CORPORATE BANKRUPTCY PREDICTION: A SYSTEMATIC LITERATURE REVIEW AND COMPREHENSIVE BIBLIOMETRIC ANALYSIS

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Abstract

Researchers from all over the world have become more interested in bankruptcy prediction during the past 50 years. The prediction of corporate financial difficulties has been the subject of numerous studies ever since Altman revealed the breakthrough bankruptcy prediction model in 1968. The main aim of this research paper is to describe the fundamental concepts associated with the subject of corporate bankruptcy prediction. By identifying the most relevant research papers, nations, and authors in the Web of Science database, an in-depth review of the publications was performed before the analysis. The bibliometric map was created in the VOS Viewer program using the final search result with all available information. The results of the bibliometric analysis reveal that the keywords bankruptcy prediction and classification are the most closely related keywords using the analysis of citations that frequently occur, and that the USA and China developed the most significant international co-author relationships.

Keywords: corporate bankruptcy prediction; prediction model; literature review; bibliometric analysis

JEL Codes: G17, G32, G33

Introduction

There are many situations associated with success, growth, and prosperity in the life cycle of every firm (Blazek, Durana & Michulek, 2023, pp. 411-430). Contrary to this, there are different situations that include crisis, failure, and decline. The purpose of the business is obviously to be in a position of growth, success, and prosperity. However, in the modern era of the global economy, enterprises are not only established but also go bankrupt considerably more frequently than they did in the past. As a result of globalization and the interconnectedness of national economies, the demise and bankruptcy of businesses are becoming more frequent (Kovacova et al., 2018, pp. 167-179). The process of corporate financial health worsening over time need not result in a sudden bankruptcy of the enterprise (Altman et al., 2017, pp. 131-171). Identifiable factors that contribute to the decline in the enterprise's financial health may be identified in non-prosperous firms. Therefore, it is essential to use them in order to predict tendencies towards a decrease in financial health (Zhou, Fu, Li & Xu, 2022, pp. 1100-1115). Knowing the presence of these factors can lead to measures that will ensure the prevention of financial health deterioration. According to Roumani, Nwankpa & Tanniru (2020, pp. 4161-4182), the level of corporate financial health is characterized by

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expectations to what extent the company will be able to satisfy the demands of investors and all creditors in the future, e.g. pay dividends, fulfill obligations from loans and non-commercial loans, or repay short-term obligations on time. The fundamental basis for predicting the financial health of the company is the correct selection of such indicators of the economic activity of the firm, the statements of which will be essential and significant in connection with the assessment of the financial situation and capability of the enterprise (Kapounek, Hanousek and Bily, 2022, pp. 265-287). The primary characteristics of a corporate financial position are tested by carefully chosen financial health indicators, which also indirectly show the impact of the most relevant external and internal environmental factors (Zelenkov & Fedorova, 2022, pp. 187-210).

According to Huang, Yao, Luo & Li (2022), predicting a corporate bankruptcy has become recognized as crucial to reducing the risk of the firm being forced out of trading. Although it is still relatively new, the area of economics that deals with financial analysis as well as forecasting corporate financial status is extremely rich in scientific theories, concepts, and models. The origins of prediction are connected with the studies of the founders of scientific prediction of the financial situation, namely Fitzpatrick (1932, pp. 727-731), Smith and Winakor (1935) and Merwin (1942), whose models we have known since the thirties of the last century. Early warning system research was first published in 1966 by Beaver (1966, pp. 71-111) and Tamari (1966, pp. 15-21), and then again in 1968 by Altman (1968, pp. 589-609). These authors are considered the founders of scientific corporate bankruptcy prediction. Over time, methods of logit analysis, based on which Ohlson (1980, pp. 109-131) created the bankruptcy model, and probit analysis, on which the model by Zmijewski (1984, pp. 59-82) is based, also began to be used to predict the bankruptcy of business entities. The study by Odom and Sharda (1990, pp. 163–168) was one of the first to use neural networks in bankruptcy prediction models. The financial indicators of the Altman model were used by the authors as inputs for bankruptcy model development and a neural network was then trained on a sample of firms. Dwyer (1992), Guan (1993), and others developed models based on the neural network approach. New model development techniques do not require any assumptions to be met compared to conventional statistical methods. As a result, they can be used with any data from this perspective, leading to the idea that they operate better than traditional statistical approaches. These techniques, such as genetic algorithms (Varetto, 1998, pp. 1421-1439; Min, Lee & Han, 2006, pp. 652-660), fuzzy logic (Korol & Korodi, 2011, pp. 92-107; Chou, Hsieh & Qiu, 2017, pp. 298-316), or support vector machines (Shin, Lee & Kim, 2005, pp. 127-135; Olson, Delen & Meng, 2012, pp. 464-473), have higher computational complexity and frequently require the use of statistical programs, but they have a higher estimation accuracy for bankruptcy.

Depending on the data used as input and the processing method applied, the performance of individual models for predicting corporate bankruptcy (Kirkos, 2015, pp. 83-123). These models are developed using empirical information from a particular economy (Durana, Blazek, Machova & Krasnan, 2022, pp. 481-510). The only economy that can generally use the model successfully is the one from which empirical data was collected during its development (Kitowski, Kowal-Pawul & Lichota, 2022). Additionally, it is impossible to regard any one model as immutable or fixed because its predictive ability could suffer due to changes in economic conditions in the country.

