Paper:

Improved Debt Rating Model Using Choquet Integral

Toshihiro Kaino*, Ken Urata, Shinichi Yoshida***, and Kaoru Hirota*****

*School of Business Administration, Aoyama Gakuin University
4-4-25 Shibuya, Shibuya-ku, Tokyo 150-8366, Japan
E-mail: kaino@busi.aoyama.ac.jp
**DENTSU INC.
1-8-1 Higashi-shimbashi, Minato-ku, Tokyo 105-7001, Japan
***Information Science Research Center, Aoyama Gakuin University
5-10-1 Fuchinobe, Sagamihara-shi, Kanagawa 229-8558, Japan
****Department of Computational Intelligence and Systems Science,
Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology
Midori-ku, Yokohama 226-8502, Japan
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Improved long-term debt rating model using Choquet integral is proposed, where the input is qualitative and quantitative data of the corporations, and the output is the Moody's long-term debt ratings. The fuzzy measure, which is given as the importance of each qualitative and quantitative data, is derived from a neural net method. Moreover, differentiation of the Choquet integral is applied to the long-term debt ratings, where this differentiation indicates how much evaluation of each specification influence to the rating of the corporation. A long-term debt rating model using Choquet integral was proposed by Kaino and Hirota [1]. Under the ambiguous information which couldn't be expressed by the statistics model, this Kaino and Hirota model [1] enabled analysis of the amount of influences of a specific variable, and showed the new possibility in the field of credit risk measurement. However, in order to develop a practical system for small and medium-sized corporations with many needs, this model must be improved so that it may correspond to the changing market or many types of industry. Moreover, this model is modified by the implementation of actual rating provider's similar process to raise the relevance ratio. The advanced model proposed herein corporations than the model is more precise than conventional model using 2-layer type neural network model.

Keywords: differentiation, Choquet integral, improved long-term debt rating model

1. Introduction

Although a credit risk is one of the historical risks in a financial market, compared with a market risk, the scientific management technology is not developed enough. In a corporate bond market, a credit spread goes up from a bankruptcy of Yamaichi Securities in 1997, and the Hokkaido Takushoku Bank. And the credit risk is increasing by the MMF extensive cancellation, the MYCAL bankruptcy and the Enron bankruptcy in 2001. Such a background demands the establishment of a scientific technique of credit-risk management. As an econometric model of a credit risk, Z score model [2] by the multivariable-analysis technique and a ZETA credit risk model [3] are proposed by Altman and others. These have been used till today. Although such an econometrics technique has been studied for a long time [4], it is criticized as the experiential model lacking theoretical backgrounds, and has been compared with theoretical approach [5]. Moreover, new approaches based on neural networks [6, 7] have been proposed. However, there is no capability for neural network model to explain the factor used as the basis of credit judgment. There are the EDF model [9] of KMV based on Merton model [8], the Longstaff, & Schwartz model [10], and the Jarrow, Lando & Turnbull model [11] as other credit risk models. Although the research on credit risk measurement progresses, the credit rating provider's role has not changed. And, the credit risk information of the credit rating provider is esteemed by the market participant [12]. For instance, Moody's publishes market-leading credit opinions, deal research and commentary that reach more than 3,000 institutions and 22,000 subscribers around the world. It is researched to make clear the rating determination process by the credit rating providers, and the influence factor of rating [13]. Moreover, Kaino and Hirota [1] proposed the model that can deal well with the qualitative information corresponding to a credit analyst's sensitivity and quantitive information as financial information. Then, Kaino and Hirota model [1] is modified by the implementation of actual rating provider's similar process to raise the relevance ratio.

2. Application to Long-Term Debt Rating Model Using Differentiation of Choquet Integral

2.1. Differentiation of Choquet Integral

The concept of fuzzy measure and fuzzy integral has been introduced by Sugeno [14] and the functional (the Choquet integral) defined by Choquet [15] has been recognized as fuzzy measure again. Choquet integrals have been applied to multi-criteria evaluation and prediction fields because of easiness to use [16, 17]. Moreover, differentiation of the Schmeidler Choquet integral based on a measurable function is defined by Kaino and Hirota [1] as Definition 1.

