the width of the confidence bounds. For completeness, we also estimate (unreported) generalized impulse responses that include one-year government rates and find marginal significant response of intermediate maturity credit spreads. When the same impulse response analysis uses shocks that exceed one standard deviation, as is common in the empirical literature, we find no statistically significant relation between shocks and future intermediate maturity credit spreads.

As a final robustness check, we also estimate a VECM that incorporates both short (3-month) and intermediate (3-year) government rates, and we again find no significant relation between credit spreads and shocks to government rates, regardless of the maturity of the corporate bonds.

CONCLUSION

In contrast to existing studies, we find little evidence that unexpected changes to government rates lead to a significant change in future credit spreads. This empirical result holds for credit spreads constructed using bonds of differing maturities and credit ratings, and is robust to shocks to both short and long maturity government bonds. This is in contrast to the existing literature, in which researchers have found that credit spreads and changes in rates are negatively correlated.

Our approach removes many of the restrictive assumptions found in the existing empirical literature. We use a vector error correction methodology that allows for interest rates to be cointegrated, thus precluding corporate and government rates from evolving in arbitrary, opposite directions over time. We also incorporate the empirical distribution of residuals when constructing the confidence intervals, thus allowing for potential fat tails in the distribution of interest rate shocks. Finally, our results condition on the prevailing interest rate environment, which may be viewed as a proxy for economic conditions. The absence of a meaningful relation between interest rates and credit spreads provides empirical evidence against the dynamic process for credit spreads captured in existing structural models for pricing corporate bonds.

References

Avramov, Doron, T. Chordia, G. Jostova, and A. Philipov. "Momentum and Credit Rating." Journal of Finance, Vol. 62, No. 5 (2007), pp. 2503-2520.

Batten, Jonathan A., W. P. Hogan, G. Jacoby. "Measuring Credit Spreads: Evidence from Australian Eurobonds." Applied Financial Economics, Vol. 15, No.9 (2005), pp. 651-666.

Black, Fischer, John C. Cox. "Valuing Corporate Securities: Some Effects of Bond Indenture Provisions." Journal of Finance, Vol. 31, No.2 (May 1976), pp. 351-367.

Black, Fischer, M. Scholes. "The Pricing of Options and Corporate Liabilities." The Journal of Political Economy, Vol. 81, No. 3 (May - June, 1973), pp. 637-654.

Bradley, Michael, S. Lumpkin. "The Treasury Yield Curve as a Cointegrated System." Journal of Financial and Quantitative Analysis, Vol. 27 (1992), pp. 449-464.

Campbell, John Y., R. J. Shiller. "Cointegration and Tests of Present Value Models. Journal of Political Economy," Vol. 95 No. 5 (Oct. 1987) pp. 1062-1088.

Campbell, John Y., G. B. Taskler. "Equity Volatility and Corporate Bond Yields." Journal of Finance, Vol. 58, No. 6 (Dec. 2003), pp. 2321-2349.

Chan-Lau, Jorge, and I. Ivaschenko. "Corporate bond risk and real activity: an Empirical Analysis of Yield Spreads and their Systematic Components." IMF Working Paper 01/158, 2001.

Chan-Lau, Jorge, and I. Ivaschenko. "The Corporate Spread Curve and Industrial Production in the United States." IMF Working Paper 02/8, 2002.

Collin-Dufresne, Pierre, R. Goldstein. "Do Credit Spreads Reflect Stationary Leverage Ratios?" Journal of Finance, Vol. 56, No. 5 (Oct. 2001), pp. 1929-1957.

Collin-Dufresne, Pierre, R. S. Goldstein, J. S. Martin. "The Determinants of Credit Spread Changes." Journal of Finance, Vol. 56, No. 6. (Dec. 2001), pp. 2177-2207.

Davies, Andrew. "Credit spread determinants: An 85 year perspective." Journal of Financial Markets, Vol. 11, No. 2 (2008), p. 180–197.

Duan, Jin-Chuan, S. R. Pliska. "Option Valuation with Co-Integrated Asset Prices." Journal of Economic Dynamics and Control, Vol. 28, No. 4 (Jan. 2004), pp. 727-754.

Duffee, Gregory R. "Treasury Yields and Corporate Bond Yield Spreads: An Empirical Analysis." Journal of Finance, Vol. 53, No. 6 (1998), pp. 2225-2242.

Enders, Walter, and C. W.J. Granger. "Unit-Root Tests and Asymmetric Adjustment with an Example Using the Term Structure of Interest Rates." Journal of Business and Economic Statistics, Vol. 16, No. 3 (Feb. 1998), pp. 304-311.

Eom, Young H., J. Helwege, J-Z. Huang. "Structural Models of Corporate Bond Pricing: An Empirical Analysis." Review of Financial Studies, Vol. 17, No. 2 (2004), pp. 499–544.

Fama, Eugene, K. R. French. "Business Conditions and Expected Returns on Stocks and Bonds." Journal of Financial Economics, Vol. 25, No. 1 (Nov. 1989), pp. 23-49.

Gilchrist, Simon, V. Yankov, E. Zakrajsek. "Credit Market Shocks and Economic Fluctuations: Evidence from Corporate Bond and Stock Markets." Journal of Monetary Economics, Vol. 56, No. 4 (2009), pp. 471-493.

Goldstein, Robert, N. Ju, H. Leland. "An EBIT-Based Model of Dynamic Capital Structure." Journal of Business, Vol. 74, No. 4 (2001), pp. 483-512.

