Credit Spread Changes and Volatility Spillover Effects

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***Abstract*—**The purpose of this paper is to investigate the influence of a number of variables on the conditional mean and conditional variance of credit spread changes. The empirical analysis in this paper is conducted within the context of bivariate GARCH-in-Mean models, using the so-called BEKK parameterization. We show that credit spread changes are determined by interest-rate and equity-return variables, which is in line with theory as provided by the structural models of default. We also identify the credit spread change volatility as an important determinant of credit spread changes, and provide evidence on the transmission of volatility between the variables under study.

***Keywords*—**Credit spread changes, GARCH-in-Mean models, structural framework, volatility transmission.

I. Introduction

THE number of empirical studies on the determinants of corporate credit spreads, which are commonly viewed as a proxy for credit risk, has increased significantly over the last years (see, among others, [2], [9], [11], [14] and [20]). [11] and [14] show that taxes, risk premia and liquidity premia, among other factors, are important in explaining corporate credit spreads. [9] find that variables such as the interest rate level, the yield curve slope, and proxies for firm leverage, volatility, business climate, and jump magnitudes and probabilities, have low explanatory power. [20] show that a number of variables, including the Russell 2000 index historical return volatility, the Conference Board composite leading and coincident economic indicators, the interest rate level, the historical interest rate volatility, the yield curve slope, the Russell 2000 index return, and the Fama-French high-minus-low factor, have significant explanatory power. Finally, [2] find that the lagged Russell 2000 index returns and changes in the yield curve slope are important determinants of credit spread changes.

The purpose of the present paper is twofold. First, within the theoretical framework provided by the so-called structural models of default, we re-examine the impact of a number of variables on the conditional mean of credit spread changes. The structural framework postulates that credit spread determinants are basically decomposed into two core factors, which are related to the risk-free interest rate and the firm asset value.

Second, we extend existing literature by investigating the impact of the proposed variables on the conditional variance of credit spread changes, following the intuition by [17]. In this way, we aim to shed light and enhance our understanding on the volatility structure of credit spread changes.

In order to explore the influence of the variables on the conditional mean and conditional variance of credit spread changes, bivariate GARCH-in-Mean models are employed. Specifically, the analysis implements the full (unrestricted) BEKK representation, introduced by [15], which enables us to study the existence of volatility spillover effects among the variables.

The remainder of the paper is organized as follows. The second section discusses the theoretical background. The third section presents the dataset and describes the empirical models. The fourth section reports the empirical results, and the final section summarizes the main findings and concludes the paper.

II. Theoretical Background

Existing literature on credit risk modeling comprises two fundamental approaches: the structural or firm-value approach, pioneered by [3] and [27], and the reduced-form approach, including, *inter alia*, [21] and [22].

The structural approach postulates that corporate debt and equity are options on the value of the firm. Within this framework, default is basically determined by the firm asset value relative to a default threshold. The Merton model implies that an increase in the risk-free interest rate increases the risk-neutral drift of the firm value process, and thus reduces the probability of default; as a result, the credit spread narrows. In accordance with theory, [12] and [26] find a negative relation between credit spreads and interest rates. In lieu of associating default with the firm value, reduced-form models assume that default is determined exogenously, typically through a jump process.

There are a number of empirical studies, including, *inter alia*, [16] and [19], that question structural models of default on the basis of their generated credit spreads compared to the empirically observed ones. Nevertheless, we follow the theoretical implications provided by this class of models, which decompose the determinants of corporate credit spreads into an interest-rate and an asset-value factor. In this paper, we use both changes in the 10-year U.S. Treasury bond yield and changes in the slope of the Treasury yield curve, as proxies

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for the interest-rate factor. [8] and [25] have shown that the interest rate level and slope mostly explain the term structure of interest rates (see also [9]). Furthermore, as a proxy for the asset-value factor, we use the return on the Standard and Poor's 500 equity index.