The main aim of this research paper is to clarify the basic concepts associated with the issue of corporate bankruptcy prediction. The analysis was preceded by a detailed study of the publications by identifying the most crucial research papers, countries, and authors in the Web of Science database. All appropriate keywords for a bibliometric map in the field of bankruptcy prediction were analysed using the VOS Viewer. Although, the study on the topic of predicting corporate bankruptcy has been ongoing for many years, there is a significant gap in the
bibliometric analysis on the researched issue. Discussions have been conducted on the implications of implementing and distributing bibliometric techniques in multiple contexts. The relevance of qualitative aspects is increasing as well, such as the implications of bibliometric analysis for the evaluation of research, in addition to quantitative data. Many research papers on bankruptcy prediction may be discovered in the scientific database, and the keywords included in the bibliometric map facilitate the identification of the most popular subjects. Given the importance of the topic of predicting corporate bankruptcy, this study also aims to highlight the most significant gaps and findings in the scientific literature related to bankruptcy prediction. In addition to the above, an analysis of the common occurrence of cooperation was carried out not only between the authors but between the countries. A review of citations of common occurrence revealed that the keywords bankruptcy prediction and classification are the two most associated keywords, and the USA and China developed the most significant international co-author relationships.

The paper is divided into the following sections. The literature review, which focuses on literary research, familiarizes the reader with the fundamental theoretical basis of bankruptcy prediction model development in previous studies, since interest in them is significant. The research methodology provides a brief overview of the sample of the most significant publications as well as the methodological steps of the bibliometric analysis. The obtained results, which are constantly being discussed worldwide, are the focus of the third part. The primary findings are explained and contrasted with other relevant studies published internationally in the discussion. At the conclusion of this study, limitations and future research on this subject are discussed with the most significant results.

**Literature review**

Every firm interacts with other economic entities and bodies that have an impact on its decision-making, which causes it to expand or even reduce as part of the economic life of the country. Before making any financial or investment decisions about the firm, it is crucial to understand its financial health (Kovacova & Kliestik, 2017, pp. 775-791) and condition (Szymura, 2022). The financial health of the firm depends on its performance (Michulek, Gajanova, Krizanova & Nadanyiova, 2023) and financial position and describes how resilient corporate finances are to internal and external operational risks in its current financial condition (Kljucnikov, Civelek, Cervinka, Voznakova & Vincurova, 2022, pp. 97-116). It can be assumed that bankruptcy and subsequent insolvency are unlikely to arise if the firm doesn't exhibit any signs of approaching financial problems. Financial health, however, cannot be determined precisely from accounting data, but it can be evaluated with a level of acceptable tolerance based on how inadequate the procedures employed are in comparison to the desired outcome.

As Ko and Lin (2006, pp. 84-91) argue, the turn of the 20th and 21st centuries was seen as a period full of turbulent changes when the world made a significant shift towards a global economy. In this ever-changing environment, there are also changes in firms. Therefore, according to Michalkova, Stehel, Nica and Durana (2021, pp. 276-295), effectively operating a business and making the decisions that result in its efficient operation require a complete comprehension of the environment in which the firm operates as well as an ongoing review of the results of its business activities. Similarly, Kaczmarek, Kolegowicz and Szymla (2022) state that a successful enterprise cannot do without financial analysis in its management. The purpose of financial analysis is an evaluation of the company's financial health, which occurs on the basis of a systematic examination of data primarily derived from financial statements, in which the entire reproduction process of the company, its conditions, progress, and results are displayed in a compressed manner (Balina, Idasz-Balina & Acszani, 2021). In general, financial analysis is focused on evaluating the past when its primary objective is to objectively
assess the processes that occurred during a particular past period (Pang, Zhou, Wang, Lin & Chang, 2020, pp. 2098-2118) but it can also be focused on the future when such financial analysis is intended to predict the development of processes in the future using selected methods, implement timely necessary corrections, and prevent financial crises in the company or its bankruptcy itself (Pech, Prazakova & Pechova, 2020, pp. 108-124). When predicting bankruptcy, it is not only about the current state of the company's financial health (Lesakova, Gundova & Vinczeova, 2020, pp. 123-136) but also the fundamental development tendency over time, stability, volatility of results, and comparison with standard values in a given field (Jaki & Cwiek, 2021)), industry (Kruticky, Machova & Dvorak, 2022, pp. 408-418) or by direct comparison with the competition (Ugur, Solomon & Zeynalov, 2022).

Predicting whether a firm will prosper or, on the contrary, not prosper has led to the spread of many theories (Kaczmarek et al., 2022). In general, bankruptcy models predict, according to Kou et al. (2021), business failure and are created on the basis of empirical data based on the given economy and market. However, the success of the company depends to a large extent on the input data (Kubenka, Capek & Sejkora, 2021, pp. 167-185), which can be distorted in various ways. Mihalovic (2016, pp. 101-118) claims that bankruptcy models deal with prediction and could predict a corporate bankruptcy in advance. This prediction is mainly intended for creditors who are interested in the ability of the firm to repay its obligations (Ansari, Ahmad, Bakar & Yaakub, 2020, 176640-176650). The purpose of the developed models is to determine whether the firm is at risk of bankruptcy. Models developed in the past draw on real data (Delina & Packova, 2013, pp. 101-112) and assume that the company has been experiencing phenomena that signal an unfavorable financial situation for several years (Serrano-Cinca, Gutiérrez-Nieto & Bernate-Valbuena, 2019, pp. 353-375), which are, for example, problems with liquidity (Valaskova, Kliestik & Kovacova, 2018, pp. 105-121), the amount of net working capital (Habib & Kayani, 2022, pp. 1567-1586), achieving a negative economic result (Sarhadi, Mansouri & Faghani, 2022, pp. 57-67), problems with the profitability of invested capital (Nagy, Valaskova, & Durana, 2022; Kovacova, Valaskova, Durana & Kliestikova, 2019, pp. 241-251; Kovacova, Krajcik, Michalkova & Blazek, 2022, pp. 41-59) and many others.

