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Review

Review of Research into Enterprise Bankruptcy Prediction in Selected Central and Eastern European Countries

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Abstract: In developed countries, the first studies on forecasting bankruptcy date to the early 20th century. In Central and Eastern Europe, due to, among other factors, the geopolitical situation and the introduced economic system, this issue became the subject of researcher interest only in the 1990s. Therefore, it is worthwhile to analyze whether these countries conduct bankruptcy risk assessments and what their level of advancement is. The main objective of the article is the review and assessment of the level of advancement of bankruptcy prediction research in countries of the former Eastern Bloc, in comparison to the latest global research trends in this area. For this purpose, the method of analyzing scientific literature was applied. The publications chosen as the basis for the research were mainly based on information from the Google Scholar and ResearchGate databases during the period Q4 2016–Q3 2017. According to the author's knowledge, this is the first such large-scale study involving the countries of the former Eastern Bloc—which includes the following states: Poland, Lithuania, Latvia, Estonia, Ukraine, Hungary, Russia, Slovakia, Czech Republic, Romania, Bulgaria, and Belarus. The results show that the most advanced research in this area is conducted in the Czech Republic, Poland, Slovakia, Estonia, Russia, and Hungary. Belarus Bulgaria and Latvia are on the other end. In the remaining countries, traditional approaches to predicting business insolvency are generally used.

Keywords: corporate bankruptcy prediction; bankruptcy risk; financial analysis; comparative analysis

JEL Classification: G33; G17; F37; C38

1. Introduction

Bankruptcy is an indispensable part of the functioning of enterprises in market economy conditions. On the one hand, it is normal, as competition forces the liquidation of unprofitable units and the creation of space for those using scarce resources more efficiently. On the other hand, every bankruptcy has a negative impact on many stakeholders, including creditors, employees, suppliers, consumers, and the local community. In particular, the creditors and suppliers are exposed to the risk of loss when the debtors go bankrupt. "*Failure to fulfill debt commitments by a customer may hamper the solvency of the supplier (creditors), who may become unable in turn to pay its own suppliers located in the upper level, which may lead to a chain of similar failures (domino effect) and in extreme cases result in bankruptcy avalanches*" (Battiston et al. 2007).

Therefore, it is important to conduct research into the prediction of bankruptcy risk. Early detection of signs of deteriorating financial situation may allow taking corrective actions. It can also prevent sustaining losses by current or potential capital providers. In the United States, such research has been conducted since the beginning of the 20th century, while in other developed countries it was initiated in the 70s of the previous century. In the countries of Central and Eastern Europe, however, the interest in this area began much later. It is a result of the fact that before the dissolution of the Soviet Union these countries had a centrally planned economy, which in principle did not provide for the existence of the institution of bankruptcy. It was only in the early 1990s that the transformation of economy started and first insolvency laws were introduced in the majority of the former Eastern Bloc countries, followed by first bankruptcy proceedings. It was only then that the researchers from these countries began to be interested in the issue of assessing enterprises in view of the threat of insolvency they face. The introduction of effective tools for corporate failure forecasting in these countries enables to identify potential bankruptcies and, consequently, reduce losses by avoiding cooperation with such entities. In addition, these tools can act as early warning systems against insolvency and allow to identify early stages of a crisis. As a result, these companies may take early recovery action to improve their financial standing and to continue as a going concern. Therefore, it is worthwhile to analyze whether these countries conduct bankruptcy risk assessments and what their level of advancement is.

That is why the main objective of the article is the review and assessment of the level of advancement of bankruptcy prediction research in countries of the former Eastern Bloc, in comparison to the latest global research trends in this area. For this purpose, the method of analyzing scientific literature was applied. The publications chosen as the basis for the research were mainly based on information from the Google Scholar and ResearchGate databases during the period Q4 2016–Q3 2017. According to the author's knowledge, this is the first such large-scale study involving the countries of the former Eastern Bloc—which includes the following states: Poland, Lithuania, Latvia, Estonia, Ukraine, Hungary, Russia, Slovakia, Czech Republic, Romania, Bulgaria, and Belarus. On that basis, differences in the level of advancement of research on forecasting the corporate bankruptcy in the analyzed countries were identified. The strengths and weaknesses of the models built in them were determined and on this basis the directions of changes in the countries with the lowest level of research advancement in this area were proposed. Moreover, specific factors in relation to highly developed countries, which had an impact on the effectiveness of the developed models, were presented.

Apart from the introduction, the article is divided into three parts. The first part describes the global history of research into bankruptcy prediction and the latest trends in this area. In the next section, the results of literature studies concerning individual countries are presented. Additionally, a ranking of countries in terms of the degree of advancement of bankruptcy prediction studies is proposed, as well as specific characteristics of some countries are highlighted. The last part of the article contains conclusions.

2. Global Experience—Literature Review

The interest in predicting bankruptcy dates to the beginning of the 20th century, and the first research was initiated in the United States. Originally, researchers used single indicators or financial parameters to distinguish between insolvent and solvent entities. For example, already in 1908 Rosendale (Beaver 1968) tried to evaluate the risk of insolvency of companies based on information on their current assets. In the later period, the ratio analysis in this research area was used, among others, by Ramser and Foster—1931 (Back et al. 1997), Fitzpatrick (1932), Smith and Winakor (1935), Merwin (1942, as in Back et al. 1997), as well as (Beaver 1966). The latter applied univariate discriminant analysis. Considering multiple financial measures, he defined the discriminative power of each of them separately. For this purpose, the percentage of correct and incorrect predictions in the five years preceding the bankruptcy of enterprises was calculated.

The breakthrough came, however, in 1968—after Altman's publication (Altman 1968). He considered simultaneous impact of several indicators on the financial condition of the company by combining them into a single measure (Z-score). He used the technique of the multivariate linear discriminant analysis to achieve this purpose. Altman (2015), alone or in collaboration with other scientists, developed later numerous other models, dedicated to both the American companies and companies from other countries (Altman and Narayanan 1997). He found many followers in the United States and abroad, and the multivariate linear discriminant analysis has become the most popular technique used to develop corporate bankruptcy forecasting models (Bellovary et al. 2007; Aziz and Dar 2006).

In the 1970s and early 1980s the linear multivariate discriminant analysis was criticized, which resulted in the appearance of the logit and probit anaylsis in studies in the field of forecasting corporate bankruptcy (Chesser 1974; Martin 1977; Ohlson 1980; Wiginton 1980, as in Härdle et al. 2004; Zavgren 1983; Zmijewski 1984). In the 1970s and 1980s as an alternative to the linear multivariate discriminant analysis method and the logit and probit method studies were published in which the authors used other techniques, such as linear programming, the method of recursive division, cluster analysis or classification trees (Prusak 2005).

Another significant breakthrough came in the early 1990s. The development of statistical and analytical tools enabled the use of more sophisticated techniques for analyzing larger data sets, and the race to find more and more effective methods continues today. At that time the non-parametric methods began to be used in evaluating the threat of corporate bankruptcy—in particular the artificial neural networks (Odom and Sharda 1990; Raghupathi et al. 1991, as in Jo et al. 1997; Coats and Fant 1991; Tam and Kiang 1992; Fletcher and Goss 1993; Rahimian et al. 1993; Wilson and Sharda 1994; Boritz and Kennedy 1995; Serrano-Cinca 1997). Recent years have also seen a group of new methods from the area of forecasting corporate bankruptcy, categorized as the so-called soft computing techniques (Korol 2010a, 2013). Such a direction of progress stems from the use of computer applications that enable the implementation of advanced computational processes. Apart from the above-mentioned artificial neural networks, this category of methods includes, among others, genetic algorithms (Shin and Lee 2002), the method of support vectors (Härdle et al. 2004), fuzzy logic (Michael et al. 2001), as well as recently fashionable swarm algorithms, the most popular of which in this research area is the ant colony algorithm (Zhang and Wu 2011; Martin et al. 2014). In contrast to traditional statistical techniques, such as linear multivariate discriminant analysis or logit and probit analysis, these methods cope better with imprecisely defined problems, incomplete data, inaccuracy, imprecision, and uncertainty. They process information in cases difficult to illustrate in the form of algorithms and do this in conjunction with the symbolic representation of knowledge (Korol 2010b).

