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An approach to evaluating the spontaneous and contagious credit risk for supply chain enterprises based on fuzzy preference relations

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ABSTRACT

Measuring credit risk for supply chain enterprises is a critical issue for credit agencies and it becomes more complicated thanks to interrelated transactions among enterprises across the supply chain. Firstly, we put forward a basic model for assessing supply chain enterprise credit risk by splitting overall credit risk into spontaneous and contagious credit risk. Secondly, after constructing an evaluation indicator system for supply chain enterprises, we determine spontaneous credit risk by employing fuzzy preference relations. Thirdly, we establish a risk numerical matrix to measure contagious credit risk based on spontaneous credit risk and analyze its cumulative effect using a matrix analysis. Finally, a real-world case study is presented to illustrate how the proposed model can be applied to assess supply chain enterprise credit risk.

1. Introduction

Nowadays, increasingly fierce competition forces financial institutions to seek new businesses for continued profits, especially when supply chain financing (SCF) is involved. In China, SCF started as a new financing model to deal with the difficulties faced by small and medium enterprises (SMEs) several decades ago. Now, it has grown to be a crucial component for commercial banks to enhance their profitability. In this process, risks have to be carefully assessed from both an individual firm's perspective and a supply chain risk management angle (Chen & Wu, 2013; Sunjka & Sklar-Chik, 2012), posing significant difficulty for commercial banks in granting credit to SMEs. Generally, banks are mainly concerned with defaults by enterprises due to changes in operation conditions, industrial environment, as well as other macrofactors. In the context of supply chains, default behavior becomes more complicated due to the interconnected transactions among supply chain enterprises, which could lead to a higher probability of defaults through a contagious way when one enterprise in the supply chain fails. As such, the problem of defaults in supply chain poses a significant challenge to the SCF business and creates an urgent need for a comprehensive method to assess credit risk in the context of supply chain network.

Extensive literature has been devoted to credit risk evaluation ranging from structural models such as the KMV model proposed by McQuown (1993) to other reduced-form models based on the structural models. For instance, Jarrow and Turnbull (1995) employed intensity functions to devise a reduced-form model. Subsequently, Lando (1998) established a Cox model to overcome the shortcoming of a constant intensity function in Ref. Jarrow and Turnbull (1995). Generally speaking, the reduced-form models require much less information compared to structural models in evaluating credit risk. Later on, new assessment models were developed based on statistics and data mining techniques, such as the neural network model (West, 2000), support vector machine model (Bellotti & Crook, 2009), logistic model (Steenackers & Goovaerts, 1989), to name a few. For practitioners in commercial banks, a general complaint about these models is that they are often too technical and complicated to be used in practice. In addition, these models generally cannot handle vague or uncertain information that is inherent in credit risk analysis. As such, when banks evaluate credit risk in practice, the classic Altman's Z-score model (Altman, 1968) and the ZETA model (Altman, Haldeman, & Narayanan, 1977) are often adopted for their easy use based on multiple indicators.

Furthermore, the afore-mentioned models assess credit risk within a single enterprise. This risk is typically caused by the firm's

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operation conditions and industrial environment, and is referred to as spontaneous credit risk in this paper. However, in the context of a supply chain, as the transactions among the supply chain enterprises are often interrelated, the credit risk of one firm is not only dependent on its own managing faculty, but also contingent upon other partners' conditions. This type of potential risk is defined as contagious credit risk herein. Until now, very limited research considers contagious credit risk. Zhou (2001) developed a first-passage-time model to provide an analytical formula to calculate credit default correlations. Giesecke (2004) proposed a model of the correlated multi-firm default with incomplete information by using default time copula as a consistent default correlation measure. However, both Zhou (2001) and Giesecke (2004) did not account for the effect of the related transactions that are closely related to contagious credit risk. As such, none of the aforesaid research can quantify contagious credit risk in SCF. To address these issues, a key contribution of this article is to put forward a model to evaluate contagious credit risk under related transactions. This innovative credit risk evaluation model introduces a risk numerical matrix (RNM) to specify the effect of the related transactions and reflect the supply chain network structure for a better evaluation of contagious credit risk.