Granger, Clive W.J., and P. Newbold. "Spurious Regressions in Econometrics." Journal of Econometrics, Vol. 2, No. 2 (1974), pp. 111-120.

Granger, Clive W.J., N. R. Swanson. "Future Developments in the Study of Cointegrated Variables." Oxford Bulletin of Economics and Statistics, Vol. 58, No. 3 (1996), pp. 537-553.

Hall, Anthony D., H. M. Anderson, C. W.J. Granger. "A Cointegration Analysis of Treasury Bill Yields." The Review of Economics and Statistics, Vol. 74, No. 1 (1992), pp. 116-126.

Jacoby, Gady, R. C. Liao, J. A. Batten. "Testing for the Elasticity of Corporate Yield Spreads." Journal of Financial and Quantitative Analysis, Vol. 44, No. 3, June2009, pp. 641-656.

Johansen, Soren "Statistical Analysis of Cointegrating Vectors." Journal of Economic Dynamics and Control, Vol. 12 No. 2/3 (1988), pp. 231-254.

Kim, Joon, K. Ramaswamy, S. Sundaresan. "Does Default Risk in Coupons Affect the Valuation of Corporate Bonds? A Contingent Claims Model." Financial Management, Vol. 22, No. 3 (1993), pp. 117-131.

Konishi, Toru, V. Ramey, and C. W.J. Granger. "Stochastic Trends and Short-Run Relationships Between Financial Variables and Real Activity." National Bureau of Economic Research Working paper 4275, 1993.

Koop, Gary, M. H. Pesaran, S. M. Potter. "Impulse Response Analysis in Nonlinear Multivariate Models." Journal of Econometrics, Vol. 74, No. 1 (1996), pp. 119-147.

Leland, Hayne, K. Toft. "Optimal Capital Structure, Endogenous Bankruptcy, and the Term Structure of Credit Spreads." Journal of Finance, Vol. 51, No. 3 (1996), pp. 987-1020.

Leland, Hayne E. "Corporate Debt Value, Bond Covenants, and Optimal Capital Structure." The Journal of Finance, Vol. 49, No. 4 (Sep. 1994), pp. 1213-1252.

Longstaff, Francis A., E. S. Schwartz. "A Simple Approach to Valuing Risky Fixed and Floating Rate Debt." Journal of Finance, Vol. 50, No. 3, (Jul. 1995), pp. 789-820.

Longstaff, Francis A., and E. S. Schwartz. "Valuing Credit Derivatives." Journal of Fixed Income, Vol. 5, No. 1 (Jun. 1995), pp. 6-12.

MacKinnon, James G. "Critical Values for Cointegration Tests." Long-Run Economic Relationships: Readings in Cointegration, R.F. Engle and C.W.J. Granger (eds), Oxford University Press, 1991, pp. 267-276.

Mehra, Yash. "An Error-Correction Model of the Long-Term Bond Rate." Federal Reserve Bank of Richmond Economic Quarterly, Vol. 80, No. 4 (1994), pp. 49-67.

Merton, Robert C. "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates." Journal of Finance, Vol. 29, No.2 (May 1974), pp. 449-470.

Mueller, Philippe. "Credit Spreads and Real Activity." Working Paper, London School of Economics and Political Science, 2009.

Pesaran, M. Hashem, S. M. Potter. "A Floor and Ceiling Model of US Output." Journal of Economic Dynamics and Control, Vol.21, No. 4-5 (1997), pp. 661-695.

Phillips, Peter. "Impulse Response and Forecast Error Variance Asymptotics in Nonstationary VARs." Journal of Econometrics, Vol. 83, No. 1-2 (1998), pp. 21-56.

Rose, Andrew. "Is the Real Interest Rate Stable?" Journal of Finance, Vol.43, No. 5 (1988), pp. 1095-1112.

Stock, James H., M. W. Watson. "Testing for Common Trends." Journal of the American Statistical Association, Vol. 83, No. 404 (December 1988), pp. 1097-1107.

EXHIBIT 1

Descriptive Statistics

The statistics are based on monthly data from 1973:2 to 2007:12. In Panel A, the AAA, AA, A and BAA series are Lehman Brothers Long-Term Corporate Yields and the 10-year Treasury series is a constant maturity series from the Board of Governors. In Panel B, the AAA, AA, A and BAA series are Lehman Brothers Intermediate-Term Corporate Yields and the 3-year Treasury series is a constant maturity series from the Board of Governors.

Panel A: Lehman Long-Term Bond Series and 10-year Treasury rates

Variables	Mean	Std. Dev.	Percentile (10%)	Percentile (90%)
Lehman AAA Long	8.52	2.33	5.83	12.21
Lehman AA Long	8.75	2.43	5.89	12.52
Lehman A Long	9.03	2.47	6.21	12.83
Lehman BAA Long	9.62	2.61	6.65	13.46
10-Year Treasury	7.59	2.61	4.50	11.67
Δ Lehman AAA Long	-0.004	0.339	-0.340	0.360
Δ Lehman AA Long	-0.003	0.331	-0.340	0.340
Δ Lehman A Long	-0.003	0.342	-0.350	0.350
Δ Lehman BAA Long	-0.003	0.372	-0.380	0.390
Δ 10-Year Treasury	-0.006	0.372	-0.390	0.410