The issue of predicting economic development was first addressed by Fitzpatrick (1932, pp. 727-731), who published a study focused on comparing indicators and determining significant differences between prosperous and non-prosperous industrial enterprises. The author drew attention to the fact that the development of selected financial indicators begins to differ in threatened enterprises long before the outbreak of serious economic difficulties, which usually result in insolvency. Smith and Winakor (1935), similar other authors, concluded that the values of selected ratio indicators were significantly different in solvent and insolvent enterprises. A few years later, Merwin (1942) also published the results of his research, which focused on comparing the arithmetic averages of selected business indicators calculated in prosperous and non-prosperous firms. The main shortcoming of this research was that the group of non-prosperous enterprises automatically included those enterprises that ceased to exist for reasons other than economic ones. Ansoff’s (1965) theory of weak signals provided a significant impulse for early warning systems improvement. In the study, the author dealt with the issue of enterprise strategic planning by developing the assumption that strategic disturbances are announced by weak signals, which are identified by the initial absence of a clear causal relationship between them and the event they herald and, as a result, are not even initially diagnosed. The second half of the 1960s was a breakthrough period in the field of business failure prediction research. Beaver (1966, pp. 71-111) used financial ratios for the first time in his study to predict corporate bankruptcy and proved that it is indeed possible to successfully use financial ratios to predict the financial difficulties of business entities operating on the market. At the end of his study, the author also pointed out that not all financial
indicators have the same predictive power. However, the study of Altman (1968, pp. 589-609), who created a prediction model that became the basis for many other models development, can be considered a worldwide pioneering work regarding bankruptcy prediction among researchers in the fields of finance, banking, and credit risk. Bankruptcy prediction models are also crucial tools for bankers, investors, asset managers, and rating agencies (Viswanathan, Srinivasan & Hariharan, 2020, pp. 226-261), therefore, the banking industry, as the primary provider of financing in the economy, is interested in minimizing the level of non-performing loans (Ben Jabeur and Serret, 2023) in order to maximize the profit from credit activity (Kliestik, Sedlackova, Bugaj & Novak, 2022, pp. 475-509; Kliestik, Hrosova, Valaskova & Svblova, 2022, pp.120-136) and reduce their own risk of failure (Pavlicko & Mazanec, 2022). Thus, according to Altman (1968, pp. 589-609), the model he developed should be useful as a manual for firms experiencing financial difficulties.

Over time, additional techniques developed, such as logit and probit statistical techniques for logistic regression analysis. The most famous author of logit bankruptcy models is Ohlson (1980, pp. 109-131). The model authored by Zmijewski (1984, pp. 59-82) is based on probit analysis. As an alternative to the approach based on the analysis of historical data, models based on a theoretical basis began to appear, primarily Merton's model (Merton, 1974, pp. 449-470). While these techniques have a wide range of practical applications, their advanced mathematical structure is a limitation. The development of the scientific area of artificial intelligence research has had a significant impact on the development of a different set of models for predicting corporate failure (Barboza, Kimura & Altman, 2017, pp. 405-417). Another important element that helped to apply these methods was the rapid development of computer technology. The result is the application of neural networks (Paliwal & Kumar, 2009, pp. 2-17) and genetic algorithms (Tseng & Hu, 2010, pp. 1846-1853) in failure prediction. These methods are characterized by their high predictive ability, but the main caveat to their use is their high lack of transparency (Kapounek et al., 2022, pp. 265-287). Many statistical methods are used to develop prediction models, the application of which is constrained by a number of inherent strict assumptions, including linearity (Delina & Packova, 2013, pp. 101-112), normality (Csikosova, Janoskova & Culkova, 2020), independence between predictor variables, and functional forms that are already related to the criterion variable and the predictor variable (Jones, 2017, pp. 1366-1422).

Many authors argue that it is still challenging to evaluate bankruptcy risk despite the existence of numerous alternative models that have been developed using a range of techniques to reach the best results. Currently, the condition of the business environment is described by a variety of prediction models that have been created internationally (Kovacova, Kliestik, Valaskova, Durana & Juhaszova, 2019, pp. 743-772; Son, Hyun, Phan & Hwang, 2019; Smiti & Soui, 2020, pp. 1067-1083; Kubenka et al., 2021, pp. 167-185; Kou et al., 2021; Michalkova, Kovacova, Cepel & Belas, 2022, pp. 529-548; and many others). In an era of accelerating globalization and internationalization, bankruptcy prediction has become crucial for firms as well as other interested groups. There are many different prediction models, each with unique requirements for development, input data complexity, number of variables, and interpretation of the results. However, in general, the existence of several models is a result of the lack of universal use in various industries and economic circumstances.

**Methodology**

The application of quantitative techniques on bibliometric data, including units of publishing and citation (Donthu, Kumar, Mukherjee, Pandey & Lim, 2021, pp. 285-296), can be defined as bibliometric analysis. According to Wang, Xu & Skare (2020, pp. 865-886), bibliometric analysis was first discussed in the 1950s, indicating that the methodology is not new. Indeed, the bibliometric methodology has been used in many areas of business research,
including business strategy (Kitsios, Kamariotou & Talias, 2020), electronic commerce (Kumar, Lim, Pandey & Christopher Westland, 2021, pp. 1-40), finance (Xu et al., 2018, pp. 160-173; Zhang, Zhang & Managi, 2019, pp. 425-430), human resources (Fernandez-Alles and Ramos-Rodriguez, 2009, pp. 161-175), management (Zupic & Cater, 2015, pp. 429-472; Ben-Daya, Hassini & Bahroun, 2019, pp. 4719-4742), and marketing (Randhawa, Wilden & Hohberger, 2016, pp. 750-772; Chabowski, Mena & Gonzalez-Padron, 2011, pp. 55-70; Michulek and Krizanova, 2023), wherein the application of bibliometrics ranges from studying publication to collaboration patterns and exploring the intellectual structure of the research field.