III. DATA & METHODOLOGY

A. Dataset

The analysis consists of monthly data of the Baa-rated corporate credit spread, the slope of the U.S. Treasury yield curve, the S&P 500 equity price index, and the 10-year constant maturity U.S. Treasury bond. The dataset covers the period over January 1985 through December 2004, and was sourced from the U.S. Federal Reserve Board (Federal Reserve Statistical Release H.15-Selected Interest Rates) and Datastream. The Baa credit spread is calculated as the yield difference between the Moody's Baa seasoned bond index and the 10-year constant maturity U.S. Treasury bond. The slope of the Treasury yield curve is calculated as the yield difference between the 10-year and 1-year constant maturity U.S. Treasury bonds. The return on the S&P 500 index is calculated as the log difference of the equity index levels.

Unit-root tests are computed for each series, including the Augmented Dickey-Fuller and Phillips-Perron unit-root tests, the test developed by [13], the test by [24], as well as the test proposed by [28]. The unit-root test results, presented in I, show that the first differences of the series, as well as the S&P 500 return series, are all stationary processes.

B. Empirical models

In this paper, we estimate a series of bivariate GARCH-in-Mean models using the BEKK parameterization, introduced by [15]. The estimated bivariate GARCH-M(1,1) models are of the following form:

$$
\begin{aligned}
x_t &= a_1 + b_1 y_t + c_1 \sqrt{h_{11,t}} + u_{1,t} \\
y_t &= a_2 + b_2 y_{t-1} + c_2 \sqrt{h_{22,t}} + u_{2,t} \\
H_t &= C'C + A'H_{t-1}A + B'u_{t-1}u'_{t-1}B
\end{aligned}
\tag{1}
$$

where x_t denotes the Baa credit spread changes, y_t is the vector of the explanatory variables, *i.e.* $y=(\Delta Tcm10y_t,\ \Delta Slope_t,\ S\&P500_{t-1})'$, h_{11} denotes the conditional variance of credit spread changes, and h_{22} denotes the conditional variance of the explanatory variable. Thus, the conditional mean of credit spread changes is parameterized to depend on contemporaneous changes in the 10-year Treasury yield (hereafter model 1), contemporaneous changes in the slope of the Treasury yield curve (hereafter model 2), and the lagged S&P 500 index return (hereafter model 3), as well as on its own volatility, given by the square root of its conditional variance, h_{11}.

The full (unrestricted) BEKK representation can also be written in the following form:

$$
\begin{aligned}
H_t &= C'C + \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}' H_{t-1} \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} + \\
&+ \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}' \begin{bmatrix} u_{1,t-1}^2 & u_{1,t-1}u_{2,t-1} \\ u_{2,t-1}u_{1,t-1} & u_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}
\end{aligned}
\tag{2}
$$

equivalently:

$$
\begin{aligned}
h_{11,t} &= c_{11} + \alpha_{11}^2 h_{11,t-1} + 2\alpha_{11}\alpha_{21} h_{12,t-1} + \alpha_{21}^2 h_{22,t-1} + \\
&\quad + b_{11}^2 u_{1,t-1}^2 + 2b_{11}b_{21} u_{1,t-1}u_{2,t-1} + b_{21}^2 u_{2,t-1}^2 \\
h_{12,t} &= c_{12} + \alpha_{11}\alpha_{12} h_{11,t-1} + (\alpha_{21}\alpha_{12} + \alpha_{11}\alpha_{22}) h_{12,t-1} + \alpha_{21}\alpha_{22} h_{22,t-1} + \\
&\quad + b_{11}b_{12} u_{1,t-1}^2 + (b_{21}b_{12} + b_{11}b_{22}) u_{1,t-1}u_{2,t-1} + b_{21}b_{22} u_{2,t-1}^2 \\
h_{22,t} &= c_{22} + \alpha_{12}^2 h_{11,t-1} + 2\alpha_{12}\alpha_{22} h_{12,t-1} + \alpha_{22}^2 h_{22,t-1} + \\
&\quad + b_{12}^2 u_{1,t-1}^2 + 2b_{12}b_{22} u_{1,t-1}u_{2,t-1} + b_{22}^2 u_{2,t-1}^2
\end{aligned}
\tag{3}
$$

As shown by the first equation in (3), the conditional variance of credit spread changes, $h_{11,t}$, is parameterized to depend on its own lagged squared errors and lagged conditional variance, as well as the lagged squared errors and lagged conditional variance of the other variable. The Broyden, Fletcher, Goldfarb and Shanno (BFGS) algorithm is implemented (see [5], [6] and [18]). To address the issue of non-normality, the so-called quasi-maximum likelihood (QML) estimator is employed (see [4]).