Panel B: Lehman Intermediate-Term Bond Series and 3-year Treasury rates

Variables	Mean	Std. Dev.	Percentile (10%)	Percentile (90%)
Lehman AAA Intermediate	7.81	2.69	4.62	11.58
Lehman AA Intermediate	8.01	2.81	4.86	11.89
Lehman A Intermediate	8.33	2.83	5.21	12.29
Lehman BAA Intermediate	8.99	2.90	5.71	13.02
3-Year Treasury	7.07	2.92	3.70	11.13
Δ Lehman AAA Intermediate	-0.005	0.401	-0.401	0.420
Δ Lehman AA Intermediate	-0.004	0.401	-0.410	0.370
Δ Lehman A Intermediate	-0.003	0.403	-0.390	0.390
Δ Lehman BAA Intermediate	-0.003	0.417	-0.410	0.460
Δ 3-Year Treasury	-0.009	0.482	-0.500	0.500

EXHIBIT 2

Sample Autocorrelations

Levels and changes autocorrelation estimates are based on monthly data from 1973:2 to 2007:12. In Panel A, the AAA, AA, A and BAA series are Lehman Brothers Long-Term Corporate Yields and the 10-year Treasury series is a constant maturity series from the Board of Governors. In Panel B, the AAA, AA, A and BAA series are Lehman Brothers Intermediate-Term Corporate Yields and the 3-year Treasury series is a constant maturity series from the Board of Governors.

Panel A: Lehman Long-Term Bond Series and 10-year Treasury rates

Variables	Autocorrelation Coefficients in Levels						Autocorrelation Coefficients in Changes					
	n=1	n=2	n=3	n=4	n=5	n=6	n=1	n=2	n=3	n=4	n=5	n=6
Lehman Aaa Long	0.99	0.97	0.96	0.95	0.94	0.93	0.07	-0.05	-0.05	-0.09	0.09	0.05
Lehman Aa Long	0.99	0.98	0.96	0.95	0.94	0.93	0.12	-0.08	-0.01	-0.07	0.08	0.05
Lehman A Long	0.99	0.98	0.96	0.95	0.94	0.93	0.10	-0.06	0.01	-0.11	0.07	0.03
Lehman Baa Long	0.99	0.97	0.96	0.95	0.93	0.92	0.11	-0.04	-0.01	-0.05	0.07	0.02
10-Year Treasury	0.99	0.97	0.96	0.95	0.94	0.92	0.13	-0.07	-0.06	-0.01	0.03	0.03

Panel B: Lehman Intermediate-Term Bond Series and 3-year Treasury rates

Variables	Autocorrelation Coefficients in Levels						Autocorrelation Coefficients in Changes					
	n=1	n=2	n=3	n=4	n=5	n=6	n=1	n=2	n=3	n=4	n=5	n=6
Lehman Aaa Intermediate	0.99	0.97	0.96	0.94	0.93	0.92	0.14	-0.06	-0.06	-0.07	0.10	-0.04
Lehman Aa Intermediate	0.99	0.97	0.96	0.95	0.94	0.93	0.13	-0.05	-0.04	-0.09	0.10	-0.04
Lehman A Intermediate	0.99	0.97	0.96	0.95	0.94	0.92	0.11	0.01	0.00	-0.13	0.09	-0.07
Lehman Baa Intermediate	0.99	0.97	0.96	0.94	0.93	0.92	0.15	0.03	-0.02	-0.11	0.01	-0.08
3-Year Treasury	0.98	0.96	0.95	0.93	0.92	0.91	0.16	-0.10	-0.09	-0.05	0.05	-0.01

EXHIBIT 3

Unit Root Tests for Levels of Interest Rates

The null hypothesis for the Dickey-Fuller and the Phillips-Perron test is that the series contains a unit root. The percentage p-values (in parentheses) are approximate asymptotic p-values calculated using the method described in MacKinnon (1991). The estimates are based on monthly data from 1973:2 to 2007:12. In Panel A, the AAA, AA, A and BAA series are Lehman Brothers Long-Term Corporate Yields and the 10-year Treasury series is a constant maturity series from the Board of Governors. In Panel B, the AAA, AA, A and BAA series are Lehman Brothers Intermediate-Term Corporate Yields and the 3-year Treasury series is a constant maturity series from the Board of Governors.

Panel A: Lehman Long-Term Bond Series and 10-year Treasury rates

	Dickey-Fuller							Phillips-Perron					
Variables	n=1	n=2	n=3	n=4	n=5	n=6		n=1	n=2	n=3	n=4	n=5	n=6
Lehman AAA Long	-1.40	-1.30	-1.23	-1.08	-1.22	-1.24		-1.34	-1.33	-1.31	-1.27	-1.27	-1.28
	(0.58)	(0.63)	(0.66)	(0.72)	(0.66)	(0.65)		(0.61)	(0.61)	(0.62)	(0.64)	(0.65)	(0.64)
Lehman AA Long	-1.47	-1.30	-1.32	-1.19	-1.33	-1.32		-1.35	-1.35	-1.34	-1.32	-1.32	-1.34
	(0.55)	(0.63)	(0.62)	(0.68)	(0.61)	(0.62)		(0.61)	(0.61)	(0.61)	(0.62)	(0.62)	(0.61)
Lehman A Long	-1.44	-1.31	-1.35	-1.16	-1.31	-1.26		-1.35	-1.35	-1.35	-1.32	-1.32	-1.33
	(0.56)	(0.62)	(0.61)	(0.69)	(0.63)	(0.65)		(0.61)	(0.61)	(0.61)	(0.62)	(0.62)	(0.62)
Lehman BAA Long	-1.49	-1.39	-1.39	-1.29	-1.41	-1.37		-1.39	-1.40	-1.40	-1.39	-1.40	-1.41
	(0.54)	(0.59)	(0.59)	(0.63)	(0.58)	(0.60)		(0.59)	(0.58)	(0.58)	(0.59)	(0.58)	(0.58)
10-Year Treasury	-1.39	-1.24	-1.16	-1.17	-1.19	-1.23		-1.27	-1.27	-1.25	-1.23	-1.24	-1.24
	(0.59)	(0.66)	(0.69)	(0.69)	(0.68)	(0.66)		(0.64)	(0.64)	(0.65)	(0.66)	(0.66)	(0.66)