At the same time, the evolution of structural models based on the option theory was observed, with the KMV model as the most popular one (Iazzolino and Fortino 2012). They mainly use market information, rather than accounting data as in the previously presented approaches, to forecast bankruptcies. Also worth mentioning are gambling models, the main advantage of which is their dynamic nature, compared to the static approach used in traditional methods (Shumway 2001).

Apart from the aforementioned concepts, belonging to the most commonly used in the field of bankruptcy forecasting, the following approaches can be found in the literature of the subject: rough set theory (Slowinski and Zopounidis 1995), cash management methods (Laitinen and Laitinen 1998), catastrophe theory (Gregory-Allen and Henderson 1991), multicriteria decision aid methodology (Zopounidis and Doumpos 1999), Case-Based Reasoning (Park and Han 2002), Data Envelopment Analysis (Premachandra et al. 2009), multidimensional scaling (Molinero and Ezzamel 1991), concepts based on the entropy theory (Bal et al. 2013), pattern recognition method (Kolari et al. 1996), the self-organizing map method (Kiviluoto 1998; Du Jardin and Séverin 2011), bankruptcy trajectories (Argenti 1976; Du Jardin and Séverin 2010) and opinions of auditors on the continuation of business activity of the surveyed companies (Carson et al. 2013).

In addition to pursuing increasingly advanced techniques, appropriate significance should be attributed to the variables used in the models being built. Initially, only financial ratios and amounts that could be derived from financial statements were used. Over time, however, other factors, such as those related to macroeconomics, business sector or corporate governance, were increasingly considered, which has affected the efficiency of models (Dyrberg 2004; Lee et al. 2003; Grunert et al. 2005).

In forecasting corporate bankruptcy, there are also two extreme approaches to building models that can be observed. On the one hand, models adapted to the specificity of the analyzed enterprises are proposed. In this case, it is suggested that models suitable for the units operating in a given country (Altman and Narayanan 1997) or sector (Altman 2000), having appropriate size (Khmerkan and Chancharat 2015) or listed or not on a stock exchange (Altman 2000) should be developed. Such models are generally characterized by higher efficiency than in the case of universal models, as they consider the specific characteristics of the examined enterprise group. However, they do not enable the comparisons of the risk of insolvency between different groups of enterprises. Therefore, the literature of the subject also presents proposals of models that are universal, i.e., based on data from companies operating in different sectors, countries, etc. The examples include models that are global (Alaminos et al. 2016) or regional, i.e., estimated based on data from companies operating in selected countries in a given area, e.g., the European Union, Central and Eastern Europe, etc. (Laitinen and Suvas 2013; Režňáková and Karas 2014; Vavřina et al. 2013; Babič et al. 2013; Novotná 2012; Klepáč and Hampel 2016).

3. Research into Business Insolvency Forecasting in Selected Central and Eastern European Countries—Results

3.1. Methodology

A critical literature analysis of the subject was used as a research method. First, the second section presents the results of research on corporate bankruptcy prediction related to highly developed countries, which reaches many years back. It depicts both the historical outline and the latest global trends in the forecasting of corporate bankruptcy. This point determines, on the one hand, an introduction to the main research and a comparative basis for the Central and Eastern European countries.

In the second stage, material was collected in the form of publications on the forecasting of corporate bankruptcy in selected Central and Eastern European countries. This group included countries which founded the CMEA (Council for Mutual Economic Assistance) or which later emerged as a result of its collapse (Poland, Lithuania, Latvia, Estonia, Ukraine, Hungary, Russia, Slovakia, Czech Republic, Romania, Bulgaria, Belarus). Information on the publications was obtained during the period of Q4 2016–Q3 2017 from Google Scholar and ResearchGate databases by entering the phrases "corporate bankruptcy prediction" or "bankruptcy prediction" in the search field. The choice of Google Scholar results from the fact that it is one of the most extensive databases, which also includes many publications indexed in Web of Science and Scopus. ResearchGate was a kind of supplement for Google Scholar and facilitated to obtain publications through, inter alia, direct contact with their authors.

3.2. Literature Review

3.2.1. Belarus

The institutions of bankruptcy in their early form, as in other post-Soviet countries, appeared in Belarus in the early 1990s. Originally, Russian bankruptcy law applied there, and the number of bankruptcies was small. It was only at the beginning of the 21st century that it increased significantly, reaching e.g., about 500 cases in 2001, and 1150 cases in 2002. This was a consequence of introducing new regulations aimed at harmonizing Belarussian insolvency law with European standards (Smolski 2006). Therefore, until the implementation of the new law interest in the problem of assessing the risk of enterprise insolvency was insignificant. The interest in these problems intensified particularly in the second half of the first decade of the 21st century, when two national models were estimated by Savitskaya. They were built using the techniques of linear multidimensional discriminatory and logit analysis and are designed to assess the risk of bankruptcy of companies in the agricultural sector. These models are rather theoretical than practical and have never been officially recognized as a tool for forecasting bankruptcy risk. This is because the Belarusian law imposes a methodology for estimating the risk of bankruptcy. It considers three indicators that refer to liquidity and funding structure (Kareleu 2015). Nevertheless, Shakun and Skrobko (2012) conducted a comparative analysis of the efficiency of foreign models (of Altman, Taffler, Tishaw, Beaver, Fedotov, Sajfulin, Kadykov and Zaitsev) and the Savitskaya linear discriminant analysis model and compared their results to the method of calculating the risk of insolvency imposed by the Belarussian law. The research was carried out based on companies from the agricultural sector and it is, therefore, not surprising that the best results were obtained in the national model. They also coincided with the results produced by the Belarussian analytical tool provided for in the national law. Vodonosova (2012) also conducted a comparative analysis of foreign models, including Russian ones; however, the research sample was not very numerous, as it included only 9 construction companies. Nevertheless, this shows that Belarussian researchers did attempt to use foreign models to assess the risk of insolvency of domestic entities. Kareleu (2015) in his polemic article also notes that due to differentiated access to data, different economic models of countries and economic cycles foreign models cannot be simply transferred to another country, as these tools should be adapted to the prevalent national standards. In addition to traditional techniques, the Belarussian scientists also paid attention to the possibility of using more sophisticated methods, such as fuzzy logic, for predicting bankruptcy. Nevertheless, the article that drew attention to this possibility was rather a presentation than a model (Lobanova et al. 2012).

3.2.2. Bulgaria

In Bulgaria, the bankruptcy procedure is governed by the Commerce Act enacted in 1994[1]. However, insolvency proceedings basically did not take place until July 1996 (Bideleux and Jeffries 2007).