IV. EMPIRICAL RESULTS

A. Estimation results for model 1

According to the estimation results for model 1, presented in II, the influence of interest rate changes on the conditional mean of credit spread changes, as measured by the coefficient b_1, is statistically significant with estimated coefficient of -0.3339, and corresponding *t*-value of -4.4033. Thus, this suggests that changes in the Baa credit spread are negatively related to changes in the level of the interest rate, which is in line with theory. The impact of the credit spread change volatility on the conditional mean of credit spread changes, as measured by the coefficient c_1, is also found to be statistically significant, with estimated coefficient of 0.8788, and corresponding *t*-value of 2.1197. The estimation results also show that the conditional variance of credit spread changes is affected by its own lagged volatility and lagged squared shocks, as well as by the lagged squared shocks of *ΔTcm10y*. Specifically, we identify a statistically significant influence of the lagged squared shocks of *ΔTcm10y* on the volatility of *ΔBaaspread*, with corresponding *t*-value of 3.3552. All eigenvalues of model 1 are less than one in modulus; therefore, the model is covariance stationary (see [15]).

B. Estimation results for model 2

The estimation results for model 2, presented in III, show that the influence of changes in the slope of the Treasury yield curve on the conditional mean of credit spread changes, as measured by the coefficient b_1, is statistically significant with estimated coefficient of -0.6058, and corresponding *t*-value of -4.9028. Thus, this implies that credit spread changes are negatively related to changes in the yield curve slope, which is in accordance with theory. The impact of the credit spread change volatility on the conditional mean of credit spread changes, as measured by the coefficient c_1, is found to be statistically significant, with estimated coefficient of 1.2548, and corresponding *t*-value of 2.6033. The estimation results also show that the conditional variance of credit spread changes is affected by its own lagged squared shocks, and the lagged squared shocks of *ΔSlope*. Specifically, we document a statistically significant influence of the lagged squared shocks of *ΔSlope* on the volatility of *ΔBaaspread*, with corresponding *t*-value of -2.5159. The conditional variance of changes in the yield curve slope is affected by its own lagged volatility, and by the lagged volatility and lagged squared shocks of *ΔBaaspread*. All eigenvalues of model 2 are less than one in modulus, suggesting that the model is covariance stationary.

C. Estimation results for model 3

According to the estimation results for model 3, presented in IV, the influence of the lagged return on the S&P 500 index on the conditional mean of credit spread changes, as measured by the coefficient b_1, is statistically significant with estimated coefficient of -0.0043, and corresponding *t*-value of -2.2763. Thus, this suggests that changes in the credit spread are negatively related to the lagged S&P 500 index return (see also [9] and [23]). In this case, the impact of the credit spread change volatility on the conditional mean of credit spread changes, as measured by the coefficient c_1, is not found to be statistically significant. The estimation results also provide ample evidence for the presence of volatility transmission between the S&P 500 index return and the credit spread changes. The conditional variance of credit spread changes is affected by its own lagged squared shocks, and by the lagged volatility and lagged squared shocks of *S&P500*. Specifically, we find a statistically significant influence of the lagged volatility and lagged squared shocks of *S&P500* on the volatility of *ΔBaaspread*, with corresponding *t*-values of 17.2612 and 2.2706, respectively. The conditional variance of *S&P500* is affected by its own lagged squared shocks, and by the lagged volatility of *ΔBaaspread*. The eigenvalues of model 3 are less than one in modulus, which confirms that the model is covariance stationary.