Panel B: Lehman Intermediate-Term Bond Series and 3-year Treasury rates

	Dickey-Fuller							Phillips-Perron					
Variables	n=1	n=2	n=3	n=4	n=5	n=6		n=1	n=2	n=3	n=4	n=5	n=6
Lehman AAA Intermediate	-1.61	-1.45	-1.38	-1.27	-1.46	-1.28		-1.47	-1.47	-1.45	-1.42	-1.43	-1.43
	(0.48)	(0.56)	(0.59)	(0.64)	(0.55)	(0.64)		(0.55)	(0.55)	(0.55)	(0.57)	(0.57)	(0.57)
Lehman AA Intermediate	-1.54	-1.42	-1.39	-1.24	-1.42	-1.26		-1.42	-1.43	-1.42	-1.39	-1.40	-1.40
	(0.51)	(0.57)	(0.59)	(0.66)	(0.57)	(0.65)		(0.57)	(0.57)	(0.57)	(0.59)	(0.58)	(0.58)
Lehman A Intermediate	-1.52	-1.50	-1.51	-1.27	-1.46	-1.26		-1.42	-1.45	-1.47	-1.44	-1.45	-1.44
	(0.53)	(0.53)	(0.53)	(0.64)	(0.55)	(0.65)		(0.57)	(0.56)	(0.55)	(0.56)	(0.56)	(0.56)
Lehman BAA Intermediate	-1.61	-1.61	-1.57	-1.36	-1.43	-1.25		-1.46	-1.51	-1.53	-1.52	-1.51	-1.48
	(0.48)	(0.48)	(0.50)	(0.60)	(0.57)	(0.65)		(0.55)	(0.53)	(0.52)	(0.53)	(0.53)	(0.54)
3-Year Treasury	-1.76	-1.51	-1.40	-1.33	-1.43	-1.34		-1.57	-1.57	-1.53	-1.48	-1.47	-1.46
	(0.40)	(0.53)	(0.58)	(0.62)	(0.57)	(0.61)		(0.50)	(0.50)	(0.52)	(0.54)	(0.55)	(0.55)

EXHIBIT 4

Cointegration Results

This exhibit uses Johansen's (1988) maximum likelihood method to estimate the rank of Π for the corporate and government rates in the two-variable regression. In Panel A the corporate rates are the Lehman Long-Term Bond series ranging from AAA to BAA, and the government rate is the 10-year constant maturity Treasury series from the Board of Governors. In Panel B the corporate rates are the Lehman Intermediate-Term Bond series ranging from AAA to BAA, and the government rate is the 3-year constant maturity Treasury series from the Board of Governors. The estimates are based on monthly data from 1973:2 to 2007:12.

Panel A: Lehman Long-Term Bond Series and 10-year Treasury rates

Variables	Maximum Rank	Trace Statistic	5% Critical Value
Lehman AAA Long	0	18.35	12.53
	1	0.46	3.84
Lehman AA Long	0	16.03	12.53
	1	0.44	3.84
Lehman A Long	0	15.79	12.53
	1	0.44	3.84
Lehman BAA Long	0	14.98	12.530
	1	0.47	3.84

Panel B: Lehman Intermediate-Term Bond Series and 3-year Treasury rates

Variables	Maximum Rank	Trace Statistic	5% Critical Value
Lehman AAA Intermediate	0	33.71	12.53
	1	0.64	3.84
Lehman AA Intermediate	0	34.63	12.53
	1	0.61	3.84
Lehman A Intermediate	0	33.09	12.53
	1	0.67	3.84
Lehman BAA Intermediate	0	24.52	12.530
	1	0.71	3.84

EXHIBIT 5

Estimates of Cointegrating Vectors

This exhibit reports estimates of λ in the cointegrating vector $(1, -\lambda)$ for the corporate and government rates using Johansen's (1988) maximum likelihood method. In Panel A the corporate rates are the Lehman Long-Term Bond series ranging from AAA to BAA, and the government rate is the 10-year constant maturity Treasury series from the Board of Governors. In Panel B the corporate rates are the Lehman Intermediate-Term Bond series ranging from AAA to BAA, and the government rate is the 3-year constant maturity Treasury series from the Board of Governors. The estimates are based on monthly data from 1973:2 to 2007:12. The Johansen normalization restrictions are imposed and we report the coefficient estimates as well as the respective p-values.

Panel A: Lehman Long-Term Bond Series and 10-year Treasury rates

Variables	Coefficient	Estimate	P-value
Lehman AAA Long	1	1	.
	λ	1.1054	0.00
Lehman AA Long	1	1	.
	λ	1.1381	0.00
Lehman A Long	1	1	.
	λ	1.1741	0.00
Lehman BAA Long	1	1	.
	λ	1.2508	0.00

Panel B: Lehman Intermediate-Term Bond Series and 3-year Treasury rates

Variables	Coefficient	Estimate	P-value
Lehman AAA Intermediate	1	1	.
	λ	1.0852	0.00
Lehman AA Intermediate	1	1	.
	λ	1.1159	0.00
Lehman A Intermediate	1	1	.
	λ	1.1599	0.00
Lehman BAA Intermediate	1	1	.
	λ	1.2480	0.00

EXHIBIT 6

Estimates of the Error-Correction Model

This exhibit reports equation (1)'s estimates along with standard errors in parentheses for the bivariate error-correction system of equations (1) and (2) in the one-lag difference case. The error-correction terms are estimated using Johansen's (1988) maximum likelihood method. X_1 represents the corporate rate, and X_2 represents the government rate. In Panel A the corporate rates are the Lehman Long-Term Bond series ranging from AAA to BAA, and the government rate is the 10-year constant maturity Treasury series from the Board of Governors. In Panel B the corporate rates are the Lehman Intermediate-Term Bond series ranging from AAA to BAA, and the government rate is the 3-year constant maturity Treasury series from the Board of Governors.