Information and communication technology, which are required for processing large amounts of data, and provide an opportunity to depict the outcomes in bibliometric maps, is credited for the increase in interest in bibliometric research nowadays (Tian, Geng, Sarkis & Zhong, 2018, pp. 148-157). Due to the fact that the data generated from bibliometric analysis is useful for scientists in carrying out their research activities, it is gradually making its way into decision-making processes and helping to identify new trends. Generally, bibliometric analysis is a scientific field that investigated the quantitative elements of the creation, dissemination, and use of recorded information. Publications, or their representations in the form of bibliographic records, are the primary objective of bibliometric research (Villasenor, Arencibia-Jorge & Carrillo-Calvet, 2017, pp. 77-104). These records frequently include the abstract, keywords, subject area, or list of bibliographic references in addition to the document title, authors, and year of publication. A science citation index was firstly described by Garfield (2006, pp. 1123–1127). For the first time, it was considered a possibility of publishing in the online collection of basic Web of Science databases, which according to Mongeon and Paul-Hus (2016, pp. 213-228), is currently considered to be the best option because of its high quality and ability to restrict individual searches using a wide range of bibliographic parameters. Despite the fact that the Web of Science is no longer the only database that provides indexation of social science citations and publications (Gajdosikova & Valaskova, 2022, pp. 210-224), it is still the largest citation database that gives access to the most reliable scientific literature worldwide (Harzing & Alakangas, 2016, pp. 787-804).

The following methodological steps are often followed when conducting bibliometric analysis. In the first step, it is necessary to define the essential criteria, keywords, and period of the search. Subsequently, a relevant database is selected, which is crucial to creating input data and modifying the search criteria. The obtained search results need to be exported for the creation and analysis of the bibliometric map, which is the final step (Linnenluecke, Marrone & Singh, 2020, pp. 175-194).

The terms bankruptcy prediction, default prediction, financial failure, financial distress, and insolvency were used as search terms for research papers published in the Web of Science database between 2010 and 2022. The starting year for the bibliometric analysis was 2010, when the number of publications in the Web of Science scientific database tripled compared to 2005, confirming the steadily rising interest in corporate bankruptcy prediction research. Following research papers published in the scientific database, a search of the Web of Science database resulted in 9,205 documents. The criteria established for this research paper, i.e. the reference period 2010–2022, have been used for these results. To generate the bibliometric map in VOS Viewer, the final search result, which included all relevant information, was exported in "txt" format and comprised 6,985 documents.

**Results**

In 1933, the scientific database first noted the issue of bankruptcy prediction. In 2005, when there were initially more than 100 publications, the number of scientific papers on the researched topic started to increase. The number of scientific papers published in the database
tripled in 2010, and this year was chosen as the starting point for the purposes of this research paper. The increase in literature-related publications on the issue of bankruptcy prediction is depicted in Figure 1. The data shows that the number of publications in the database increased steadily until 2016, after which there was a year-on-year growth in papers that were published. There were 765 papers published on corporate bankruptcy prediction in 2021, the year with the most research papers in the database. The following year, the number of publications in the Web of Science database decreased slightly to 732 research papers.

**Figure 1. Annual growth of documents in given period 2010-2022**

Several documents were published in the scientific database Web of Science over the monitored period of 2010–2022, and Table 1 summarizes the various categories of these research papers by type. Scientific articles, which include scientific research and full papers published in scientific journals, account for the majority (up to 80.07%) of all documents from 2010 to 2022. Proceedings Papers, i.e. the contributions in the proceedings of realized scientific conferences, of which there were 1,003, represented 14.36% of all documents related to the issue of corporate bankruptcy prediction. The following are Book Chapters that include a monograph or other work that was produced on a specific topic and are contained within a significant section of a book. The least common types of documents, which were merged into one category of others consisting of 3 publications, or 0.04% of all documents related to the bankruptcy prediction issue, are Book Reviews, Corrections containing bug fixes found in published documents, and Data Papers including scholarly publications describing a particular dataset or collection of datasets.

**Table 1. Types of documents in given period 2010-2022**

<table>
<thead>
<tr>
<th>Document type</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Article</td>
<td>5,593</td>
<td>80.07%</td>
</tr>
<tr>
<td>Proceedings Paper</td>
<td>1,003</td>
<td>14.36%</td>
</tr>
<tr>
<td>Book Chapters</td>
<td>238</td>
<td>3.41%</td>
</tr>
<tr>
<td>Review Article</td>
<td>84</td>
<td>1.20%</td>
</tr>
<tr>
<td>Editorial Materials</td>
<td>64</td>
<td>0.92%</td>
</tr>
<tr>
<td>Others</td>
<td>3</td>
<td>0.04%</td>
</tr>
</tbody>
</table>

*Source: own processing based on data in the scientific database Web of Science*
The bibliometric map has 1,434 items divided into 8 clusters and was generated by monitoring the most frequently used keywords in scientific publications related to the issue of bankruptcy prediction with a minimum occurrence in five research papers. Figure 2 depicts a bibliometric map of all terms associated with the issue.

1. The first cluster (pink), containing 316 items, includes keywords bankruptcy, bankruptcy model, bankruptcy risk, business failure, COVID-19, default, failure prediction, financial distress, logistic regression, multivariate discriminant analysis, risk management, and so on.

2. The second cluster (orange), containing 314 items, includes keywords such as classification, credit scoring, data mining, decision tree, decision making, genetic algorithms, machine learning, neural network, support vector machine, and so on.

3. The third cluster (green) consists of 297 items containing keywords such as algorithm, bankruptcy prediction, cash flow, clustering, credit, failure, networks, regression, systems, and so on.

4. The fourth cluster (purple) contains 268 items, including bankruptcy model, capital structure, corporate governance, credit risk, debt, firm, investment, performance, and so on.

5. The fifth cluster (light blue), containing 184 items, includes keywords such as cost, company law, contracts, creditors, debt restructurings, debtors, liquidation, reorganization, and so on.

6. The sixth cluster (dark blue) consists of 30 items, containing keywords such as bankruptcy costs, contracts, demand, economic distress, financial distress cost, liabilities, market value, solvency, taxes, and so on.

7. The seventh cluster (yellow) contains 24 items, including keywords bankruptcy forecasting, crisis management, discount, financial ratio, logistic model, and so on.