D. Robustness test

The analysis concludes with estimating a series of bivariate diagonal BEKK GARCH-M(1,1) models, and then testing them against the models presented before, using likelihood ratio tests. The underlying rationale is to assess the previously reported evidence on the presence of volatility spillover effects among the variables. The diagonal BEKK models do not allow for spillover effects, that is, the parameters α_{12}, α_{21}, b_{12} and b_{21} in (3) are set to equal zero. The corresponding likelihood ratio test results are presented in V. In all cases, the log likelihood value of the restricted (diagonal BEKK) models is lower than that of the unrestricted (full BEKK) models. With the exception of model 1, the likelihood ratio test results reject the null hypothesis of the restricted (diagonal) models. Thus, this provides evidence in support of the models that incorporate spillover effects.

V. Conclusion

In this paper, we have examined the influence of a number of variables, based on the structural models of default, on both the conditional mean and conditional variance of credit spread changes. The empirical analysis, which is implemented within a bivariate GARCH-in-Mean modeling framework, produces the following results.

First, we find that both changes in the level of the interest rate, and changes in the slope of the Treasury yield curve, have a significant negative effect on credit spread changes, which is consistent with theory and empirical evidence documented by [12] and [26]. We also find that the S&P 500 index return has a significant impact on credit spread changes, in line with empirical evidence provided by [9], among others.

Recent empirical studies show that historical and implied volatility are important determinants of corporate credit spreads (see [7] and [10]). We find that the volatility of credit spread changes, defined by a GARCH model, comprises an important component of credit spread changes. Furthermore, we provide evidence on the existence of volatility transmission between the variables under examination. In particular, the empirical findings indicate that the S&P 500 index return and the yield curve slope changes are important in explaining the volatility of credit spread changes.

APPENDIX

TABLE I
UNIT-ROOT TESTS

Series	ADF test	PP test	DF-GLS test
ΔBaaspread	-8.47*	-10.99*	-8.23*
ΔTcm10y	-8.02*	-11.04*	-7.10*
ΔSlope	-6.22*	-11.55*	-2.91*
S&P500	-15.58*	-15.64*	-10.15*

	KPSS test	ZA test
ΔBaaspread	0.05	-11.74* (2001:11)
ΔTcm10y	0.09	-11.11* (1987:04)
ΔSlope	0.10	-11.52* (1987:03)
S&P500	0.22	-16.45* (2000:02)

Notes: ΔBaaspread stands for the Baa credit spread changes. ΔTcm10y stands for the change in the 10-year constant maturity Treasury bond, and ΔSlope stands for the change in the slope of the Treasury yield curve. S&P500 is the return on the Standard and Poor's 500 equity index. Lag length is determined on the basis of the Schwarz Criterion. (*) denotes statistical significance at the 5% level.

TABLE II
PARAMETER ESTIMATES FOR MODEL 1

	Coefficients	T-Stat.
Panel A: Conditional mean equations		
α_1	-0.0987	-2.3897
b_1	-0.3339	-4.4033
c_1	0.8788	2.1197
α_2	-0.0888	-0.6452
b_2	0.3380	5.5745
c_2	0.3138	0.5634
Panel B: Conditional variance equations		
c_{11}	0.0710	7.4195
c_{12}	-0.0030	-0.0962
c_{22}	0.1849	6.8853
α_{11}	0.3409	2.4784
α_{21}	0.0241	0.3254
α_{12}	-0.7659	-1.2067
α_{22}	-0.4130	-1.4061
b_{11}	-0.3844	-3.4672
b_{21}	0.1954	3.3552
b_{12}	0.0882	0.2996
b_{22}	0.4445	3.2631
Panel C: Covariance stationarity		
	0.4862	-0.4624
	-0.3104	0.2954