Panel A: Lehman Long-Term Bond Series and 10-year Treasury rates

Dependent Variable	Independent Variables		
	Error-Correction	$\Delta X_{1,t-1}$	$\Delta X_{2,t-1} = \Delta$ 10-Year Treasury $_{t-1}$
$\Delta X_{1,t} = \Delta$ Lehman AAA Long $_t$	-0.0653 (0.0166)	-0.1262 (0.0354)	0.6038 (0.0356)
$\Delta X_{1,t} = \Delta$ Lehman AA Long $_t$	-0.0578 (0.0159)	-0.0971 (0.0348)	0.6103 (0.0343)
$\Delta X_{1,t} = \Delta$ Lehman A Long $_t$	-0.0545 (0.0155)	-0.1206 (0.0376)	0.5931 (0.0374)
$\Delta X_{1,t} = \Delta$ Lehman BAA Long $_t$	-0.0511 (0.0143)	-0.0809 (0.0384)	0.612 (0.0410)

Panel B: Lehman Intermediate-Term Bond Series and 3-year Treasury rates

Dependent Variable	Independent Variables		
	Error-Correction	$\Delta X_{1,t-1}$	$\Delta X_{2,t-1} = \Delta$ 3-Year Treasury $_{t-1}$
$\Delta X_{1,t} = \Delta$ Lehman AAA Intermediate $_t$	-0.1042 (0.0189)	-0.0702 (0.0303)	0.5674 (0.0306)
$\Delta X_{1,t} = \Delta$ Lehman AA Intermediate $_t$	-0.1027 (0.0185)	-0.0765 (0.0309)	0.5599 (0.0309)
$\Delta X_{1,t} = \Delta$ Lehman A Intermediate $_t$	-0.0892 (0.0166)	-0.1192 (0.0355)	0.5211 (0.0334)
$\Delta X_{1,t} = \Delta$ Lehman BAA Intermediate $_t$	-0.0619 (0.0131)	-0.0319 (0.0372)	0.5111 (0.0348)

EXHIBIT 7: Response of Lehman AAA Long Spread to shock in 10-year Treasury rate
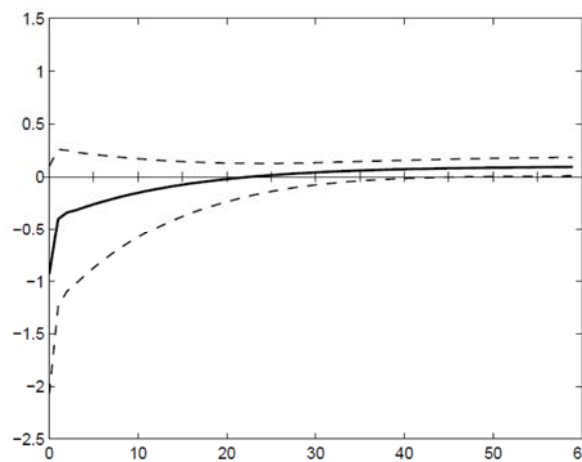
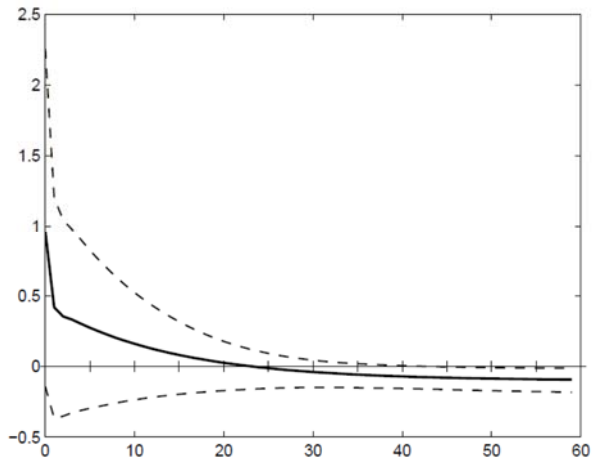Exhibit 7a.   Exhibit 7b.

Exhibit 7: This exhibit shows the response of Lehman AAA Long spreads to a positive (Exhibit 7a) and negative (Exhibit 7b) two-standard-deviation shock in the 10-year government rate. The graph is obtained by constructing generalized impulse response functions (GIRF) that capture both the short-term dynamics and the long-run relation between corporate and Treasury rates. The generalized impulse response functions are defined as the difference in month $t+i$ between the conditional expectation of the corporate bond spread (corporate yield – treasury yield) following a large shock to Treasury yields at month t, and the conditional expectation across all possible shocks to Treasury yields. Both expectations condition on interest rates at $t-1$.