8. The last cluster (grey) is created by a single item, the keyword logit regression.

Figure 2. Network visualization of all keywords related to the issue of corporate bankruptcy prediction

Source: own processing
Several keywords were published on Web of Science in scientific publications dealing with the issue of corporate bankruptcy prediction. Table 2 summarizes the most frequently used terms in research papers from 2010 to 2022, although due to a large number of keywords, the minimum occurrence was set at level 5.

Table 2. The most frequently used keywords with the minimum occurrence of five times in the monitored period 2010-2022

<table>
<thead>
<tr>
<th>Keyword</th>
<th>Number of occurrences</th>
<th>Keyword</th>
<th>Number of occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>financial distress</td>
<td>1,181</td>
<td>determinants</td>
<td>371</td>
</tr>
<tr>
<td>bankruptcy prediction</td>
<td>903</td>
<td>classification</td>
<td>306</td>
</tr>
<tr>
<td>bankruptcy</td>
<td>872</td>
<td>failure</td>
<td>300</td>
</tr>
<tr>
<td>performance</td>
<td>616</td>
<td>firms</td>
<td>288</td>
</tr>
<tr>
<td>financial distress prediction</td>
<td>546</td>
<td>corporate governance</td>
<td>303</td>
</tr>
<tr>
<td>risk</td>
<td>472</td>
<td>model</td>
<td>303</td>
</tr>
<tr>
<td>discriminant analysis</td>
<td>461</td>
<td>credit risk</td>
<td>266</td>
</tr>
<tr>
<td>financial ratios</td>
<td>460</td>
<td>capital structure</td>
<td>259</td>
</tr>
<tr>
<td>prediction</td>
<td>408</td>
<td>insolvency</td>
<td>241</td>
</tr>
<tr>
<td>neural networks</td>
<td>388</td>
<td>logistic regression</td>
<td>205</td>
</tr>
</tbody>
</table>

Source: own processing

In a bibliometric map, items are often represented using a circle and an inscription. The size of the circle depends on the item weight. Generally, the higher the item weight, the larger the inscription and the circle. The strength of the connection between the two keywords is shown by the individual lines linking them. The resulting bibliometric map, which is depicted in Figure 3, reveals that the most closely related keywords are bankruptcy prediction and classification, as well as bankruptcy prediction and financial ratios.

Figure 3. The most frequently used keywords with minimum occurrence of one hundred times in given period 2010-2022

Source: own processing
The analysis of published documents by geographical area (Table 3) indicates how attractive the corporate bankruptcy prediction issue is. The table shows that most articles on bankruptcy prediction issues were published in the countries of the Americas, with more than a third of all research articles published in this part of the world. Approximately 25% of research papers were published in Central and Eastern Europe. Less than 10% of the research papers published worldwide were in the African and Eastern Mediterranean region.

<table>
<thead>
<tr>
<th>Region</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Countries of the Americas</td>
<td>2,349</td>
<td>33.63</td>
</tr>
<tr>
<td>Central and Eastern European region</td>
<td>1,757</td>
<td>25.15</td>
</tr>
<tr>
<td>Asian region</td>
<td>1,176</td>
<td>16.84</td>
</tr>
<tr>
<td>Western European region</td>
<td>878</td>
<td>12.57</td>
</tr>
<tr>
<td>African region</td>
<td>562</td>
<td>8.05</td>
</tr>
<tr>
<td>Eastern Mediterranean region</td>
<td>263</td>
<td>3.77</td>
</tr>
</tbody>
</table>

Source: own processing

The network visualization between 70 distinct countries of international co-authorship is depicted in the bibliometric map below. The different parts of the bibliometric map are once again represented by an inscription and a circle in the offered perspective, even if it is true that the more significant a country is in terms of international co-authorship, the larger its label and circle. Individual lines between the two countries represent co-authorship between the monitored countries. Figure 4 depicts the created bibliometric map, which includes six clusters.

**Figure 4.** Network visualization of all countries, where the issue of corporate bankruptcy prediction is addressed in the given period 2010-2022

Source: own processing
The bibliometric map indicates clearly that the topic of corporate bankruptcy prediction is highly topical and has gained popularity in many countries, but the most crucial international co-author relationships in the development of scientific publications emerged between the USA and China (4.54%), the USA and England (3.15%), and the USA and Canada (1.92%). Table 4 provides a summary of the countries that were most involved during the period under review and indicates that the USA published the majority of papers on bankruptcy prediction-related topics, accounting for about a 20% of all articles published in the scientific database. The value of the ratio of citations to the number of all documents is the highest also in the USA. The number of publications published in cooperation with another country is referred to as the total link strength (TLS) value. Additionally, TLS reached the highest value of 696 in USA, resulting in 696 cooperations with the given country. According to the data in the table, many publications on corporate bankruptcy prediction are dominated by China, Taiwan, and India from the Asian region, England, Spain, Germany, Italy and Czech Republic from the European region, the USA from the American area, and Australia is a crucial part.

### Table 4. The most frequently dealing countries with corporate bankruptcy prediction issues in the given period 2010-2022

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of documents</th>
<th>Percent</th>
<th>C/D</th>
<th>TLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>1,380</td>
<td>19.76%</td>
<td>19.45</td>
<td>696</td>
</tr>
<tr>
<td>China</td>
<td>730</td>
<td>10.45%</td>
<td>14.37</td>
<td>380</td>
</tr>
<tr>
<td>England</td>
<td>674</td>
<td>9.65%</td>
<td>14.41</td>
<td>495</td>
</tr>
<tr>
<td>Australia</td>
<td>408</td>
<td>5.84%</td>
<td>8.80</td>
<td>204</td>
</tr>
<tr>
<td>Spain</td>
<td>327</td>
<td>4.68%</td>
<td>11.57</td>
<td>164</td>
</tr>
<tr>
<td>Germany</td>
<td>295</td>
<td>4.22%</td>
<td>1.24</td>
<td>213</td>
</tr>
<tr>
<td>Italy</td>
<td>285</td>
<td>4.08%</td>
<td>9.88</td>
<td>149</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>259</td>
<td>3.71%</td>
<td>4.59</td>
<td>61</td>
</tr>
<tr>
<td>Taiwan</td>
<td>220</td>
<td>3.15%</td>
<td>2.38</td>
<td>55</td>
</tr>
<tr>
<td>India</td>
<td>213</td>
<td>3.05%</td>
<td>7.52</td>
<td>95</td>
</tr>
</tbody>
</table>

