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Municipal credit rating modelling by neural networks

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ABSTRACT

The paper presents the modelling possibilities of neural networks on a complex real-world problem, i.e. municipal credit rating modelling. First, current approaches in credit rating modelling are introduced. Second, previous studies on municipal credit rating modelling are analyzed. Based on this analysis, the model is designed to classify US municipalities (located in the State of Connecticut) into rating classes. The model includes data pre-processing, the selection process of input variables, and the design of various neural networks' structures for classification. The selection of input variables is realized using genetic algorithms. The input variables are extracted from financial statements and statistical reports in line with previous studies. These variables represent the inputs of neural networks, while the rating classes from Moody's rating agency stand for the outputs. In addition to exact rating classes, data are also labelled by four basic rating classes. As a result, the classification accuracies and the contributions of input variables are studied for the different number of classes. The results show that the rating classes assigned to bond issuers can be classified with a high accuracy rate using a limited subset of input variables.

1. Introduction

Credit rating process is an independent evaluation whose aim is to find out how an object is capable and willing to meet its payable obligations, specifically based on complex analysis of all the known risk factors of the assessed object. It is realized by a rating agency. A higher credit rating shows a low credit risk. According to the assessed object, credit ratings of the state, company, municipality, financial institution, single bond, etc. exist. Credit rating is a result of a credit rating process. It is represented by a rating class defined on a rating scale. Rating classes are assigned to assessed objects.

Credit ratings are used by bond investors, debt issuers, and governmental officers as a measure of the risk of a company. They provide a means of determining risk premiums and marketability of bonds, allowing firms issuing debt to estimate the likely return investors require. Bankers and companies considering providing credit rely on credit ratings to make important investment decisions, many regulatory requirements for financial decisions are based on credit ratings, etc.

Credit ratings are costly to obtain because rating agencies invest large amount of time and human resources to perform the credit rating process. Therefore, there has a large much effort made in order to simulate the credit rating process of rating agencies through statistical (e.g. [23], [34], [35]), and soft-computing methods (e.g. [7], [32], [51]). The difficulty in designing such models lies in the subjectivity of the credit rating process. Complex relations between financial and other variables are evaluated. Such a complex process makes it difficult to classify rating classes through statistical methods. However, soft-computing methods (neural networks [7], [38], [36], fuzzy systems [3], [51], evolutionary algorithms [6], artificial immune systems [14], [40], and hybrid systems [37]) can be applied for the modelling of such complex relations. High classification accuracy has been achieved especially by neural networks (NNs) [7], [50] and support vector machines (SVMs) [32], [41] in corporate credit rating modelling. In economics and finance, NNs (including SVMs) are usually applied in such cases where variables are in non-linear relations. This is reported to be typical for economic and financial data [24]. NNs make it possible to model these relations as they learn the dependencies in training data. As a result, gained knowledge is stored in synapse weights. Moreover, the knowledge can also be applied for unknown input data which were not used in the training process. This is also known as generalization ability of NNs. The disadvantage of NNs lies in the fact that NNs are usually designed as so-called “black boxes”, i.e. it is difficult to extract understandable knowledge from them. Therefore, prior studies in modelling credit rating are aimed at quantifying the effect of input variables for classification, i.e. to find out which input variables are crucial for credit rating process. Mostly, sensitivity analysis has been employed for this purpose. Based on the mentioned facts, it is possible to state that the methods capable of processing and learning the expert knowledge, enabling their user to generalize and properly interpret, have proved to be most suitable for credit rating modelling.

The paper is structured as follows. First, basic components of credit rating process will be introduced. Further, current methods used for

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municipal credit rating modelling will be reviewed. Then, basic notions of NNs will be presented with an emphasis on NNs' models suitable for classification problem realization. Using a number of NNs for credit rating modelling has so far not been reported in prior studies. Using probabilistic NNs, GMDH NNs, or cascade correlation NNs is novel in credit rating modelling. Moreover, the modelling of municipal credit rating process has only been realized through statistical methods previously. The input variables for the modelling are designed based on all the aspects of economic and financial performance of municipalities. Most input variables used in this study have also been used in previous works. However, compared to previous studies, a more complex set of input variables is proposed in this study. It involves economic, debt, financial, and administrative categories. In order to get an optimum set of input variables, a novel two-step approach is proposed. First, the original set of input variables is optimized by a combination of a correlation-based approach and genetic algorithms (GAs). Then the contribution of selected input variables is studied using sensitivity analysis, with the intention to compare the relative importance of the input variables. The contribution analysis of input variables for different numbers of rating classes has also not been previously realized. Finally, the gained results will be compared across selected models of NNs and benchmark methods.