EXHIBIT 8: Response of Lehman AA Long Spread to shock in 10-year Treasury rate
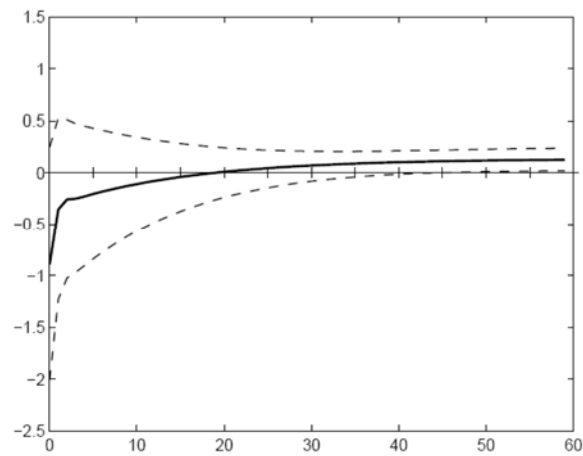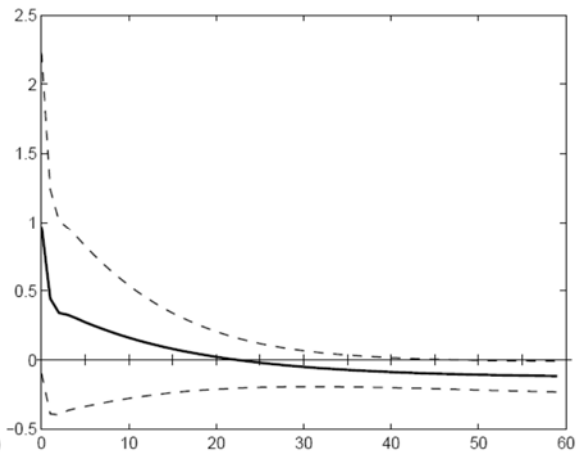
Exhibit 8a.   Exhibit 8b.

Exhibit 8: See Caption to Exhibit 7

EXHIBIT 9: Response of Lehman A Long Spread to shock in 10-year Treasury rate
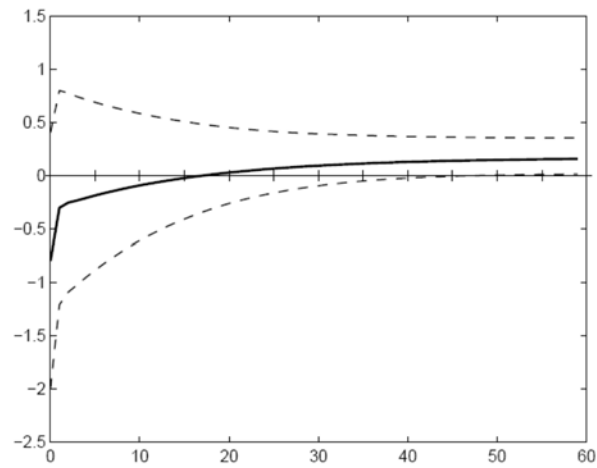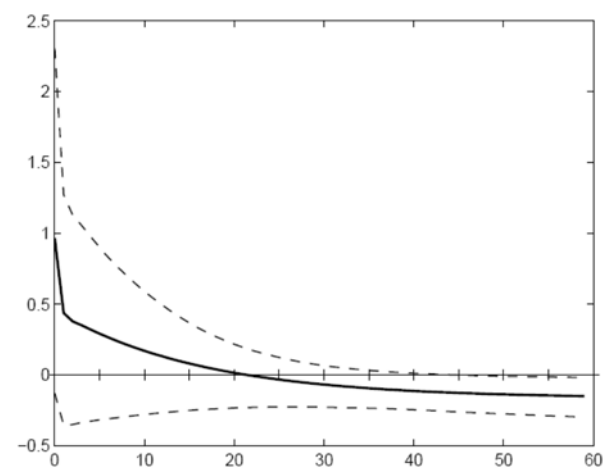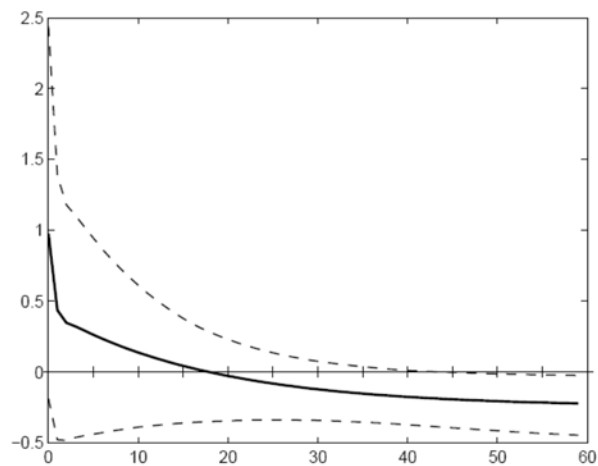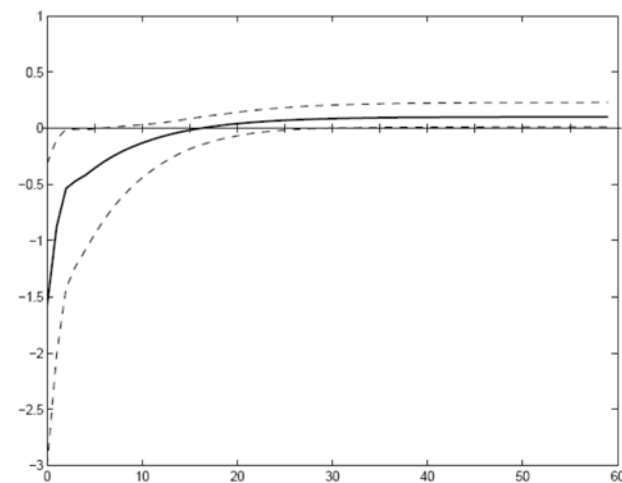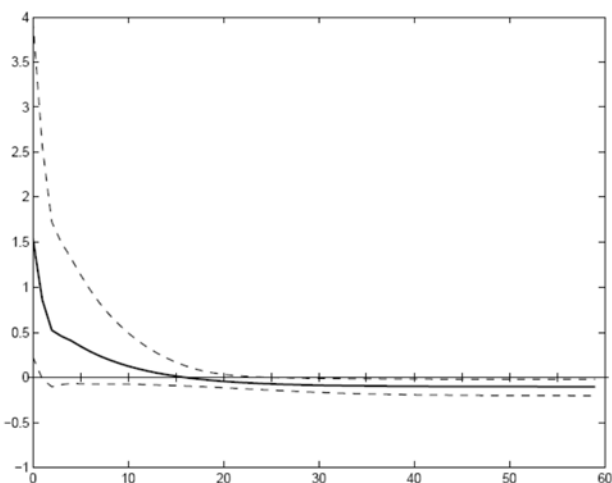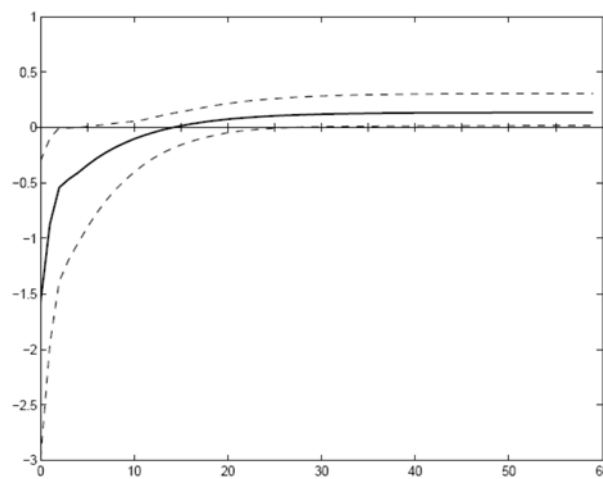