One of the first studies on the financial condition of Bulgarian public companies and investment preferences at the same time, using bankruptcy prediction models, was carried out by Popchev and Radeva (2006). They used the Altman, Fulmer, Springate, R and Voronov-Maximov models to assign the investigated business units to three groups: risky, financially secure to a satisfactory degree and having a very good financial position. In the later period Radkov and Minkova (2011); Radkov (2013) presented the possibility of applying the ASFR-asymptotic single-risk factor and Merton models to estimate the likelihood of bank failures in their country. On the other hand, Angelov (2014) used foreign models, i.e., Beaver, Altman, Fulmer, Springate, Fox and Taffler, to analyze the threat of bankruptcy of six Bulgarian public companies. More extensive research in this area was conducted by Delev (2014, 2016a). He used primarily Western models (of Taffler, Taffler and Tishaw, Springate, Lis, Zmijewski) and Polish models (Pogodzińska and Sojak, Hadasik, poznański) to assess the risk of insolvency of Bulgarian public companies. The models that proved highly efficient in Bulgarian conditions included the approaches of Taffler and Tischaw and Zmijewski, as well as all Polish models. As part of his doctoral dissertation, Delev also presented a model developed for Bulgarian conditions based on 60 non-financial companies listed on the Bulgarian stock exchange. He used linear multiple discriminant analysis (Delev 2016b) to construct his model.

3.2.3. Czech Republic

In the Czech Republic bankruptcy law was enacted on 1 October 1991, while a larger number of bankruptcy petitions appeared only in 1993 (Venyš 1997). The first attempt at developing a national bankruptcy risk assessment model was made by Neumaiers in 1995 (so-called IN95 model). In the following years, the same authors, having a larger sample of companies, built other national models—IN99, IN01 and IN05 (Divišová 2011). Then a significant number of publications on this subject appeared. The main conclusions are presented below, divided into two areas: suggestions of original national models and the proposals related to using already existing domestic and foreign models and financial measures to assess the risk of bankruptcy of Czech companies.

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1 See Delchev, Insolvency Law in Bulgaria, https://www.delchev-lawfirm.com/practice-areas/insolvency/ (accessed on 5 September 2017).

An interesting study in bankruptcy of Czech small and medium enterprises was conducted by Korab (2001). A fuzzy logic technique was used to assess the threat of corporate bankruptcy and, in addition, both quantitative (financial and non-financial) and qualitative (e.g., location, qualifications and skills of management team or quality of products and services) measures were applied as explanatory variables. The studies on forecasting bankruptcies of Czech companies were also conducted by Dvořáček and Sousedíková (2006), along with other authors. Originally, they used univariate discriminant analysis (Dvořáček and Sousedíková 2006), which was followed by multidimensional linear discriminant analysis, logit analysis and artificial neural networks that led to the development of several models, mainly of universal nature (Dvořáček et al. 2008, 2012a, 2012b). They used financial ratios as explanatory variables and the best results were obtained using the neural network model. Jakubík and Teplý (2011) built a logit model for predicting bankruptcy based on a large sample of non-financial Czech enterprises. What is new is that they proposed the aggregation of data derived from this model as the next step and, on this basis, they established a measure they called 'JT index', the purpose of which was to illustrate the financial condition of the non-financial sector. Hampel et al. (2012) proposed a model for forecasting the bankruptcy of enterprises from the Czech agribusiness industry sector. They used the function of production for this purpose, which is rare in this research area. The results were then compared with those obtained using the Altman model. They appeared comparable in terms of efficiency, but it should be noted that the research sample was small and the conclusions that can be drawn are not very significant. Kalouda and Vaníček (2013) proposed two national bankruptcy prediction models, CZ2 and FK, constructed using linear multidimensional discriminant analysis. They then compared their performance with the Altman and IN05 models. In particular, the CZ2 model proved superior to the remaining ones. The studies on forecasting bankruptcies of Czech companies were also conducted by Karas and Režňáková, along with other authors. At first, they verified the performance of the Altman model in Czech conditions, which turned out to be low. They then tried to adapt this model to national conditions by modifying weights and the grey zone to get better forecasts (Karas et al. 2013). Later, they built national models using linear multidimensional discriminant analysis and the boosted tree method. In a direct comparison, a model developed based on a nonparametric method was demonstrated to be more efficient (Karas and Režňáková 2013; Karas and Režňáková 2014). Also, based on a sample of manufacturing and construction companies, they conducted a comparative analysis of their own model of linear discriminant analysis (BI—bankruptcy index), another Czech model of linear multidimensional discriminant analysis IN05 and the Altman model. The models generated similar, although low (less than 60%), efficiency levels (Karas and Režňáková 2015). Kocmanová et al. (2014) proposed a measure for the assessment of Czech manufacturing companies in terms of their sustainable development, the so-called SCPI (Sustainable Corporate Performance Index). It is not a typical measure of bankruptcy prediction, as apart from the financial aspects it includes other explanatory variables of environmental, social, and corporate governance nature. Nevertheless, it is an interesting addition to the models discussed in this article. Machek et al. (2015) proposed using linear discriminant and logit analysis to create models allowing to verify the risk of bankruptcy of companies operating in the cultural sector, which is a novelty in relation to other studies. Vochozka et al. (2015a) built a highly efficient model for transportation and shipping companies using logit analysis and financial variables. Bemš et al. (2015) proposed a new solution in enterprise insolvency forecasting, namely the concept of a modified magic square which was used in macroeconomics, among others. They used financial ratios as explanatory variables and the objects were Czech companies. By comparing the models estimated using different techniques, they used the model they proposed to obtain results similar to those obtained using the logit model, artificial neural networks, evolutionary algorithms, and Bayes classifiers. As the added value of this model in relation to others, they recognized the possibility of presenting the results of the financial condition of a company together with the impact of particular explanatory variables graphically. Vochozka et al. (2015b, 2016) developed models for predicting the bankruptcy of Czech manufacturing and construction companies using artificial neural networks having the accuracy of over 90%. On the other hand, Němec and Pavlík (2016) built a logit model for the Czech conditions and then compared its efficiency with other Czech and foreign models based on a validation test. It turned out that their model generated the highest efficiency of 83.97%.

Research using both financial ratios and domestic and foreign models to assess the risk of bankruptcy of Czech companies from different sectors and of different sizes was conducted among others by: Klecka and Scholleova (2010); Divišová (2011); Pitrová (2011); Kubíčková (2011, 2015); Cámská (2012, 2013, 2016); Čámská and Hájek (2012); Šlégr (2013); Mičudová (2013a, 2013b); Kubecová and Vrchota (2014); Machek (2014); Rudolfova and Skerlíkova (2014); Dolejšová (2014, 2015); Hajdíková et al. (2015); Daniela et al. (2016). In addition, Kubíčková and Nulicek (2016) proposed potential indicators that act as predictors of enterprise bankruptcy under Czech conditions. Kubíčková (2011) came to interesting conclusions. She determined the values of the financial measures necessary to calculate the value of the Altman function for selected Czech companies based on the financial statements drawn up in accordance with the Czech accounting standards and in accordance with the International Accounting Standards. It turned out that both the values of the indicators and the Altman model parameters differed and, in some cases, generated contradictory predictions regarding the risk of bankruptcy.

3.2.4. Estonia

In Estonia, as in other post-Soviet countries, the problem of corporate insolvency emerged in the early 1990s, when the country regained its independence. The bankruptcy law was passed on 10 June 1992 and entered into force on 1 September 1992 (Varul 1999).