**Source:** own processing  
**Note:** C/D Number of citations per document (calculated as the ratio of the number of citations of documents in the country to the number of all documents in the country), TLS Total Link Strength

In 2010–2022, all documents published in the scientific database Web of Science received 75,289 citations, averaging 10.78 citations per document, while the most cited publication received 981 citations. Many research papers on bankruptcy prediction may be discovered in the scientific database, and the keywords included in the bibliometric map facilitate the identification of the most popular subjects. Given the importance of the topic of predicting corporate bankruptcy, this study also aims to highlight the most significant gaps and findings in the scientific literature related to bankruptcy prediction. In addition to the above, an analysis of the common occurrence of cooperation was carried out not only between the authors but between the countries. A review of citations of common occurrence revealed that the keywords bankruptcy prediction and classification are the two most associated keywords, and the USA and China developed the most significant international co-author relationships.

**Discussion**

There are many studies on the issue of corporate bankruptcy in the professional literature, denoted by several terms, such as prediction of failure (Manthoulis, Doumpos, Zopounidis & Galariotis, 2020, pp. 786-801), prediction of bankruptcy (Kovacova & Kliestik,
prediction of financial distress (Svabova, Michalkova, Durica & Nica, 2020), prediction of default (Lee, 2020, pp. 115-129), credit risk assessment (Malakauskas & Lakstutiene, 2021, pp. 4-14), early warning systems (Myskova & Hajek, 2020, pp. 1422-1443), and others. However, many of these terms are found in the created bibliometric map with the most frequently used keywords in the given period 2010-2022. In addition, the keyword financial distress was used 1,181 times in the research papers in question, ranking it the most frequently used keyword in professional publications on the issue of bankruptcy prediction. Financial distress, according to Valaskova, Androniceanu, Zvarikova & Olah (2021, pp. 167-184), is a situation in which a company is unable to pay its debt obligations to creditors, which in return leads to either restructuring or bankruptcy. Financially distressed firms are reportedly facing a wide range of difficulties, including operational insolvency, dividend reductions, losses, plant closings, lower stock prices, and the loss of important clients, suppliers, and employees (Durana, Michalkova, Privara, Marousek & Tumpach, 2021, pp. 425-461). The bibliometric map concerning the researched issue also pointed to the keyword failure, which appeared in publications 300 times. Normally, a firm does not go bankrupt instantaneously but goes through a failure process that varies considerably in length. Compared to small to medium-sized enterprises, it has been demonstrated that major corporate failures frequently include a protracted failure process (Zhu, Zhou, Xie, Wang & Nguyen, 2019, pp. 22-33; Kou et al., 2021; Durana & Valaskova, 2022). The last stage of the decline process can be characterized as bankruptcy (Klucnikov, Civelek, Krajcik, Novak, & Cervinka, 2022, pp. 867-890). The keyword bankruptcy, which is found in the research paper in monitored period 873 times, ranking third position, can be considered as another keyword that is related to the issue of bankruptcy prediction. Nowadays, many firms have financial difficulties and approach bankruptcy as a result of both faulty managerial decisions and fiscal pressure or competition. Corporate bankruptcy can also emerge from changes in the business environment brought on by expanding into new markets or restructuring the economy (Lelyk, Olikhovskyi, Mahas & Olikhovska, 2022, pp. 299-310; Valaskova, Nagy, Zabojnik & Lăzăroiu, 2022).

In general, comprehensive knowledge of the financial condition of the firm is an essential requirement for managers to make responsible decisions (Brygala, 2022). Subjects who collaborate with the firm and are, therefore, in the position of business partners, individual or institutional investors, banks, and other creditors are also interested in knowing the financial situation. In many advanced economies, in addition to classical financial analysis procedures focused on past company results (Kitowski et al., 2022) and the factors that determined them (Maier & Yurtoglu, 2022), much attention is paid to methods and models for predicting the financial health of enterprises (Gavurova, Jencova, Bacík, Miskufova & Letkovsky, 2022, pp. 1215-1251). Corporate bankruptcy prediction is a constantly growing and attractive topic, as shown by the frequency with which this keyword appears in scientific papers published in the Web of Science database between 2010 and 2022. The keyword bankruptcy prediction as well as the synonym financial distress prediction appears in 1,449 articles in the monitored publications, indicating that it occurs in nearly 21% of all publications dealing with bankruptcy prediction issues. The management of the enterprise works to ensure the firm's liquidity, which may be evaluated using appropriate financial analysis techniques. The term bankruptcy prediction is thus associated with corporate financial health and is used to express its satisfactory financial situation. The requirements of long-term liquidity, i.e., that the payment of payable obligations is maintained in the future, can be included in the definition of corporate financial health by Michalkova et al. (2022, pp. 529-548), which reflects the meaning of that term. Additionally, the created bibliometric map contained the keyword insolvency. It appeared 241 times in research papers included in the Web of Science database between 2010 and 2022, ranking eighteenth in the total number of occurrences. In general, the issue of bankruptcy and insolvency prediction has been the focus of several research papers and has increased over
recent years. Business failure has been a topic of study for decades among researchers in a wide range of social science disciplines. Some of them (Gepp, Kumar & Bhattacharya, 2010, pp. 536-555; Giunipero, Denslow & Rynarzewska, 2022) concentrated on its causes and consequences, while others (Altman, 1968, pp. 589-609; Edmister, 1972, pp. 1477-1493; Warner, 1977, pp. 337-347; Altman, 1984, pp. 171-198; Dimitras, Slowinski, Susmaga & Zopounidis, 1999, pp. 263-280; Shumway 2001, pp. 101-124; Terceno, Vigier & Schegger, 2018, pp. 21-38; Yousaf, Jebran & Wang, 2021, pp. 663-684) concentrated on tools that could recognize the first indications of a forthcoming company bankruptcy. In general, insolvency is the primary factor in corporate failure. The risk of a firm becoming bankrupt due to its inability to pay its debt is closely related to the issue of predicting corporate bankruptcy. The research papers in question included 472 times the keyword risk, ranking it as the sixth most common in published research on the issue of bankruptcy prediction. When a firm is unable to pay its debts due to both endogenous (Li, Ou & Gu, C. 2023, pp. 287-299) and exogenous causes (Muller, 2022, pp. 824-845), bankruptcy is a potential. Several determinants lead companies to bankruptcy, with negative impact on ability to pay. However, it is not possible to deal with the existence of a bankruptcy risk of the firm in the absence of a financial-accounting diagnosis to determine the state of insolvency, defined as the state of the patrimony of a business entity characterized by insufficient funds for the payment of determined, liquid, and matured debts (Pasternak-Malicka, Ostrowska-Dankiewicz & Dankiewicz, 2021, pp. 250-267).