Notes: The parameters are estimated based on the following specification:

$$\Delta Baaspread_t = a_1 + b_1 \Delta Tcm10y_t + c_1\sqrt{h_{11,t}} + u_{1,t}$$

$$\Delta Tcm10y_t = a_2 + b_2 \Delta Tcm10y_{t-1} + c_2\sqrt{h_{22,t}} + u_{2,t}$$

$$H_t = C'C + A'H_{t-1}A + B'u_{t-1}u'_{t-1}B$$

TABLE III
PARAMETER ESTIMATES FOR MODEL 2

	Coefficients	T-Stat.
Panel A: Conditional mean equations		
α_1	-0.2058	-2.6722
b_1	-0.6058	-4.9028
c_1	1.2548	2.6033
α_2	-0.1785	-2.7044
b_2	0.2324	4.5385
c_2	1.0478	2.7658
Panel B: Conditional variance equations		
c_{11}	-0.0001	-4.77907e-04
c_{12}	0.1206	8.2518
c_{22}	0.0975	4.0556
α_{11}	-0.1922	-1.1618
α_{21}	0.0669	0.4270
α_{12}	0.7801	4.9092
α_{22}	-0.8757	-5.3313
b_{11}	0.7935	5.2567
b_{21}	-0.4326	-2.5159
b_{12}	0.5123	4.3866
b_{22}	-0.2074	-1.6016
Panel C: Covariance stationarity		
	0.9592	0.2647
	0.1732	0.0868

Notes: The parameters are estimated based on the following specification:

$$\Delta Baaspread_t = a_1 + b_1 \Delta Slope_t + c_1 \sqrt{h_{11,t}} + u_{1,t}$$

$$\Delta Slope_t = a_2 + b_2 \Delta Slope_{t-1} + c_2 \sqrt{h_{22,t}} + u_{2,t}$$

$$H_t = C'C + A'H_{t-1}A + B'u_{t-1}u'_{t-1}B$$

TABLE IV
PARAMETER ESTIMATES FOR MODEL 3

	Coefficients	T-Stat.
Panel A: Conditional mean equations		
α_1	-0.0041	-0.1592
b_1	-0.0043	-2.2763
c_1	0.0218	0.0948
α_2	1.4338	2.4824
b_2	-0.1144	-1.9426
c_2	-0.1482	-1.0518
Panel B: Conditional variance equations		
c_{11}	0.0000	1.33669e-05
c_{12}	0.0152	2.6621
c_{22}	0.4716	2.7705
α_{11}	0.0462	0.3420
α_{21}	0.0292	17.2612
α_{12}	28.6886	13.9747
α_{22}	-0.0197	-0.1532
b_{11}	-0.1895	-3.1426
b_{21}	0.0039	2.2706
b_{12}	-1.6822	-0.8343
b_{22}	-0.5086	-7.1566
Panel C: Covariance stationarity		
	0.9850	0.9446
	-0.7354	-0.7061

Notes: The parameters are estimated based on the following specification:

$$\Delta Baaspread_t = a_1 + b_1 S\&P500_{t-1} + c_1 \sqrt{h_{11,t}} + u_{1,t}$$

$$S\&P500_t = a_2 + b_2 S\&P500_{t-1} + c_2 \sqrt{h_{22,t}} + u_{2,t}$$

$$H_t = C'C + A'H_{t-1}A + B'u_{t-1}u'_{t-1}B$$

TABLE V
LIKELIHOOD RATIO TEST RESULTS

Unrestricted model	L_u	D
Model 1	226.7180	14.19
Model 2	259.3446	40.26*
Model 3	-491.1248	37.21*
Restricted model	L_r	
Model 1	219.6243	
Model 2	239.2146	
Model 3	-509.7307	

Notes: The likelihood ratio test is calculated as $D = -2(L_r - L_u)$, where L_r represents the value of the likelihood function of the restricted model and L_u is the value of the likelihood function of the unrestricted model. The unrestricted model refers to the full BEKK-GARCH model and the restricted model to the diagonal BEKK-GARCH model. The D statistic follows a χ^2 distribution with 12 degrees of freedom. (*) denotes statistical significance at the 5% level.

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