The first studies on the prediction of business insolvency using the appropriate models appeared, however, only at the end of the 20th century. In 1999, Künnapas (as in Männasoo 2007) built a model for forecasting the bankruptcy of Latvian manufacturing companies using linear multidimensional discriminative analysis, and seven years later Lukason proposed national models (for Estonian conditions) that were estimated using the following techniques: linear multidimensional discriminant analysis, logit analysis, artificial neural networks, and recursive division methods. Männasoo (2007) applied the survival analysis for this purpose. Later, Grünberg and Lukason (2014) developed two models of forecasting bankruptcy of production companies using, respectively, the logit analysis and artificial neural networks. Data of 11,542 sound enterprises and 58 bankruptcies from the years 2005–2008 were used to estimate these figures. As the explanatory variables for the model the financial ratios, the size of the company measured by the level of assets and the age of the company were chosen. Model testing was performed on a validation sample for two periods, i.e., the period of economic growth (2005–2008) and the years of recession (2009–2010). The results can be considered unsatisfactory as far as the efficiency of the forecasts is concerned. In particular, the first type accuracy proved to be low. In the case of one-year time advance, the logit model for the growth period yielded 72% efficiency, while during the recession it amounted to 51%. For a model developed using artificial neural networks, the results were as follows: 84% and 65%. For two- and three-year advance for the economic growth period, the logit model generated first type accuracy close to 40%, while the artificial neural network model achieved efficiency close to 60%. Generally, the predictive results obtained using the artificial neural network model were slightly better than in the case of the logit model. These studies also show that models developed based on data from the period of economic growth do not work well for predicting the bankruptcy of companies that occurred during the recession. Other studies on forecasting the bankruptcy of Estonian companies were carried out by Käsper (2016). He focused exclusively on forecasting the bankruptcy of micro-enterprises which obtained grants for starting up business in the period 2004–2009. Using the logit method, he estimated his own model with financial indicators as the explanatory variables and then compared its performance with

Stahlman[2] and Altman[3] models. The efficiency of all models for the period of one year and two years preceding the bankruptcy proved to be very low—it did not exceed 60%. Only in the case of two-year advance the Käsper model allowed for reaching 67.9% of correct classifications. It is also worth noting that in the case of each of the models there were significant differences between first- and second-type accuracies. These analyses show that traditional bankruptcy prediction models failed to predict the financial condition of small businesses. The same author, in cooperation with Lukason (Lukason and Käsper 2017), expanded his research in the field of forecasting bankruptcy risk by considering all start-ups that received government grants in the period 2004–2013. Upon selection, data were collected for 417 companies, based on which models were built using logistic regression. However, they generated low efficiency, which is why the concept of trajectory, called 'financial patterns' by the authors, was also used in the research.

3.2.5. Hungary

In Hungary, as in other post-Soviet countries, the problem of corporate insolvency emerged in the early 1990s[4]. The first models of bankruptcy risk prediction for the Hungarian market were developed by Hajdu and Virág (2001). To this end, they selected a sample of 154 companies, of which half were insolvent. As explanatory variables, the indicators based on the financial statements of 1990–1991 were used. The models were constructed based on linear discriminant analysis and logistic regression. Later, in 1996, they developed several industry models using the same methods (they presented in their publication 26 industries). In 2005, Virág and Kristóf (2005) published a paper in which, based on the same data from 1990–1991 used to build previous models, they built another model using artificial neural networks. Compared to earlier models, it was characterized by higher efficiency, which confirmed the superiority of artificial neural network techniques over linear multidimensional discriminant analysis and logistic regression in predicting the risk of insolvency of enterprises. A similar research was conducted on another sample of companies by Bozsik (2010). He built models using linear multidimensional discriminant analysis and artificial neural networks and compared their efficiency on a validation sample. The results were comparable to those obtained by Virág and Kristóf, i.e., models of neural networks proved to be better, and among them the one with two layers was exceptionally superior. In subsequent studies, using the same learning sample from the years 1990–1991, Virág and Kristóf (2014) built models using the techniques of support vector machines and rough set theory. Based on the validation sample it was found that both models generated efficiencies similar to the one of the model developed using artificial neural networks.

Very extensive research on the forecasting of bankruptcy of Hungarian small and medium-sized enterprises was conducted by Kristóf and Koloszár (2014). They estimated their own models using the following techniques: linear discriminant analysis, logit analysis, classification trees and artificial neural networks, and then compared the efficiencies of these models with the efficiencies of other Hungarian (Virág-Hajdú discriminant and logistic models) and foreign (Altman, Springate, Comerford, Ohlson, Zmijewski) models both on the learning sample and on the validation sample. What is not surprising is that for the learning sample the models estimated by them were highly efficient—their efficiency was much higher than in the case of other models. Out of these, the best models were estimated using classification trees and artificial neural networks. The results obtained for the validation sample were much worse, as the best model built by the authors achieved an overall error of 26.7%. The other models were characterized by significantly higher errors. This means that under no circumstances should foreign models be used to predict the bankruptcy of Hungarian companies and national models can only serve as supplementary tools for assessing the risk of bankruptcy of units from

2 The Stahlman logit model is based on the financial data derived from the micro and small companies (Käsper 2016).
3 In these studies, the author used the Altman logistic model from 2014 (Altman et al. 2017).
4 Act XLIX of 1991 on Bankruptcy Proceedings and Liquidation Proceedings, http://matraholding.hu/images/userfiles/files/Legislation.pdf (accessed on 10 March 2017).

the SME sector. In the same year the results of the financial analysis of Hungarian dairy companies were published by Andrea (2014). She used the ratio analysis and the Altman and Springate models. The Altman, Springate, Comerford and Virág-Hajdú models were also used for assessing the risk of bankruptcy of Hungarian companies in studies of Dorgai et al. (2016). As part of these analyses, Altman and Springate models proved to be the best, but it should be noted that the sample was not very large. Finally, Bauer and Edrész (2016), based on data from 1996–2014, built a probit model for predicting the insolvency of private Hungarian companies. One of the distinguishing features of their research was the inclusion of, apart from typical explanatory variables such as financial indicators, also macroeconomic variables (GDP growth, cost of borrowing and the rate of total bank loan volume growth) and qualitative variables (company size, age, ownership structure, industry, exporter status etc.).

3.2.6. Latvia

In Latvia, the first bankruptcy law was introduced in the same year in which the country regained its independence, i.e., in 1991. Later amendments were made, and new regulations were introduced (Klauberg and Gebhardt 2007; Draba 2012).

Probably the first model adapted to local conditions was developed by Šorins and Voronova (as in Sneidere and Bruna 2011) and published in 1998. The next study results available to the author come from the end of the first and the beginning of the second decade of the 21st century and concern mainly the use of foreign models for forecasting the risk of bankruptcy of Latvian companies. In 2009 Koleda and Lace (2009) presented a tool to assess the risk of bankruptcy of Latvian enterprises from the SME sector. It was based on combining the concepts of four foreign models, i.e., the two-factor model, the models of Altman and Tafler, as well as the R-model into one measure, and each of them was given different weights. Two years later Sneidere and Bruna (2011) published the results of a study on assessing the risk of insolvency of Latvian companies from four sectors: services, manufacturing, trade, and construction. They used foreign models of Altman, Fulmer and Zmijewski, as well as the national model of Šorins and Voronova. Based on them, different accuracy scores were obtained depending on the type of sector, while only the Altman and Fulmer models accounted for over 80% of accurate forecasts in the complete validation sample. In the same year, Genriha et al. (2011) proposed a national logit tri-factor bankruptcy risk assessment model and compared its efficiency with ten foreign models. It turned out to have the highest level of accuracy. The publication of Voronova (2012), which presents various concepts of bankruptcy risk measurement, is also worth noting. Based on the conducted literature research Voronova showed that the Altman models had been used to assess bankruptcy risk in many Central and Eastern European countries (Belarus, Estonia, Czech Republic, Poland, Latvia, Lithuania, Romania, Russia, Ukraine). She suggested that in the case of the SME sector during the early stage of risk management system creation companies used simple methods, such as the Kraliček test and the Duran technique.

