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Interfaces with Other Disciplines

Behaviour-based short-term invoice probability of default evaluation

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ABSTRACT

In this paper, the effect of behavioural analytics on short-term default predictions at the invoice level is addressed by answering a question that slightly diverges from the traditional probability of default definition: 'What is the probability that this invoice will be paid within the next 30 days?' Resultantly improving short-term liquidity planning accuracy and supporting financial management in companies.

To provide a valid answer to the research question, a set of issues needs to be resolved, including identifying an appropriate data set, increasing the data predictive power, and creating and testing predictive models. Since the appropriate data set is not yet presented, we primarily focus on the first two issues: identifying appropriate data and raising its predictive power.

In this paper, we propose to build predictive models upon a new data source from multiple companies, acquired by business partners' data sharing concept. Furthermore, we upgrade these data with behavioural analysis to test the assumption that the probability of default depends not only on payment capability but also on payment preparedness.

The predictive power of shared invoice data and the effects of behavioural analysis are tested in a two-phase experiment: first, basic shared data are used to predict short-term invoice defaults, and in the second phase, the behavioural analysis results are included in the dataset. Lastly, the predictive models' test results are compared. Both results are positive: the already high accuracy of models, build upon basic data is significantly upgraded in models, using the behaviour analysis extended data set.

1. Introduction

The commonly used metric for determining partners' financial state, the probability of default (PD), is focused on assessing the company's long-term ability to comply with financial obligations (Allen, 1981; Blochlinger, 2012; Doumpos, Kosmidou, Baourakis, & Zopounidis, 2002; Kim & Sohn, 2010). PD and related metrics are used by multiple stakeholders: financial institutions in the role of creditors and investors, owners, and business partners. Most of them are involved in long-term business relationships and are using PD as a long-time variable. Probability of default on invoice level is consequently derived from the probability of default on a company level and lack of the research efforts focusing on invoice level PD prediction is evidenced.

Even though diverse approaches have been taken to improve the accuracy of the predictions (Hu & Ansell, 2007; Kim & Sohn, 2010; Premachandra, Bhabra, & Sueyoshi, 2009), the long-term PD accuracy is relatively low, usually with prediction accuracy around 80%, mostly due to the long prediction horizon and to the fact that it is evaluated on highly aggregated data, revealing only the company-level results.

In the day-to-day business environment, **short-term payment predictions** are of existential importance (Leow & Crook, 2014). The company-level PD is insufficient to support operational-level management decisions that involve selecting the best steps for risk mitigation and payment optimisation. The same is true for tactical-level liquidity planning, where the probability of payments must be assessed on an invoice level. The related scientific literature does not provide adequate research results in this field. We will contribute in the OR scope of research, by proposing a new combination of data analysis processes, and upgrade financial management scientific literature by providing a model for short-term payment predictions.

If the focus is established from observing the long-term company survivability to the short-term business event prediction, we should rephrase the probability of default question from 'Will the company survive in the long term?' to 'Will the invoice be paid within a time limit?' This question requires a much higher precision level than an overall company PD can deliver, since it focuses on the ability and preparedness of the company to pay an exact instance in the financial traffic. The invoice-level PD enables better selection of operational-level risk mitigation strategies than a company-level PD. It also provides a significant improvement in financial management decision-making support.

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In the proposed solution, an innovative combination of OR approaches, with special attention to data sources discovery and data upgrading methodologies is proposed. Sharing invoice payment data provides insight into the high-granularity operational data; behavioural patterns analysis provides additional knowledge about commonly used strategies; and state-of-the-art prediction algorithms provide accurate results on a more detailed level than the state-of-the-art PD-related research.

The first issue that requires a solution is the acquisition of a valid data source. Currently, two major data sources are used to assess PD: The first is the data reported by the evaluated companies, and the second is personal experience, obtained by doing business with the company. Both have limitations.

1. Financial reports are highly synthesised, and potentially biased: We can assume that a company's management will try to exaggerate its own successes and underplay or even hide failures (Perko & Mlinaric, 2016; Wang & Zhang, 2009). Additionally, these data are usually synthesised on a company level and therefore lack the granularity level required for assessing PD on the invoice level.
2. Personal experience usually represents only a small fragment of the overall company business collaborative relationships; therefore, predictions regarding future behaviour are limited to this narrow scope of information. We can only see how our partners are behaving towards us, while for correct behaviour assessment, a full picture is required.

