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The effect of the subprime crisis on the credit risk in global scale

Sangwook Lee [a,1], Min Jae Kim [b,1], Sun Young Lee [c,1], Soo Yong Kim [a,*], Joon Hwa Ban [b]

[a] Department of Physics, Korea Advanced Institute of Science and Technology, Daejeon 305-701, Republic of Korea

[b] Financial Engineering Research Center, FnPricing Inc., 197-27, Insa-Dong, Jongro-Gu, Seoul, Republic of Korea

[c] Financial Engineering Department, Woori Investment & Securities, 23-4 Yoido-dong, youngdungpo-gu, Seoul, Republic of Korea

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ABSTRACT

Credit default swap (CDS) has become one of the most actively traded credit derivatives, and its importance in finance markets has increased after the subprime crisis. In this study, we analyzed the correlation structure of credit risks embedded in CDS and the influence of the subprime crisis on this topological space. We found that the correlation was stronger in the cluster constructed according to the location of the CDS reference companies than in the one constructed according to their industries. The correlation both within a given cluster and between different clusters became significantly stronger after the subprime crisis. The causality test shows that the lead lag effect between the portfolios (into which reference companies are grouped by the continent where each of them is located) is reversed in direction because the portion of non-investable and investable reference companies in each portfolio has changed since then. The effect of a single impulse has increased and the response time relaxation has become prolonged after the crisis as well.

1. Introduction

Until recently, most researchers in econophysics have analyzed the statistical characteristics of stock markets, interest rate markets, and foreign exchange markets exclusively [1–3]. However, as most fund managers and traders went through the recent consecutive crises from the subprime crisis to the sudden increase of commodity prices, they have paid much more attentions to alternative investment securities. Academics have been required to analyze how the crisis broke out related to some investment securities. In particular, the influences of shocks originated from credit derivatives need to be studied since they are pointed out as main causes of the notorious subprime crisis. Of course, there are works which tried to handle the credit-related issue in statistical physics. For example, there was reported a power-law scaling in debt over assets (for both bankrupt and surviving firms) which may be considered as an estimator for credit risk [4]. And the enhanced correlation matrix approach and the weighted linkage of network model were suggested to study credit risk [5–8], and the collective default and the implied correlation problem within credit derivatives were explained with a simple model [9,10].

The main difficulty of the empirical study on credit risk is that a credit event – which the payoff of a credit derivatives depends on – has not frequently been observed, and is nontradable, and so cannot be regarded as a tangible security. For these reasons, the default model of a single company is based on a proxy of a credit event: an easily observable stock

* Corresponding author. Tel.: +82 42 869 2529.
E-mail address: sykim@kaist.ac.kr (S.Y. Kim).

[1] The first three authors contributed equally to this paper.

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price. It assumes that the stock price of a given company is determined by a call option price whose underlying asset is its asset value and whose strike price is its liability amount. The model built on this assumption is called the structural model, and the Merton model and Moody's KMV model are the most popular ones in this family [11–13]. With the advent of more complex-structured credit instruments like collateral debt obligation, a model that can handle the simultaneous or consecutive defaults of reference companies is required. The reduced form model is commonly used to satisfy this need since it prices credit derivatives written on several reference companies [12,13]. Unfortunately, the reduced form model cannot successfully calibrate the dependence structure of a credit event, since it fixes the transition probabilities from one credit rating to another credit rating. In other words, it fails to consider more realistic dependence structures between default risks of reference companies. Some econophysics papers have noticed this problem and tackled it [14,15], but more research will be needed on this subject.

Credit default swap (CDS) is the insurance to prevent the value of a stock ownership from declining when a credit event occurs. In this contract, CDS buyers pay the predetermined spread periodically to transfer default risks to CDS sellers who are willing to take risks. The CDS spread, the periodical payment obligated to buyers, is the equilibrium rate of quotes made by CDS buyers and sellers. This CDS spread differs according to the credit rating of its reference company and time to maturity of the contract, and changes according to the expected credit dynamics. As the CDS becomes actively traded and many countries keep trying to enhance its liquidity, the CDS spread can successfully measure credit ratings of the reference companies in a timely manner. Therefore, newly invented exotic credit derivatives need to refer to the CDS spread, as the parameters of exotic equity options are calibrated to match implied volatilities of liquid vanilla options [16]. In other words, credit risk can be classified as a tangible asset in light of the CDS spread. The structure of credit risk dynamics can be studied using the CDS spread dynamics, and this work can be helpful to construct more realistic credit risk models. Furthermore, since the market of credit derivatives including CDS is still regarded as a 'blue ocean' for traders, there must be plenty of opportunities to achieve excessive returns if we can find an unobserved market anomaly.

In this paper, we analyze the dependence structure of credit risks based on the CDS spreads written on many international companies. We found that financial companies play a role as the links between different continental regions and that the factor of a reference company's geographic location is the most important one driving the CDS spread dynamics. We also studied how the hierarchy structure changed after the subprime crisis, and confirmed that the correlation of all the variables increased like in the stock market case [17]. Then, we grouped all the sample reference companies into several portfolios composed of those with the same continent in their geographic locations and revealed the lead lag effect, i.e., how long in terms of time lag one random variable influences another one, between their different continent groups. For this analysis, we used the vector autoregression (VAR) model, which is commonly used to test the causality between random variables, and we also calculated the response function, which represents the influence of one random variable on another random variable [18–21].

This paper is organized as follows. In Section 2, we briefly refresh a concept of the network, the vector autoregression model, and we disclose the data set for this research. In Section 3.1, the internal structure of the CDS spread in a single reference company is presented to enhance comprehension of the dependence structure of the CDS spread for time to maturity. Then the networks constructed by the dynamics of the CDS spread are analyzed for the total sample period in Section 3.2. A study of the influence of the subprime crisis on the topological space of the CDS follows. In Section 4, the VAR methodology is used to research a statistical causality between movements of CDS portfolios which consists of reference companies whose headquarters are located in the same continent. For this test, a Granger causality test and impulse response functions are applied. Finally, this paper is closed with a brief summary in Appendix.

2. Methodology

2.1. Network

Two types of network are selected to analyze the structure of the CDS spreads written on the different companies placed in various countries. In the first network, the nodes are connected only if the correlation between the CDS returns is over a given threshold $\tilde{\rho}$ as follows:

$$\rho(r_t^i, r_t^j) \geq \tilde{\rho}. \tag{1}$$

Here, $\rho(r_t^i, r_t^j)$ is the correlation between two time series of r_t^i and r_t^j, which are defined as

$$\rho(r_t^i, r_t^j) = \frac{\langle (r_t^i - \langle r_t^i \rangle)(r_t^j - \langle r_t^j \rangle) \rangle}{\sigma(r_t^i)\sigma(r_t^j)}, \tag{2}$$

where $\langle \ldots \rangle$ is the average of ..., $\sigma(\ldots)$ is the standard deviation of ..., and the return of the CDS spread, r_t^i, is

$$r_t^i = \ln\left(\frac{S_t^i}{S_{t-1}^i}\right). \tag{3}$$