3.2.7. Lithuania

In the period after the Second World War the Lithuanian bankruptcy law in Lithuania it was adopted on 15 October 1992, while the first cases of corporate bankruptcies appeared only in 1993[5]. Probably the first national model built in 2003 by Grigaravičius (2003). To do this, he used the logit method with a sample of 88 entities. The estimates of other models dedicated to the Lithuanian market were provided by Purvinis et al. (2005a, 2005b). They used the technique of linear multivariate discriminant analysis and artificial neural networks with the learning sample consisting of only 13 companies. In 2008, the same authors presented hybrid models combining the technologies of artificial

[5] See Republic of Lithuania, Law of Enterprise Bankruptcy, http://www.litlex.lt/litlex/eng/frames/laws/Documents/21.HTM (accessed on 20 July 2016) and Spaičienė (2008).

neural networks and fuzzy logic (Purvinis et al. 2008). In this case, the study sample was more numerous and comprised of 30 sound and 200 bankrupt companies. Their best performance model allowed them to obtain, based on a validation sample, the first type accuracy of slightly more than 80%, which still was higher by 7 percentage points than the result obtained using the Altman's model. In 2006, based on 56 companies, Stundžienė and Boguslauskas (2006) developed a model for assessing the risk of bankruptcy using cluster analysis. It provided higher efficiency in relation to the Altman's one. In the same period Merkevicius et al. (2006) modified, by using the technique of self-organizing maps, the weights in Altman's model to better adapt it to the conditions prevalent in Lithuania. Four years ago, Butkus et al. (2014) built several models using the logit method. It is noteworthy that they had a sectoral nature (related to construction, commercial and industrial companies) and were supplemented by additional models estimated for enterprises of various sizes. The last of the available models was developed by Šlefendorfas (2016). The author used a sample of 145 enterprises for this purpose and the linear multivariate discriminant analysis method. The efficiency determined for learning sample was 89%.

Similar to other countries, Lithuanian scientists have also used foreign models to assess the risk of enterprise insolvency. The first studies with their use were conducted at the end of the 20th century, and a detailed review of the literature in this area was presented by Kanapickiene and Marcinkevicius (2014). It showed that native researchers often used foreign models to assess the threat of insolvency of Lithuanian companies—they employed the models of Altman, Taffler and Tishaw, Springate, Zavgren, Lis and Chesser. Their efficiency in different studies was varied. This means that none of these systems can be considered to work best in conditions prevalent in Lithuania. It should also be noted that these studies were carried out based on companies from different sectors and the sample size in some cases was very small.

3.2.8. Poland

In Poland in the postwar period bankruptcy and reorganization law was in force, supplemented by appropriate ministerial ordinances[6]. Due to the economic system, however, it was dead. Only upon the commencement of economic transformation did it start to be actually applied, and the first corporate bankruptcies took place in 1990. In 2003, the new bankruptcy law was introduced, which, with later amendments, is still in force[7]. On 1 January 2016, it was supplemented by new restructuring law[8].

The problems of forecasting corporate bankruptcies in Poland have been of interest to the researchers only since mid-1990s, although it must be said that since then the studies dealing with this issue have been numerous. For this reason, only an overview of the most important literature on this topic is presented below. The pioneering research was aimed at using foreign models, particularly the Altman model, to predict bankruptcies of Polish enterprises (Mączyńska 1994; Gasza 1997; Łukaszewski and Dąbroś (1998a, 1998b); Bławat 1999; Zdyb 2001). Zdyb (2001) proposed, among other things, adjusting the cutoff point in Altman's model to Polish conditions, so that it generates more efficiency. In the similar period the Polish researchers also started using the ratio analysis (Wędzki 2000; Stępień and Strąk 2003; Michaluk 2003; Kniewski 2004; Prusak 2005), as well as building first national models allowing for predicting corporate bankruptcies (Pogodzińska and Sojak 1995; Gajdka and Stos 1996; Hadasik 1998; Wierzba 2000). Due to the limited access to or scarcity of data, these models were created using small samples and based on multivariate linear discriminant analysis. Later, several other models were created using the same statistical technique and the sizes of learning samples were mostly higher (Hołda 2001; Sojak and Stawicki 2000; Mączyńska 2004; Appenzeller and Szarzec 2004; Korol 2004; Hamrol et al. 2004; Prusak 2005;

6 *Ordinance of the President of the Republic of Poland of 24 October 1934 Bankruptcy Law*, Journal of Laws no. 93 item 834 and *Ordinance of President of Republic of Poland of 24 October 1934 on the composition of a proceeding*, Journal of Laws no. 93 item 836.
7 *Bankruptcy and Rehabilitation Law* of 28 February 2003, Journal of Laws no. 60 item 535, as amended.
8 *Restructuring Act* of 15 Mai 2015, Journal of Laws, item 978.

Siudek 2005; Jagiełło 2013; Juszczyk and Balina 2014). As in the developed countries, newer statistical techniques also began to be used, such as the logit method (Gruszczyński 2003; Michaluk 2003; Wędzki 2004; Stępień and Strąk 2004; Prusak and Więckowska 2007; Jagiełło 2013; Pisula et al. 2013; Pociecha et al. 2014; Karbownik 2017), artificial neural networks, genetic algorithms, classification trees or survival analysis using the Cox model (Michaluk 2003; Korol 2004; Pisula et al. 2013; Pociecha et al. 2014; Pisula et al. 2015; Gąska 2016; Ptak-Chmielewska 2016), a naive Bayesian classifier, a method indirectly based on the logit model, the k-nearest neighbors method, potential functions, kernel classifiers, random forests, Bayesian networks and methods for combining classifiers into an aggregate model (Gąska 2016). Korol (2010b) also applied the method of support vectors and fuzzy logic. This concept was also used by Pisula et al. (2015). It is worth noting that in addition to universal models, many sectoral models were created, dedicated to, among others:

- companies from the logistics sector (Brożyna et al. 2016; Karbownik 2017),
- companies dealing with: wholesale trade in food, beverages and tobacco products, construction of buildings or road transport of goods (Balina and Jan Bąk 2016),
- transport, construction, service, commercial and industrial companies (Jagiełło 2013; Karbownik 2017),
- forwarding companies (Juszczyk and Balina 2009; Karbownik 2017),
- or cooperative banks (Siudek 2005).

Apart from sectoral models, systems of bankruptcy risk assessment considering the criterion of enterprise size were developed (Jagiełło 2013). It is also worth mentioning that Polish researchers used not only financial ratios but also macroeconomic measures (Korol 2010a) as explanatory variables to construct the models of enterprise bankruptcy risk assessment. In addition, Pociecha and Pawełek (2011) based on the conducted research showed that the risk of bankruptcy depends on the economic cycle and therefore suggested that enterprise bankruptcy forecasting models should consider measures showing changes in economic conditions.

3.2.9. Romania

In Romania the bankruptcy regulations had been in operation since 1887 and were included in the Commercial Code. Because of economic and political changes, they lost their significance in 1948. After the fall of the Soviet bloc and the introduction of market mechanisms, new law on restructuring and liquidation was adopted in 1995 (Branch et al. 2010).

Already in the second half of the 1990s several national models of enterprise insolvency forecasting have been developed (Manecuta and Nicolae—model for metallurgical enterprises in 1996, Bailesteanu model in 1998, Ivonciu model in 1998). These proposals were mainly based on ratio analysis and univariate discriminant analysis. Research in this area was continued in the 21st century (models: Anghel—2002—linear multidimensional discriminant analysis, Siminica—2005, Robu-Mironiuc ZRM—2012—linear multidimensional discriminant analysis, an aggregated index of financial condition of construction companies in Galati County developed by Barbuta-Misu—2012, Armeanu et al.—2012) (Barbuta-Misu 2012; Robua et al. 2014; Dinca and Bociu 2015). Most of these models were estimated using linear discriminant analysis. Other techniques were also considered. For example, Robua et al. (2013) used survival analysis and the Cox regression model to predict the bankruptcy of Romanian companies listed on a stock exchange. A very extensive study for Timis county was carried out by Brîndescu-Olariu and Goleţ (2013a, 2013b), who, based on a sample of 26,980 companies first developed a linear multidimensional discriminant analysis model and then based on a more homogeneous sample of 4327 units estimated also a logit model. A logit and probit model for large and medium companies was developed by Megan and Circa (2014). On the other hand, Ioan-Bogdan Robua et al. (2014) used such statistical techniques as: analysis of variance (ANOVA), linear regression and analysis of covariance (ANCOVA) models for assessing the risk of insolvency of Romanian companies listed on the Bucharest Stock Exchange (BSE). These models were built based on

70 companies and their purpose was to support the decision to buy/sell shares. They connected the risk of insolvency calculated using the Robu-MironiucRM model with stock return rates. It turned out that companies with high/low risk of default generated negative/positive returns, which confirmed the correlation between the risk of default and the rate of return on shares.