In this paper, **sharing business partner invoice payment data** is explored for capacities as a valid data source for invoice PD prediction. Sharing business data with customers and partners in supply chains is common practice; examples include inventory listings, and operational and logistic data. Customer data are also shared between financial institutions (Jappelli & Pagano, 2002). We expect that invoice payment-related data gathered from multiple sources, at the appropriate granularity level, can provide a required holistic picture of a company performance and reduces the risk of biased reporting to an acceptable level.

In short-term invoice PD, particular attention is devoted to the companies already in situations of stress, where their preparedness of paying an invoice must also be taken into account. We expect that financial officers of companies in distress generally develop similar strategies about which invoices to pay regularly and which not to pay. When behavioural patterns of multiple companies are observed, these patterns can be identified and used to predict the forthcoming behaviour of other financial officers in similar circumstances.

Behavioural analysis is used to enhance the data reasoning capabilities. First, we identify common behavioural patterns and rules for assessing affinity towards them on multiple levels; then we assess the company affinity towards these pattern rules. Last, for every invoice, we enhance the basic invoice data with the appropriate affinity data.

To test the proposed solution, an experiment is executed based on invoice data shared by large Slovenian companies. Short-term PD is calculated using multiple data mining algorithms in two phases. First, only basic shared data are used, and secondly, behaviour pattern affinity data are added. The created models are then tested and the results compared. A high prediction accuracy due to short-term prediction span and the low granularity of the data is expected in the first run, and an accuracy improvement due to better explanation is expected in the second phase of the experiment.

The paper is organised as follows: first, the literature background is elaborated, and then the proposed invoice PD data model is presented, focusing on sharing mechanisms and the interpretation of behaviour strategies. The model test results are presented and thoroughly analysed. Finally, implications for financial management and OR are discussed, and potential future research projects are proposed.

2. Background

The probability of default is among the most important forms of information in financial institutions' credit management processes. In a formal definition (Basel, 2006, p. 96) default occurs when the obligor is unlikely to pay its credit obligations or when the obligor is past due more than 90 days on any material credit obligation. PD is the fundamental measure in the regulatory frameworks for financial institutions (BIS, 2011) and thereby has been heavily researched (Crouhy, Galai, & Mark, 2000; Doumpos et al., 2002; Li & Miu, 2010; Tong, Mues, & Thomas, 2012). Its shortcomings are also strongly disputed. Finlay (2009), for instance, addresses the issues of incorrect problem specification, while the lack of time definition in PD is addressed by invoking time-varying covariates (Orth, 2013) and past-due time thresholds (Harris, 2013). A valid solution systematically resolving the PD time indistinctness has not been found in the literature.

Research efforts in supporting the needs of corporate financial officers are not well documented comparing with the finance institutions' related research. Barro and Basso (2010) define counterparty risk and determine the impact of important player defaults on the market. The scarcity of corporate-focused research could be the consequence of special needs, focusing on short-term liquidity, or of limited data sets, prohibiting the employment of successful data mining. Using this paper, we intend to help to close this gap.

The predictive assessment quality depends on the research question definition, predictive algorithm selection, the data quality, and the process management. The PD-related operational research is largely focused on upgrading predictive models and algorithms using variations and combinations of support vector machines (SVM), neural networks, genetic algorithms, logistic regression, and other methods including hybrid solutions (Harris, 2013; Kim & Sohn, 2010; Yao, Crook, & Andreeva, 2015). Nonetheless, less than the required focus is set to understanding the drivers of a default, achieving the required data predictive power, and formulation of a valid research question to address specific PD related issues.

Is the probability of default the correct predictive research question for assessing short-term debts? Finlay, (2010) discusses the question by determining the objectives in the credit relationship. Dionne and Laajimi (2012) imply default thresholds and elaborate liquidity shortage and strategic default. Ju, Jeon, & Sohn, (2015) research the effects of behavioural technology in assessing the effects of economic environment in stress situations. Nevertheless, a solution capable of resolving the need for short-term default assessment has not yet been provided, according to our insight.

Providing the required data quality level for successful predictive analysis is the most time consuming part of the predictive analytic process (Davidson & Tayi, 2009), resulting in only limited records to the scientific scope. The main focus of data quality related research is set to resolving data issues as completeness, validity, consistency, timeliness and accuracy (Zhang, Zhang, & Yang, 2003). In this paper, we extend the data quality formulation by examining the importance of data relevance and data explanatory power for the accuracy of the predictive models. In a shorter term: data predictive power.

Data quality has a significant effect on prediction accuracy (Coculescu, Geman, & Jeanblanc, 2008; Florez-Lopez, 2010; Wolter & Roesch, 2014). Piramuthu (2006) point outs the significance of data understanding, correct interpretation, and pre-processing effects on prediction quality. After examining the PD-related literature, we can conclude that most of the models use company-level

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