Definition 1. Let $(X, \mathbf{F}, \mu)$ be a fuzzy measure space. Let f be a nonnegative measurable function and F be a $[0, r]$ limited Schmeidler Choquet integral of f with respect to a fuzzy measure μ. For any measurable function f, if $\mu(X) < \infty$ and

$$\lim_{\Delta r \to +0} \frac{F(r+\Delta r) - F(r)}{\Delta r} = D^+F(r) = F'_+(r) \quad . \quad (1)$$

exists, this limit is called an upper differential coefficient of the $[0, r]$ limited Schmeidler Choquet integral F of f with respect to μ at r. Similarly, if

$$\lim_{\Delta r \to -0} \frac{F(r+\Delta r) - F(r)}{\Delta r} = D^-F(r) = F'_-(r) \quad . \quad (2)$$

exists, this limit is called a lower differential coefficient of the $[0, r]$ limited Schmeidler Choquet integral F of f with respect to μ at r. If the only if both the upper differential coefficient and the lower differential coefficient of F at r exit and are equal, they are denoted by

$$DF(r) = F'(r) = \frac{dF(r)}{dr} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and is called a differential coefficient of the $[0, r]$ limited Schmeidler Choquet integral F of f with respect to μ at r.

2.2. Long-Term Debt Rating Model

Generally, the long-term debt ratings of each rating institutions are determined by the analyst's experience and know-how. Then, it is very difficult for each rated corporations to find how to raise their rating results, clearly. So, after the identification of the long-term debt ratings model using the real interval limited Choquet integral, the advisory system to raise the rating using differentiation of the Choquet integral was proposed by Kaino and Hirota [1]. Now, the following 10 quantitative index and 4 qualitative index, which are often used actually, are selected as the input data (see **Table 1**). The total evaluation of each corporation is given by the importance of each index μ which is determined by the neural network method using qualitative and quantitative index as Eq.(4).

Table 1. Kaino & Hirota model's index [1].

10 quantitative Index
business profit, cash flow, interest coverage, quick ratio, current assets ratio, inventory turnover, turnover of receivables, ROE, ROA, leverage
4 qualitative Index
share, management, organization, regulation

Table 2. Improved model's index.

9 quantitative Index
leverage, interest coverage, ROE, ROA, logarithm equity capital, current assets ratio, fixed assets ratio, inventory turnover, turnover of receivables
3 qualitative Index
market condition, corporate image, type-of-industry trend

$$F(\infty) = (C)\int_X f d\mu = \sum_{i=1}^{14} \{D^-F(r_i) - D^+F(r_i)\} r_i. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Now, on Eq.(4), it is noticed that the coefficient of each r_i is "the lower differential coefficient $(D^-F(r_i))$ − the upper differential coefficient $(D^+F(r_i))$". So, this coefficient is considered to be the change of the total evaluation of the each corporation as the evaluation of each index change slightly. Hence, let $V(x_i)$ be the change of the total evaluation of the corporations as the evaluation of index change slightly as

$$V(x_i) = D^-(r_i) - D^+F(r_i). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

3. Improved Debt Rating Model Using 2-Layer Neural Network Model

3.1. Improved Index

According to the efficient market hypothesis, financial data is reflecting only the information on the past of the company. Therefore, in order to raise the generality of a model, it is necessary to use the index explaining the present market condition. Moreover, in order to raise the precision of rating, the characteristic for every type of industry for an index must be taken into account. In the proposed model, the index of **Table 2** was selected in consideration of the index, which is raising the result with the credit risk measurement model [18] by Moody's Investors Service as a financial index. Since there are ROE and ROA that is the index of profitability, business profit and cash flow are not selected and the logarithm equity capital that expresses a company scale is added for the new model's index.