Romanian scientists also used foreign models to assess the risk of insolvency, for example: Burja and Burja (2013) used the revised Altman Z-score model to assess the financial condition of BSE-listed Romanian companies from the agricultural sector; Barbuta-Misu together with Codreanu (Barbuta-Misu and Codreanu 2014) and Stroe (Barbuta-Misu and Stroe 2010) used the Altman and Conan-Holder models to assess the risk of bankruptcy of construction companies. The same models were recognized as efficient in the research on insolvency risk of companies from mining and energy sectors conducted by Catalin and Ion (2016). On the other hand, Crăciun et al. (2013) and Dinca and Bociu (2015) used the Altman model and Romanian Anghel model for bankruptcy forecasting.

3.2.10. Russia

After the dissolution of the Soviet Union bankruptcy law was passed in Russia on 19 November 1992 and entered into force on 1 March 1993. In the first two years of its existence, the number of bankruptcies was insignificant and reached slightly over 100 in 1993 and 240 in 1994 (Vitryansky 1999). Therefore, as in other Central and Eastern European countries, interest in the problem of predicting bankruptcy of enterprises appeared relatively late compared to developed countries.

The first Russian models were built using mainly linear multidimensional discriminant analysis in the mid-1990s by Sayfulin-Kadykov, Zaytseva, Davydova and Bielikov. Fedorova et al. (2013) compared the performance of these models with the results obtained using models created in developed countries (by Altman, Springate, Taffler and Zmijewski) and it unexpectedly appeared that the latter were better at predicting the bankruptcies of Russian manufacturing companies. Later, these authors built national models using the following techniques: linear multidimensional discriminant analysis, logit method, classification trees and neural networks. The best classification results were obtained using neural networks—their overall accuracy reached 88.8%. Moreover, the studies included the indicators recommended by the Russian legislation for investigating the threat of bankruptcy of enterprises. It turned out that only 1 out of 13 of these measures was statistically significant and exhibited discriminatory power. In another publication, Fedorova et al. (2016) proposed a change of thresholds to obtain the highest efficiencies for domestic and foreign models in the various sectors. Foreign models allowed for achieving higher efficiencies and the best of them was Zmijewski's model. Moreover, these authors built their own model using logit analysis, based on a sample of Russian large and medium enterprises. In addition to the above-mentioned models, national models for assessing enterprise insolvency risk using linear multidimensional discriminant analysis were also built by: Fedotova—1995, Lugovskaya—2010—model for small and medium enterprises (Voronova 2012) and Burganova and Salahieva (2015)—model for the forecasting the bankruptcy of manufacturers of building materials based in the Tatarstan Republic. One novelty of the latter model was the fact that the authors considered as variables the average annual rates of change of certain financial ratios, which to a certain extent allowed them to dynamize the model. The researchers who assessed national models of insolvency risk using techniques other than multidimensional linear discriminant analysis include, among others, Evrostopova, who built a logit model (Makeeva and Neretina 2013a, 2013b), and Makeeva and Neretina (2013a, 2013b), who applied logit and probit approaches in addition to the aforementioned multidimensional linear discriminant analysis. Models developed by the latter of the above-mentioned authors are dedicated to the companies in the construction sector. A slightly different approach to predicting bankruptcy risk was presented by Shirinkina and Valiullina (2015). In the first place, they selected the most commonly used metrics in different foreign and domestic models. Next, they examined their impact on the risk of bankruptcy and proposed a simplified model in the form of a pyramid of insolvency risk.

Apart from assessing the risk of bankruptcy of enterprises from different sectors, due to the banking crisis in Russia in 1998 research into forecasting bankruptcies of banks has been very popular. Studies were performed by both Russian and foreign researchers. For example, Peresetsky et al. (2004, 2011) applied cluster analysis and showed that the use of macroeconomic variables (export-to-import rate and ruble/dollar exchange rate) in a model increases its efficiency. Lanine and Vennet (2006) used logit analysis and the trait recognition approach. Both methods yielded satisfactory results and the latter one was slightly better. On the other hand, Kaminsky et al. (2012) used a logit model. They selected measures using the CAMEL (capital adequacy, asset quality, management, earnings, liquidity) model and considered also macroeconomic and institutional variables, among which the consumer price index (positive correlation) and the monopolistic power (negative correlation) proved to have a significant impact on the probability of bank bankruptcies.

3.2.11. Slovakia

In Slovakia, the bankruptcy regulations were introduced in 1993, when the division of Czechoslovakia took place (Janda and Rakicova 2014).

Chrastinová (Chrastinová 1998) and Gurčík (Gurčík 2002) belonged to the first researchers who developed models for the Slovak conditions—they were based on using linear multivariate discriminant analysis. Both concerned business units from the agricultural sector. In the second half of the first decade of the 21st century Hiadlovský and Král' (Bod'a 2009) developed several national models using such techniques as factor analysis, discriminant analysis, logit analysis and fuzzy set theory. Gavliak (Bod'a 2009) also applied a linear probability model. On the other hand, Bod'a (2009) tried to use the artificial neural network technique to predict the bankruptcy of Slovak companies. In the second decade of the 21st century Král' et al. (2014) used penalized logistic regression and random forest techniques to test whether enhancing a model with variables reflecting the changes of indicators over time can improve its efficiency for a sample of Slovak enterprises. The results of their research indicate that models that account for changes in financial indicators over time generated slightly better predictive results than models with static data. In subsequent studies, the above-mentioned authors, in cooperation with Kakaščík (Stachová et al. 2015), verified whether obtaining data from a longer period in the past may improve the efficiency of models. The results show that prolonging the time from which the data for model construction is collected leads to lower predictive errors, which confirmed their hypothesis. Bányiová et al. (2014) applied the Data Envelopment Analysis (DEA) method to predict the bankruptcy of agricultural companies operating in Slovakia. They proposed four models with low overall accuracy (between 54% and 70%). Considering previous research, these authors concluded that better forecast results can be derived from models built on such techniques as linear multidimensional discriminant analysis, logit analysis and classification trees. The DEA method was also used to forecast the bankruptcies of enterprises in Slovakia by Roháčová and Pavol (2015). In this case, however, the validation of the model was not performed. Interesting research carried out on a large sample of Slovak enterprises was conducted by Kubicová and Faltus (2014). They used measures reflecting income taxation to forecast corporate insolvency. It was shown, however, that single indicators of this kind have low discriminatory power. A logit model based on three measures related to taxation generated much better prognostic results than single measures but it failed to provide a guarantee of efficiency higher than in the case of models including other financial measures. Mihalovic (2016) built two national models based on a linear multi-dimensional discriminatory analysis and logit analysis using a balanced sample of 236 bankrupt and non-bankrupt enterprises. As explanatory variables, financial indicators were used. The results obtained for a validation sample of enterprises showed the superiority of the logit model, with general efficiencies being not very high (logit model—68.64%, model based on linear multidimensional discriminative analysis—61.86%).