Generally speaking, when banks evaluate credit risk, it is typical that multiple criteria should be considered, consisting of quantitative and qualitative factors. It is often a significant challenge to unify these distinct factors and obtain a risk metrics value. In recent years, multi-criteria decision making has been proven an efficient method to deal with various problems, such as the choice of suppliers in supply chain (Sinha & Anand, 2016), the evaluation of the industrial robotic systems (Kahraman, Çevik, Ates, & Gülbay, 2007), and the problem of a bi-objective personnel assignment (Huang, Chiu, Yeh, & Chang, 2009). Naturally, a risk assessment problem also needs to account for multiple criteria. For instance, the fuzzy judgment methods (Nieto-Morote & Ruz-Vila, 2011; Wang & Elhag, 2007; Wang, Liu, & Quan, 2016) have been widely used for risk assessments. In addition, when banks assess credit risk of supply chain enterprises, some information may be readily available in a crisp manner, but it is often the case that some other aspects can only be assessed in a fuzzy or uncertain manner. This type of fuzzy input data could not be properly processed by the traditional credit risk evaluation methods, calling for a new method for assessing the credit risk in SCF. The existing research has demonstrated that fuzzy preference relations are a popular tool to elicit a decision maker's fuzzy and uncertain judgments in a pairwise comparison matrix, thereby facilitating the derivation of his/her priority weights among difference choices (Wang & Fan, 2007). To respond to the need for a new method, this paper employs fuzzy preference relations (Zhu, Xu, Zhang, & Hong, 2015) for processing the decision input data in SCF credit risk assessments.

The aforesaid literature review reveals that existing literature has not paid enough attention to contagious credit risk, which is a significant issue in the context of SCF. This paper aims to close this gap by proposing a comprehensive decision framework for evaluating credit risk in SCF. We firstly describe the path of two types of credit risk, then establish a model to evaluate them quantitatively by combining the evaluation indicator system and the concept of fuzzy preference relations. Furthermore, in the evaluation process, we take the cumulative effect of default contagion into account via a matrix analysis. Our work is closely related to the classic Altman's Z-score model (Altman, 1968) and the ZETA model (Altman et al., 1977), and the approach constructed in this paper is easy for use in practice.

The contribution of this research is threefold: Firstly, it categorizes credit risk into spontaneous and contagious credit risk, and assesses them separately based on their specific features. This treatment makes our model more reliable and easier to quantify, thereby making it more understandable and acceptable to the analyst and practitioners. Secondly, by employing fuzzy preference relations to process the indicator judgment inputs, this approach facilitates the analyst or the practitioners to offer their judgment information and extends the application of fuzzy preference relations in a new branch. Thirdly, the proposed framework can properly assess contagious credit risk and furnish a convenient quantitative tool for commercial banks to evaluate the credit risk in SCF, thereby facilitating their decision-making process.

The remainder of this paper is organized as follows. In Section 2, we establish a basic model for assessing credit risk in supply chains by dividing credit risk into spontaneous and contagious default risk and linking them by using a matrix analysis. In Section 3, we evaluate the spontaneous credit risk for supply chain enterprises by constructing an evaluation indicator system, where fuzzy preference relations are employed as an information processing tool. In Section 4, based on the spontaneous credit risk evaluation, we establish a RNM under the framework of the contagious path to evaluate contagious credit risk for supply chain enterprises. In Section 5, we provide a case study to illustrate how the proposed model can be applied in practice. Section 6 concludes the paper with brief remarks.

2. Basic model for measuring the supply chain enterprise credit risk

In this section, we describe the model used to evaluate the supply chain enterprise credit risk. We divide the credit risk of supply chain enterprises into two components: spontaneous credit risk and contagious credit risk. Spontaneous credit risk refers to the probability of credit default by some supply chain enterprises against financial institutions, such as banks due to the changes in their operating conditions, the industrial environment, or other factors. Contagious credit risk refers to the probability of credit default by some supply chain enterprises against financial institutions such as banks due to the credit default behaviors of other supply chain enterprises or declines in their credit status. To facilitate the construction of the basic model for measuring the supply chain enterprise credit risk, we make the following three assumptions:

Assumption 1. An enterprise may default more than once during transactions. The risk probability is cumulative and it is derived from the existence of several key factors or one factor that may arise several times.

Assumption 2. There is no added or removed risk, i.e., the structure of supply chain will not change during the period of analysis.

Assumption 3. The credit risk of one enterprise can infect that of related enterprises via direct contagion, while indirect contagion can allow the credit risk of one enterprise to infect unrelated enterprises by spreading credit risk to other related enterprises.

In the supply chain system, we assume that there are N upstream and downstream enterprises, and one core enterprise, which is a leading enterprise connected to the upstream and downstream enterprises, and coordinates the allocation of resources and improves the competitiveness of the supply chain. To measure an enterprise's credit risk in the supply chain system, we have to consider the spontaneous credit risk, which may be amplified through the transaction with others. Furthermore, the contagious credit risk should also be considered.