2. Credit rating modelling

Credit rating modelling is regarded as a classification problem, i.e. as supervised learning. For its realization, rating classes assigned by a rating agency should be known in advance. The rating classes represent a result of credit rating process. Therefore, credit rating process and credit rating modelling is introduced in this part of the paper.

2.1. Credit rating process

As presented above, credit rating process represents a subjective assessment of both quantitative and qualitative factors of a particular object (company, municipality, etc.) as well as industry and market factors.

The credit rating process begins with an application to the rating agencies by the issuer (object). The object contacts a rating agency and requests an issue of credit rating to the new debt or to the object. Documentations like financial statements, the preliminary official statement, a prospectus for the debt issue, other non-financial information, etc. are provided to the rating agencies. Discussions take place between the rating agency and management of the object, and a rating report is prepared by the credit analysts examining the object. Key analytical factors are discussed in the rating report. The credit analyst provides a recommendation for credit rating to a rating committee. The committee decides the credit rating to be assigned to the object. The result of this process is represented by an assignment of a rating class to the assessed object. The assignment is based on an evaluation of relevant economic, financial, and management factors. Finally, the rating is released to the issuer, followed by a publication of a full credit report. The assessed objects pay a fee to the rating agencies for the credit rating.

Rating agencies emphasise that the credit rating process involves consideration of financial, as well as non-financial, information about the object, and also considers industry and market-level factors. The precise factors, and related weights of these factors used in determining a credit rating, are not publicly disclosed by the rating agencies. As a result, credit ratings issued by different rating agencies need not to be the same. In a comparison of the ratings of Standard & Poor's and Moody's [39], it was found that in a sample of 1607 US bond ratings of investment grade, the two rating agencies differed in 836 credit ratings. In the cases where the rating classes differed, the difference was more than one rating class in 111 cases. Rating agencies should preserve independency and objectivity in their evaluation. Their assessment is widely respected by financial markets.

All public credit ratings are monitored on an ongoing basis. It is common to schedule an annual review with management. Subsequent to the initial credit rating, an object may be re-rated upwards (upgrade) or downwards (downgrade) if the object or environmental circumstances change. The effect of an object being assigned a lower rather than a higher credit rating is that its riskiness is considered to be higher, and consequently the required interest yield of the bonds rises.

Credit rating can be defined as the process of a rating class assignment to an object according to expected default probability. Rating class indicates the probability that the given object will be capable to meet its payable obligations. It is defined on the rating scale. Rating classes are ranked in the rating scale according to credit risk rate. Although the precise notation used by individual rating agencies to denote the credit rating of an object varies, in each case, the credit rating is primarily denoted by a 'letter'. Rating agencies such as Standard & Poor's (S&P's), Moody's, and Fitch belong to the most important rating agencies. Taking the rating scale of Moody's as an example, the credit ratings are broken down into 9 broad rating classes. The strongest rating class is denoted as Aaa, and the rating classes then decrease in the following order, Aa, A, Baa, Ba, B, Caa, Ca, and C. Therefore, credit ratings are typically conveyed to investors by means of a discrete, mutually exclusive, letter grade. Rating classes between Aaa and Baa (inclusive) are considered by investors to represent 'investment grade', with lower quality rating classes considered to represent debt issues with significant speculative (risky) characteristics (non-investment grade or 'junk' bonds). A 'C' grade represents a case where a bankruptcy petition has been filed, or a case where the borrower is currently in default on its financial obligations. Moody's applies numerical modifiers 1, 2, and 3 in each generic rating classification from Aa through Caa. The modifier 1 indicates that the obligation ranks in the higher end of its generic rating class; the modifier 2 indicates a midrange ranking; and the modifier 3 indicates a ranking in the lower end of that generic rating class.

Credit rating cuts the costs of assessed object, investors and banks. For the assessed object, good rating classes are reflected in lower interest rates [9], and they can represent an impetus to new business contracts. A good credit rating secures favourable credit terms too. As rating agency compares key features of the accounts, budget, etc. with benchmarks derived from assessing similar objects' operations in the country or internationally, the rating process helps the management to identify areas that need improvement. In similar structures, a stronger credit rating may often mean better financial management. Credit ratings also serve as an external validation of financial health.

For investors and banks, credit rating makes decision-making more effective and faster, mainly due to lower transaction and personal costs necessary for information acquisition about the business partners. Commercial banks may have the skills and willingness to assess the credit quality of an object. However, investors rarely have the specialist skills to investigate the financial health and management competence of a borrower, so they tend to rely on experts (rating agencies) to do this for them.

Based on the given facts it is desirable to design such models which make it possible to simulate the credit rating process using publicly available data.

2.2. Municipal credit rating modelling

The specific position of municipalities associated with their financial management, requires the use of different input variables than for companies. Municipalities dispose, same as companies, of internal and external financial resources. Internal financial resources come mostly from municipal taxes, while loans and bonds represent