It is important to note how precise corporate bankruptcy prediction involves a thorough understanding of bankruptcy causes and its forecast methodology. Many financial variables considered relevant to bankruptcy prediction tasks have been identified in the literature. Since financial ratios is a keyword that appears 460 times in all publications dealing with bankruptcy prediction issues, it can be said to be the one that is used the most frequently. As stated by Valaskova, Kliestik, Svabova and Adamko (2018), the current financial situation of the firm is a fact that needs to be extended into the future with reasonable reliability. It additionally provides the opportunity for specific changes to be made in the reproductive process before serious problems occur (Kumar & Ravi, 2007, pp. 1-28). The evaluation and interpretation of the results achieved in the present, since they include indications of further development, is the foundation for the potential of predicting the firm's financial situation, its development, and its future prosperity or failure. According to Liang, Lu, Tsai and Shih (2016, pp. 561-572), it is possible to identify difficulties in the previous development in advance and put remedial measures in place before a crisis occurs with the correct assessment of financial indicators, considered indicators of future development. Financial indicators frequently represent the most popular technique for financial analysis (Kliestik, Vrba & Rowland, 2018, pp. 569-593; Miskufova, Jencova & Petruska, 2022, pp. 49-60) because they make it possible to quickly and affordably comprehend the fundamental economic characteristics of a firm (Nyitrai, 2019, pp. 317-332). There was a major interest in predicting bankruptcy several years before it manifested itself (Krasteva & Nagy, 2022, pp. 18-36). The ability of the business to pay taxes on time (Prochazka & Cerna, 2022, pp. 581-605), the extent to which equity can cover long-term debt (Nagy & Valaskova, 2022, pp. 360-375), as well as the financial resources currently available are indicators specific to liquidity and financial solvency that are crucial to recognizing financial issues at the level of the economic entity (Liang et al., 2016, pp. 561-572). The created bibliometric map contained the keyword classification. It appeared 306 times in research papers included in the Web of Science database between 2010 and 2022, ranking twelfth in the total number of occurrences. Barboza et al. (2017, pp. 405-417) at the same time state that the methods of forecasting the financial situation of the company must allow reasonable reliability to classify the company into the category of prosperous or non-prosperous enterprises, and this requires that the overall financial and economic performance and results of the enterprise be transformed into a single number statements. Liang, Tsai and
Wu (2015, pp. 289-297) point out in their study that such a discriminator, which allows any company to be classified into one of the two created groups, presupposes the selection of appropriately discriminating financial indicators.

