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Predicting multilateral trade credit risks: comparisons of Logit and Fuzzy Logic models using ROC curve analysis

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Abstract

Employing pooled data of 3344 listed firms from seven Asia-Pacific countries, this is the first empirical study to classify and predict trade credit risks in the international trade context. In addition, this paper extends previous work by applying receiver operating characteristic (ROC) curve analysis to compare the model performance of Logit to that of Fuzzy Logic (FL). We are unaware of any other paper that has discussed the application of ROC curve analysis in the business and finance literature.

The results show that FL exceeds Logit in terms of overall classification accuracy and prediction accuracy. However, by incorporating measurement in the form of ROC curves, Logit is proven to outperform FL in classifying non-default firms. This suggests that though FL is superior in overall accuracy and in classifying default firms, Logit is preferable in situations where higher accuracy in classifying non-default firms is preferred. The stability of the models is also demonstrated.

Keywords: Trade credit risk prediction; Logit; Fuzzy Logic; Receiver operating characteristic curve analysis

1. Introduction and background to research

In recent years, intensified market competition in international trade has led to letter of credit (L/C) being replaced by open account (O/A). For exporters, however, sales on credit have greatly increased the amount of their foreign receivables and thus have had a severe impact on the operational risks, causing problems such as difficulties in capital turnover, fluctuations in exchange rate, bad debts, and decrease of profits due to the de facto discounts. The bad debt risk generated from accounts receivable default of the client on credit is usually called the credit risk of trade.

The empirical data from one of our prior studies (Tang & Chi, 2002) seeking to set out the export-credit-granting decisions made by 1200 credit managers of Taiwan manufacturing firms showed that 41.6% of their O/A-credit sale was granted to their Asian foreign buyers in 2001. We also found that 65.2% of exporters experienced late payment and 53% experienced non-payment from their trade credit applicants. Furthermore, the study showed that 54.3% of export credit managers assessed the creditworthiness of the foreign buyers most highly on the basis of their subjective judgment and past experiences, and not on a scoring or rating system. The study concluded by asserting that the seller's failure to employ an effective credit risk prediction system to conduct prior evaluation on the buyers' creditworthiness was the main contributing factor of non-performing receivables.

Default problems of trade credit applicants fall basically within the scope of discrimination and classification problems (Johnson & Wichern, 1998). During the past 30 years, there have been developments in the statistical techniques used to construct models and the measurement of explanatory variables. Altman (1968) and Beaver (1966) contribute significantly to the classification and prediction of business creditworthiness by adopting a univariate model and a multiple discriminant analysis (MDA), respectively. However, the validity and effectiveness of such methods depend largely on some restrictive assumptions. To avoid the defects of MDA, Ohlson (1980) proposes the logistic regression (Logit), which is found to be the most accurate of the traditional statistical methods for prediction

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and classification problems (see Barniv, Agarwal, and Leach (2002), Poon, Firth, and Fung (1999), and West (2000)).

Trading decision-making or the process of predicting default risks involves a high degree of subjective human judgment. Human value systems and perceptions, however, are usually imprecise or vague and cannot be directly captured by conventional precise mathematics. In light of this, since the 1980s scholars have tried adopting artificial intelligence techniques to find better classification tools. Fuzzy Logic (FL), formulated by Zadeh (1965), provides a systematic way of handling vague and imprecise information on input data, their effects on the system, and the output. Subsequent research extending the methodology and context of FL has been studied extensively in many business applications including default risks prediction (see Levy, Mallach, and Duchessi (1991) and Romaniuk and Hall (1992)). Many other researchers also report that the FL-based model is found to have good predictive ability (Dourra & Siy, 2002; Lia, Mukaidonob, & Turksenc, 2002).

Amongst the methods employed to compare the effectiveness of different statistical models, receiver operating characteristic (ROC) curve analysis is often used in biomedical and psychophysical applications to summarize the discriminatory accuracy of a diagnostic test as well as to compare the performance of different models for binary outcomes (Lloyd, 1998; Marzban, 1998; Pepe, 2000). To date, however, the research issue relating to the application of ROC curve analysis has not been discussed in prior business and finance literature. Starting out from an innovative perspective, this paper classifies and predicts trade credit risks in the Asia-Pacific business context using, respectively, Logit and FL. We are unaware of any other paper that has developed such trade credit risk models in an international context. In addition, this paper extends previous work by providing an empirical exposition of the ROC curve analysis, where we present the results of an experiment which applies the ROC curves to compare the model performance of Logit to that of FL.

We use a sample of 3344 listed Asia-Pacific firms for which we have data during the period 1999–2002. We show that FL models give good results and get the better of Logit models in terms of overall classification accuracy and prediction accuracy. However, by incorporating the measurement in the form of ROC curves, we also find that Logit outperforms FL in classifying non-default firms. This suggests that even though FL is superior in overall accuracy and in classifying default firms, Logit is preferable in situations where higher accuracy in classifying non-default firms is preferred.

The remainder of the paper is organized as follows. In Section 2, we give a brief exposition of FL and ROC curve analysis. Section 3 describes the data sources, sample selection criteria, and variable selection process. Section 4 presents the empirical results. Section 5 concludes.

2. An overview of FL and ROC curve analysis

2.1. An overview of FL

Unlike conventional methods that entail an understanding of a system, exact equations, and precise mathematical values, FL incorporates an alternative way of thinking and reasoning, which allows anticipating or modeling the complex problem domain using a higher level of vagueness via our knowledge and experience. One of the characteristics of FL is its ability to be both linguistically tractable and mathematically sound. It resembles human decision-making with its ability to work from approximate information and find precise results. Hence, FL allows expressing knowledge with subjective beliefs and expert judgments such as ‘the industry risk is low’ and ‘the product life cycle is very long’, which are mapped into exact numeric ranges.

2.1.1. Fuzzy set theory

A classical set is a set with a crisp boundary, i.e. an element of the universe either belongs or does not belong to the classical set. By contrast, a fuzzy set is a set that allows the degree of membership for each element to range over the unit interval [0, 1]. This feature of fuzzy membership functions (MFs) provides a more robust mathematical technique to deal with non-linear and complex problems, mimicking the way that the brain handles vague information and formulating pertinent rules from the data.

A fuzzy set F in a universe of discourse U can be formulated as a set of ordered datasets,

$$F = \{(x, u_F(x)|x \in U\}$$

where $u_F(\cdot)$ is called the MF of F and $u_F(x)$ is the degree of membership of x in F, which suggests the degree that x belongs to F. The types of parameterized functions, namely triangular, trapezoidal, sigmoid, and Guassian MFs, used to define fuzzy MF mainly rely on the particular modeling issue. The MF is a graphical representation of the magnitude of each input. It associates a weighting with each of the inputs that are processed, defines functional overlap between inputs, and decides an output response. The rules use the input membership values as weighting factors to determine their influence on the fuzzy output sets of the final output conclusion. But the meanings in nature and how MFs are originated are not yet clearly explicit. Typically, the MF selected is often a compromise between the available information, the expert knowledge and the context.

Many set operations have been defined in the literature. The most common operations are union, intersection, and complement. Let A and B be fuzzy sets in the universe of discourse U with MFs and u_A and u_B, respectively. The union of fuzzy sets A and B denotes as $A \cup B$ or A OR B. The intersection of fuzzy sets A and B denotes as $A \cap B$ or A AND B. The complement of fuzzy set A denotes as $\bar{A}$ or