Exhibit 9a.   Exhibit 9b.

Exhibit 9: See Caption to Exhibit 7

EXHIBIT 10: Response of Lehman BAA Long Spread to shock in 10-year Treasury rate
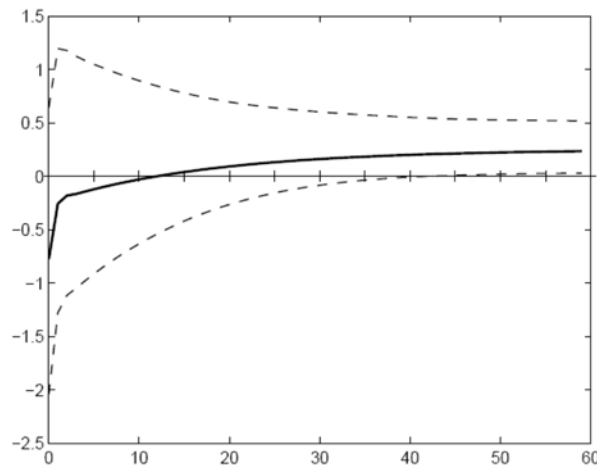
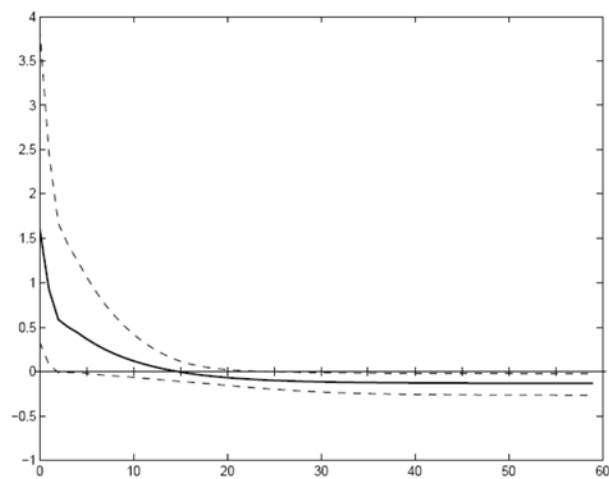Exhibit 10a.   Exhibit 10b.

Exhibit 10: See Caption to Exhibit 7

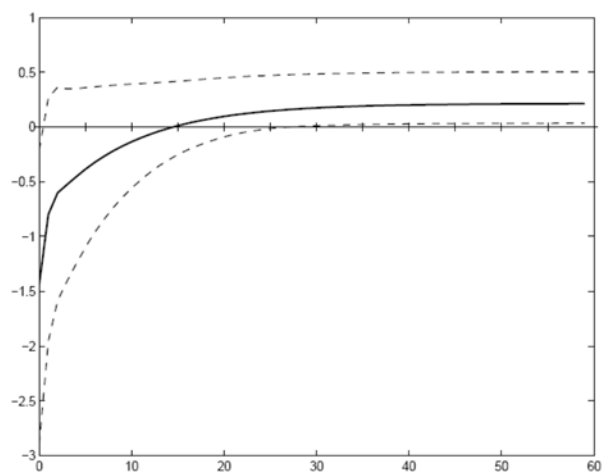**EXHIBIT 11: Response of Lehman AAA Intermediate Spread to shock in 3-year Treasury rate**

Exhibit 11a.   Exhibit 11b.