Researchers from Slovakia also performed comparative analyses of the efficiency of different models, including foreign ones. Delina and Packová (2013) analyzed 1560 Slovak enterprises, out of which 103 were bankrupt. The financial data of these companies came from the years 1993–2007.

Three measures of bankruptcy risk assessment were selected for the study: the Altman model, IN05 index and Bonity index. Each of them was characterized by low efficiency. Therefore, these authors proposed to create their own national model using the regression technique. In principle, this model generated better forecasts in comparison to the other three measures, but it should be noted that the efficiencies were determined based on a learning sample, which requires further verification using a validation test. Šofranková (2013) used the Altman model to assess the financial condition of 46 companies offering accommodation (hotels) and verified the relationship between the results from the Altman model and four non-financial measures, i.e., the organizational form, the number of employees, the number of beds offered and the type (class) of the hotel measured by the number of stars. Dependence between the last three measures and the Altman index was observed and on this basis the author suggested constructing an original model considering the specificity of the hotel industry. Later, Šofranková (2014) conducted similar studies but using the IN01 and IN05 models. She reached similar conclusions, namely that it would be worthwhile to include the following non-financial variables in hotel risk assessment models: the class of the hotel measured by the number of stars, the number of beds and the type of hotel ownership (state or private). On the other hand, Braunová and Jantošová (2015) used the Altman model to assess the risk of bankruptcy of hospitals in Žilina region. Adamko and Svabova (2016) verified the efficiency of three Altman logit models from 2014 on a sample of Slovak enterprises for which 2013 and 2014 data were obtained. These results were promising in comparison with the results obtained in other countries, and the AUC (area under curve) measure was between 0.8116 and 0.8835, depending on the model and years.

3.2.12. Ukraine

Ukraine gained independence in 1991, while its bankruptcy law came into force on 1 July 1992[9]. The first national models for predicting the bankruptcy of Ukrainian companies appeared in the early 21th century and were developed by Martynenko and Tereschenko (Voronova 2012). Both authors used the linear discriminative analysis technique to estimate them. Matviychuk (2010) reached interesting conclusions—he provided arguments confirming the claim that foreign models would not work in Ukrainian conditions. This is due, among other factors, to the fact that many Ukrainian companies understate their income to avoid taxation. The group of main indicators in foreign models includes profitability measures, which automatically results in underestimating their value and leads to the indication of increased risk of insolvency. That is why Matviychuk developed national models using linear discriminant analysis techniques and fuzzy logic with financial indicators as explanatory variables. The discriminatory model he developed was validated on a sample consisting of 40 bankrupt and 40 non-bankrupt companies. The overall efficiency was 80.1% and was significantly higher than in the case of the results obtained with the following models: Altman, Davydova-Bielikov and Tereschenko. What is more, the fuzzy logic model was significantly better than the discriminatory model, achieving efficiency above 90%. The comparative analysis of the efficiency of the following models: Altman, Conan and Holder, Lis, Taffler, Springate, Beaver, the universal model based on discriminant function, Chepurko, Saifullin and Kadykov and Sumy was conducted by Druzin (2013) on a sample of 15 enterprises. It turned out that the best results were achieved using the Springate, Lis and Beaver models. The author also pointed out that one of the main problems in forecasting the bankruptcy of Ukrainian companies is the low credibility of publicly available financial data. An interesting concept of enterprise bankruptcy forecasting model was proposed by Kozak et al. (2013). It combines quantitative and qualitative variables by generating causal relationships. The authors used a combination of fuzzy logic and cognitive technology to construct the model. This method is known in theory as fuzzy cognitive maps. Nevertheless, the authors apart from presenting the concept of this model did not show how it should be implemented in practice. Harafonova and Ulchenko (2014)

[9] The Law of Ukraine Bankruptcy dated 14 May 1992 Vidomosti of the Supreme Rada, No. 31, item 440.

characterized in their article the Altman and Ohlson models. They presented their advantages and disadvantages, paying attention to the different accounting standards and conditions of enterprise operation in Ukraine and in the countries in which these models originated. They said that after making appropriate adjustments, these models could be used to forecast the bankruptcy of Ukrainian companies. Kornyliuk (2014) conducted a study on the key determinants enabling the identification of the risk of bankruptcy of Ukrainian banks. He tested 12 financial indicators, the most discriminating of which were the measures of profitability and the ratio of household deposits to liabilities. Among the qualitative factors, the risk of bankruptcy of Ukrainian banks was most influenced by their ownership structure. Banks with foreign capital were much less exposed to the risk of bankruptcy than those with domestic capital. Neskorodeva and Pustovgar (2015) used the Kohonen neural network and financial metrics to build a model enabling the assessment of the risk of bankruptcy of companies from the steel industry. In 2015, Kleban (2015) proposed the use of fuzzy logic for forecasting the insolvency of enterprises. He used the Takagi-Sugeno algorithm, with financial indicators and figures as explanatory variables. Lytvyn (2015) developed the models for forecasting the bankruptcies of insurers using the technique of support vehicle machine. Among the best models, overall efficiency was close to 90%. Klebanova et al. (2016) developed based on 12 bankrupt and 24 non-bankrupt enterprises a model for forecasting bankruptcy of enterprises in the agricultural sector. To this end, they applied a concept combining artificial neural networks and fuzzy logic.

3.3. Summary of Results

Based on the literature review conducted in Section 3.2, in Table 1 the most important conclusions from the research were presented. For this purpose, three most important areas have been identified, i.e., the techniques used to develop national corporate bankruptcy prediction models, types of variables and information on sectoral models.

Table 1. Summary of research on forecasting enterprise bankruptcy in Central and Eastern Europe.

Techniques Used in National Models	Variables	Sectoral Models
	Belarus	
linear multiple discriminant analysis and logit technique	financial ratios	agricultural sector
	Bulgaria	
linear multiple discriminant analysis	financial ratios	non-financial companies listed on the Bulgarian stock exchange
	Czech Republic	
univariate discriminant analysis, linear multiple discriminant analysis, logit technique, artificial neural networks, fuzzy logic technique, function of production, boosted tree technique, Sustainable Corporate Performance Index, modified magic square, evolutionary algorithms and Bayes classifiers	quantitative (financial and non-financial—e.g., variables of environmental, social, and corporate governance nature) and qualitative (e.g., location, qualifications, and skills of management team or quality of products and services) measures	non-financial enterprises, agribusiness industry sector, manufacturing companies, cultural sector, transportation, and shipping companies
	Estonia	
linear multiple discriminant analysis, logit technique, artificial neural networks, recursive division methods, survival analysis, financial patterns	financial ratios, size of the company	production companies, micro-enterprises which obtained grants for starting up business
	Hungary	
linear multiple discriminant analysis, logit and probit analysis, artificial neural networks, support vector machines, rough set theory, classification trees	financial indicators, macroeconomic variables (GDP growth, cost of borrowing and the rate of total bank loan volume growth) and qualitative variables (company size, age, ownership structure, industry, exporter status etc.)	small and medium-sized enterprises, 26 different industries