In the professional literature, it is possible to find many methods for developing prediction models. One-dimensional analysis methods try to find a simple quantitative characteristic that summarizes the financial and economic situation of the firm and can relatively reliably distinguish enterprises with threatened financial health from prosperous ones (Smorada, Lukackova, Hajduova, Srenkel & Havier, 2023, pp. 147-155). One-dimensional bankruptcy prediction models include one-dimensional discriminant analysis or dichotomous classification tests, the author of which is Beaver (1966, pp. 71-111). While many indicators have an appropriate ability to forecast the development of the financial situation only in connection with other indicators, resulting in the use of multivariate analysis, such one-dimensional discriminant analysis has not gained a more significant position among prediction methods due to its ambiguity and the ability to evaluate the company based on just one indicator (Csikosova, Janoskova & Culkova, 2019). In addition, the keyword discriminant analysis was used 461 times in the research papers in question, ranking it the seventh frequently used keyword in professional publications on the issue of bankruptcy prediction. When using multivariate analysis, more complex mathematical and statistical methods are used to select suitable ratio indicators and possibly determine their weights. Since the model is developed based on data and not expert evaluation, it can also be described as exact (Khoja, Chipulu and Jayasekera, 2016, pp. 483-518). Historically, the most popular methods to create prediction models included both discriminant analysis and logistic regression. Although it is true that if this assumption is not met, it is appropriate to use quadratic discriminant analysis rather than linear discriminant analysis (Cindik and Armutlulu, 2021, pp. 237-255), the agreement of covariance matrices is a crucial assumption when using discriminant analysis (Viswanathan, Srivathsan & Winston, 2022, pp. 92-115). Additionally, corporate financial health may be predicted using the logistic regression technique. The bibliometric map concerning the researched issue also pointed to the keyword logistic regression, which appeared in publications 205 times. The task of logistic regression is to find a model that characterizes the relationship between the explained variable, which in the case of prediction models is the probability of the occurrence of financial problems for the firm, and a group of explanatory variables, i.e. financial and economic indicators (Himmelstein, Thorne, Warren & Woolhandler, 2009, pp. 741-746). The advantage of logistic regression compared to discriminant analysis is that when using this method, the normality assumption is not required (Csikosova et al., 2019), and the covariance matrices do not match (Park, Choi, Lee & Kyung, 2022, pp. 543-560). Currently, however, in the development of prediction models, methods such as decision trees, which represent a data mining alternative to discriminant analysis and logistic regression (Hosaka, 2019, pp. 287-299), point evaluation methods, in which the construction of models using this method consists of assigning a certain number of points by expert assessment to individual financial indicators (Lessmann, Baesens, Seow & Thomas, 2015, pp. 124-136) and multicriteria assessment methods, which represent a combination of expert assessment, graphical methods, and mathematical-statistical methods (Zopounidis, Galariotis, Doumpos, Sarri & Andriosopoulos, 2015, pp. 339-348), are used. The keyword neural networks, which is found in the research paper in monitored period 388 times, ranking tenth position, can be considered as another keyword that is related to the issue of methods for prediction models development. Neural networks represent a relatively new way of constructing classification models (Ben Jabeur and Serret, 2023), while the neural network is a collective term for a group of procedures from the field of artificial intelligence, some of which can be used as classification methods (Huang et al., 2022).
In the past, many authors have implemented bibliometric analysis with a focus on corporate bankruptcy prediction. By presenting new knowledge and important insights, Shi and Li (2019) aimed to advance the theoretical development of bankruptcy prediction modelling. To evaluate its development and summarize the general direction of research during the last fifty years, the authors aimed to explore the use of intelligent approaches in bankruptcy prediction. The results show that although there has been a noticeable rise in publications after the financial crisis of 2008, author collaboration remains insufficient, particularly on an international level. To evaluate its development and summarize the general direction of research during the last fifty years, the authors aimed to explore the use of intelligent approaches in bankruptcy prediction. The results show that although there has been a noticeable rise in publications since the financial crisis of 2008, author collaboration remains insufficient, particularly on an international level. The co-occurrence analysis indicates that the keywords bankruptcy prediction, neural networks, discriminant analysis, financial distress prediction, and classification are the most often used, and all of these keywords also exist in the bibliometric map that was developed in this paper. Grosu, Chelba, Melega, Botez and Socoliuc (2023) also conducted a bibliometric analysis with a focus on corporate bankruptcy prediction, and the results of the study were concretized in the draft bibliometric analysis of bankruptcy risk assessment models, which offers a summary of recent developments in the field of research on bankruptcy risk assessment models. Thus, it has been demonstrated that the majority of research concentrates on assessing the efficiency of bankruptcy risk assessment techniques and discovering new possibilities to enable risk prediction. Prado et al. (2016, pp. 1007-1029) performed a bibliometric analysis to evaluate research publications on credit risk and bankruptcy. Their findings support what has been published in the literature and in earlier bibliometric reviews, as well as highlighting other indications regarding the construction and development of research fields. Business failure research has been analysed bibliometrically by Farias, Martínez and Martín-Cervantes (2021), who additionally recognized the fundamental areas of current study and identified challenges for future research. Their findings show that the term business failure is closely related to keywords such as bankruptcy, prediction, regression analysis, and risk management. In the last ten years, terms like logistic regression, principal component analysis, and discriminant analysis have been used in research papers that explain business failure through statistical models. The aim of the research conducted by Campobasso and Boscia (2022) is to confirm that Altman’s score remains dominant as the best approach for evaluating corporate financial bankruptcy. The findings show a remarkable increase in the number of publications on the topic during the previous two decades, confirming its importance in academic discussion.

Investors, creditors, and governments have long been interested in bankruptcy predictions. Undoubtedly desired is the prompt identification of the imminent state of bankruptcy of a firm. Bankruptcy prediction has been the subject of an increase in research articles, and publications are accepted in practice to varied degrees, not simply in the academic and professional spheres.

Conclusions
The ability to generate and maintain an appropriate balance of assets is a crucial part of a financial analysis of an enterprise. In general, financial stability is part of the competitiveness assessment and is the key to the financial and economic efficiency of the company. The financial health prediction is a fundamental element of the comprehensive review of the firm since it is used to determine future corporate financial stability. There are a variety of models that, based on historical data, may predict corporate bankruptcy with a certain probability to determine whether the company is at risk of financial difficulties. Due to the results of the developed bibliometric maps, it can be stated that the keywords bankruptcy prediction and
classification, as well as bankruptcy prediction and financial ratios, are the most closely related. Many authors included these co-related keywords in their papers and dealt with the historical development of the given scientific discipline and the subsequent discovery of the links between the keywords. Because significant international co-author relationships were developed with the USA, such as those between the USA and China, the USA and England, and the USA and Canada, it is obvious that the researched issue was the most widespread in the period under review.

Using the bibliometric analysis, the paper examines and discusses the generalized problem of predicting corporate failure and explains its theoretical difficulties, consequences, and financial management implications. The most significant theoretical and practical contribution of the paper can be related to the identification of a substantial gap in published research by the use of bibliometric analysis, which was specifically focused on bankruptcy prediction issues, as well as the most commonly associated keywords and countries exploring the theory of bankruptcy prediction. The problem of corporate bankruptcy prediction has been discussed for several decades, and publications are accepted in practice to varying extents, not just in the academic and professional spheres. Identification of the most significant gaps as well as findings in the scientific literature was necessary considering the growing interest in this issue. The following limitations have to be highlighted despite the fact that the paper contributes to the existing literature. Therefore, to increase the generalization and application of this research paper, it would be interesting to investigate the relationships between various keywords related to the issue of the bankruptcy prediction of firms over a longer period of time than has been established for this study. Similarly, using only one scientific database might be considered not only a limitation of the research but also a challenge for its subsequent direction.

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