Exhibit 11: See Caption to Exhibit 7

EXHIBIT 12: Response of Lehman AA Intermediate Spread to shock in 3-year Treasury rate

Exhibit 12a.   Exhibit 12b.

Exhibit 12: See Caption to Exhibit 7

EXHIBIT 13: Response of Lehman A Intermediate Spread to shock in 3-year Treasury rate
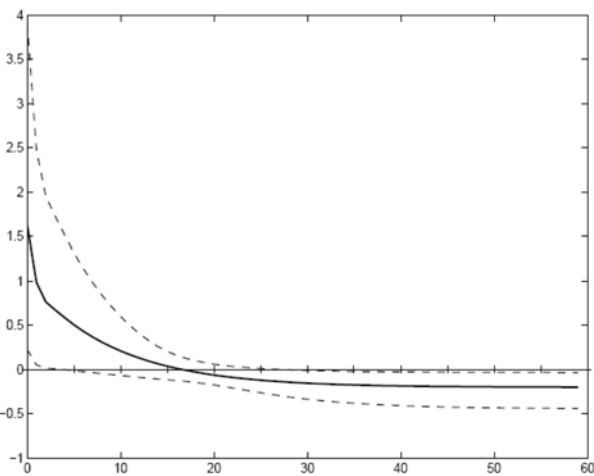
Exhibit 13a.   Exhibit 13b.

Exhibit 13: See Caption to Exhibit 7

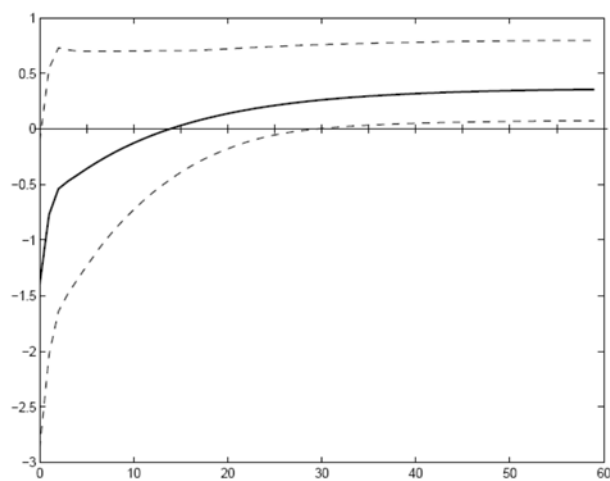**EXHIBIT 14: Response of Lehman BAA Intermediate Spread to shock in 3-year Treasury rate**
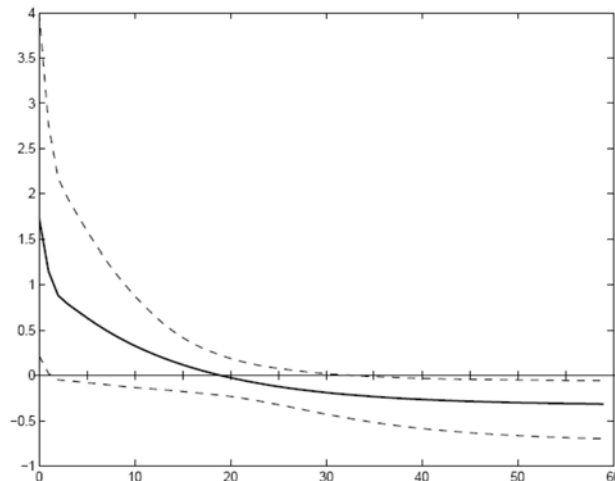

Exhibit 14a.   Exhibit 14b.

Exhibit 14: See Caption to Exhibit 7

ENDNOTES

[1] See Black and Cox [1976], Leland [1994], Collin-Dufresne and Goldstein [2001], Eom, Helwege and Huang [2004], Schaefer and Strebulaev [2008] and Ericsson, Jacobs and Oviedo [2009].

[2] While cointegration is intuitively appealing, it assumes that the underlying variables are nonstationary. We impose the assumption of unit root processes not because we believe that interest rates can exhibit unbounded variation, but because it provides the distribution theory that best represents the finite sample properties of our data. Our view is consistent with Granger and Swanson [1996] and Phillips [1998] who show that nonstationary distribution models provide superior inference for both unit root and near-unit root processes.

[3] For instance, see Fama and French [1989], Chan-Lau and Ivaschenko [2001, 2002], Davies [2008], and Mueller [2009].

[4] See Rose [1988], Stock and Watson [1988], Hall, Anderson and Granger [1992], Bradley and Lumpkin [1992], Konishi, Ramey and Granger [1993], and Enders and Granger [1998] for short-term rates; Mehra [1994] and Campbell and Shiller [1987] for long-term rates.

[5] While cointegration is intuitively appealing, it assumes that the underlying variables are nonstationary. We impose the assumption of unit root processes not because we believe that interest rates can exhibit unbounded variation, but because it provides the distribution theory that best represents the finite sample properties of our data. Our view is consistent with Granger and Swanson [1996] and Phillips [1998] who show that nonstationary distribution models provide superior inference for both unit root and near-unit root processes.

[6] An attractive feature of the cointegration framework is that it allows one to distinguish between short-run and long-run behavior. We estimate the models with a two-stage procedure that first identifies the cointegration vector, and then includes the vector in a second-stage regression of changes in corporate rates on changes in treasury rates.

[7] **EDITED For purposes of comparing across models, we fix the number of lags for changes in rates to one, which implies that there are two lags in the levels. We also consider other forms as a robustness check where we select variable lags with Akaike's information criterion, and our results remain the same.**