Table 1. *Cont.*

Techniques Used in National Models	Variables	Sectoral Models
	Latvia	
linear multiple discriminant analysis, logit technique	financial ratios	small and medium-sized enterprises
	Lithuania	
linear multiple discriminant analysis, logit technique, artificial neural networks, fuzzy logic, cluster analysis	financial indicators	construction, commercial and industrial companies
	Poland	
univariate and linear multiple discriminant analysis, logit analysis, artificial neural networks, fuzzy logic technique, genetic algorithms, classification trees, survival analysis using the Cox model, method of support vectors, a naive Bayesian classifier, a method indirectly based on the logit model, the k-nearest neighbors method, potential functions, kernel classifiers, random forests, Bayesian networks and methods for combining classifiers into an aggregate model	financial indicators, macroeconomic measures	small and medium-sized enterprises, logistics sector, wholesale trade in food, beverages and tobacco products, construction of buildings or road transport of goods, transport, construction, service, commercial and industrial companies, forwarding companies, public companies
	Romania	
univariate and linear multiple discriminant analysis, logit technique, survival analysis and the Cox regression model, ANOVA, linear regression, ANCOVA	financial indicators	metallurgical enterprises, construction companies, public companies
	Russia	
linear multiple discriminant analysis, logit and probit analysis, artificial neural networks, classification trees, pyramid of insolvency risk, cluster analysis	financial ratios, in case of banks macroeconomic and institutional indicators	small and medium-sized enterprises, manufacturers of building materials, construction sector, banks
	Slovakia	
linear multiple discriminant analysis, factor analysis, logit analysis, fuzzy set theory, linear probability technique, random forest, DEA method, classification trees	financial ratios, measures reflecting income taxation	agricultural sector
	Ukraine	
linear multiple discriminant analysis, fuzzy logic technique, Kohonen neural network, Takagi-Sugeno algorithm	financial ratios, in case of banks qualitative factors (e.g., ownership structure)	banks, steel industry, agricultural sector

Source: own work.

Table 1 presents that the most advanced techniques are used in the Czech Republic and Poland, while only classical methods were implemented in Bulgaria, Belarus, Romania, and Latvia. In many countries, in addition to financial ratios, other variables were applied as explanatory variables. The exceptions were Belarus, Bulgaria, Latvia, Lithuania, and Romania. In most countries, sectoral models have been developed. The exception was Bulgaria, in which only a universal model limited to companies listed on the stock market was created. The highest number of sector model proposals was recorded in Poland and Hungary.

Considering the information included in Table 1 and the literature analysis conducted in Section 3.2, the rating of the countries is proposed in terms of the state of advancement of bankruptcy forecast models in the Central and Eastern European countries (Table 2). Countries have been assigned with grades 0 to 4, with a higher score resulting in a more advanced research toolbox for forecasting corporate failure. A detailed description of the evaluation criteria is presented in Table 2.

Table 2. Comparative analysis of the level of advancement of research on forecasting enterprise bankruptcy in Central and Eastern Europe.

Country	Rating	Comment
Belarus	1.5	Mainly foreign models have been used to assess the risk of enterprise bankruptcy. National solutions have also been proposed and they are not numerous.
Bulgaria	1.5	Mainly foreign models have been used to assess the risk of enterprise bankruptcy. National solutions have also been proposed and they are not numerous.
Czech Republic	4	Numerous studies have been performed in this area. Many national and sectoral models have been evaluated using the latest statistical methods. Both financial and non-financial information has been used as explanatory variables. In addition, several new solutions have been proposed, such as the modified magic square and the Sustainable Corporate Performance Index.
Estonia	3	National models have been evaluated using the latest techniques. Models have been proposed that considered the specificity of given groups of companies (e.g., manufacturing companies or micro-enterprises obtaining grants).
Hungary	3	Many national models have been proposed, including those built using the latest statistical methods. Sectoral models and models considering business size have been also developed. Financial ratios have been used as explanatory variables, but other economic and non-financial measures were also proposed.
Latvia	2	Mainly foreign models have been used to assess the risk of bankruptcy, while several national models were estimated using basic statistical methods.
Lithuania	2.5	Foreign and national models have been used to assess the risk of bankruptcy—the latter were estimated using more sophisticated statistical methods. There have also been isolated attempts to build sectoral models.
Poland	4	Numerous studies have been performed in this area. Many national and sectoral models have been evaluated using the latest statistical methods. Both financial and non-financial information have been used as explanatory variables. Additionally, attention was paid to the impact of the economic climate on the efficiency of models for the forecasting of enterprise insolvency.
Romania	2	Foreign and national models have been used to assess the risk of bankruptcy—the latter were estimated using more traditional statistical methods. There have also been isolated attempts to build sectoral models.
Russia	3	National models have been evaluated using the latest techniques. Models have been proposed that consider the specificity of given groups of companies (e.g., the construction sector and building materials manufacturers, banks, SME sector).
Slovakia	3.5	Numerous studies have been performed in this area. Many national and sectoral models have been evaluated using the latest statistical methods. For the first time, attempts have been made to use measures that consider income taxation to assess the bankruptcy risk of companies.
Ukraine	2.5	Foreign and national models have been used to assess the risk of bankruptcy—the latter were estimated using more sophisticated statistical methods. There have also been isolated attempts to build sectoral models.

Ratings:
0—There are no studies in enterprise bankruptcy risk prediction in the given country.
1—Analyses are conducted to assess the risk of bankruptcy of enterprises using only foreign models in the country concerned.
2—Both national and foreign models are used to assess the risk of business insolvency in the country concerned, with national models being constructed using less sophisticated statistical methods, i.e., linear multidimensional discriminant analysis, logit and probit methods etc.
3—Both national and foreign models are used to assess the risk of business insolvency in the country concerned, with national models being constructed using also more advanced methods: artificial neural networks, genetic algorithms, the support vector method, fuzzy logic, etc. Moreover, national sectoral models are also estimated.
4—The most advanced methods are used in enterprise bankruptcy risk forecasting in the country concerned and the researchers propose new solutions that affect the development of this discipline.

Source: own work.

The level of experience and advancement of corporate bankruptcy prediction research is varied, but it should be added that many of the latest developments in this area were implemented in most of the countries. Among the analyzed countries, the most advanced research in the field of enterprise bankruptcy forecasting was observed in the Czech Republic, Slovakia, and Poland. Advanced statistical techniques for modelling are employed and other new solutions are proposed in these countries. At the other end were Belarus, Bulgaria and Latvia, where only attempts at constructing national models using basic statistical techniques have been made. The remaining countries are in the middle of this group, but it is worth noting that in most of them the latest statistical techniques to build national models are used and sectoral models were also proposed.

4. Conclusions

Due to the political and economic changes, the institution of bankruptcy in the countries of Central and Eastern Europe began to function in the first half of the 1990s. During this period, the first cases of bankruptcy emerged, which caused interest in the problem of forecasting the risk of insolvency of enterprises. Due to the lack of statistical material in these countries, foreign models were originally used. It was only later that more sophisticated solutions known in developed countries were introduced and national models were built.

According to literature analysis, it means that even though the institution of bankruptcy was introduced in Central and Eastern Europe relatively late, in terms of research on enterprise bankruptcy risk forecasting, some countries currently do not depart from global patterns. The literature review shows that the best world practices are reflected in the research provided in Poland, the Czech Republic and Slovakia. Advanced models have also been developed in Russia, Estonia, Hungary and, to smaller extent, Ukraine. In Romania and Lithuania, mainly classical techniques were used to create bankruptcy forecasting models, using only financial indicators. Bulgaria, Belarus, and Latvia were ranked the weakest. In these countries, there have been single attempts to develop national models using the simplest statistical techniques and applying only financial indicators as explanatory variables.

It is also worth noting that some of these countries are characterized by certain specifics which influence the development of the research area analyzed in this article. For example, in Ukraine profitability metrics have limited prognostic value because of the lowering of income by tax-avoiding enterprises. In Russia and Belarus, the methodology used to examine the risk of bankruptcy of enterprises was included in legal acts, but the efficiency of the proposed tools was not confirmed by research. Moreover, research conducted in Ukraine has shown that the probability of bankruptcy of local banks is lower for those with foreign capital. Regarding the development of bankruptcy forecasts, it is also worth mentioning the differences that may occur when applying different accounting standards. Differing results are also obtained when financial statements are prepared in accordance with national or international accounting standards.

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