QUANTITATIVE METHODS IN ECONOMICS
Vol. XVI, No. 1, 2015, pp. 96 – 107

ISSUES IN MODELLING THE FINANCIAL DISTRESS AND BANKRUPTCY OF COMPANIES

Marek Gruszczyński
Institute of Econometrics, SGH Warsaw School of Economics
e-mail: marek.gruszczynski@sgh.waw.pl

Abstract: Paper presents selected issues in designing and implementing models for financial distress and/or bankruptcy of companies. Major topics include: (1) definition of financial distress, (2) approaches to specify the distress variable, (3) aims and extent of the research on distress, (4) quantitative approaches in the field, including the attempt by Campbell, Hilscher and Szilagyi [2008], (5) survey of recent papers on the topic published in Poland.

Keywords: financial distress, bankruptcy, corporate failure, default risk

INTRODUCTION

"Stop using Altman Z-score!" Such title of a short note on a financial advisory page caught recently my attention. Advocate of a new innovation in predicting bankruptcy? Someone not satisfied with performance of Z-score? Yes and no. The note referred to a paper by Campbell, Hilsher and Szilagyi [2008] who, inspired by the developments stemming directly from the works of Altman and others, propose a new philosophy of investing on distressed stock.

Professor Edward Altman is the honorary doctor of my Alma Mater[1]. Therefore I have decided to investigate the issue. Also due to my commitment to collecting news on modelling and predicting the financial distress and bankruptcy of companies. The experience of such modelling in Poland dates back to late nineties and has been more or less alive since then.

Paper is organized as follows. Section FINANCIAL DISTRESS describes the notion of financial distress, specifying question of its vague designation and its

[1] In May 2015 professor Edward Altman has been awarded Honoraty Doctor of SGH Warsaw School of Economics.

importance to a number of stakeholders. Section OBSERVING AND MEASURING FINANCIAL DISTRESS presents a short survey of approaches to specify the distress variable in typical models. Section RESEARCH ON FINANCIAL DISTRESS points on broader subject of research on financial distress, asking about the goals of modelling and indicating the dangers in using plethora of financial ratios as distress predictors. Section METHODS discusses briefly the multitude of methods used in the research on distress. Then, in the section's second part, results of Campbell et al. [2008, 2011] are presented in short. The last section comments on the research on financial distress in Poland.

This short contribution is aimed at reviving the interest in modelling the financial distress in Poland, more than one decade after last major contributions in the field.

FINANCIAL DISTRESS

What is financial distress of a company?

Corporate finance and accounting define financial distress in various ways. Everybody understands what is the financial distress or corporate insolvency. When it comes to precise definition, the outcome is less than satisfactory. Platt and Platt [2006] state that "definition of financial distress is less precise than the legal actions that define proceedings such as bankruptcy or liquidation; despite this uncertainty, it is clear that the condition of being financially distressed deviates from corporate normality in a manner similar to bankruptcy".

Some of the issues accompanying the understanding and explaining the financial distress are as follows:

- Distress is somehow spanned between bankruptcy and good financial health of a company.
- Usually distress precedes bankruptcy, although it is not clear that the same factors are causes of both.
- Financially distressed company may possibly have unclear future, with significant probability of discontinuation. The bankrupt company terminates the activity under given legal form but sometimes it may continue with good perspectives.
- Objective measure of distress is challenging to agree upon: a company may feel like financially sound while some of its stakeholders may be already on alert.
- Category of financial distress is fuzzy and dynamic. Data on company's financial stand are usually delayed, of little use for investors. Prevailing studies concentrate on cross-sectional view. Time series analysis of distress might be better suited for practical purposes.

Parties involved/interested

Information on the financial health of a company is crucial for many stakeholders. These are:

1. Owners of equity
- The signs of distress are expressed e.g. in the possible going concern audit opinion. The opinion shall be publicly disclosed and understandably is of great importance to company owners.
- As the result, the company valuation on the market may be affected.

2. Creditors
- Financial distress of companies in banks' credit portfolios is the key to evaluation of risk in the banks. The issue has been systematically recognized by Basel Committee of Banking Supervision, specifically by recommendations of Basel II in 2004 and Basel III in 2010. Modelling probability of default, calculating loss given default etc. are fundamental for internal rating systems which are supposed to be installed in the banks. Some of those scoring systems are described by Altman and Hotchkiss [2006, Polish edition 2007].
- Evaluation of risk by internal rating systems in banks and in other crediting institutions is more and more important since the last crisis when rating agencies did not supply correct predictions on risk.

3. Investors in equity
- Investors tracking the financial performance of companies have evident interest in all news on possible distress. The likely strategy would be reducing positions on such stocks. See more in Section METHODS.

OBSERVING AND MEASURING FINANCIAL DISTRESS: MANY SHADES OF GREY?

Dichotomy or more?

Various studies indicate the necessity to strictly distinguish between Yes-No bankruptcy modelling and possibly more than two states of distress. In fact, there exists a kind of differentiation between bankruptcy and distress modelling. The first consider only two possible states, the latter – more states, although their features, number etc. are not satisfactorily established. It should be noted that conventional studies on bankruptcy give finally the probability of failing, i.e. some measure of distress. Therefore, also the two-state explanatory variable should be considered as measuring distress.

Consequently, typical studies consider two and more states of financial distress. This is usually the characteristic of explained variable in distress models. What follows is a selection of variables expressing distress in various studies.

- Cheng, Su and Li [2006], Lau [1987] – five states of increasing severity of financial distress:
  0: financial stability,
  1: omitting or reducing dividend payments,
  2: technical default and default on loan payments,
  3: protection under Chapter 10/ 11 of the Bankruptcy Act,
  4: bankruptcy and liquidation.
- Campbell, Hilscher and Szilagyi [2008, 2011], Shumway [2001], Chava and Jarrow [2004] – two states:
  0: non-failed firms,
  1: filing for bankruptcy (Ch.7, Ch.11), delisting for performance related reasons, receiving D rating from rating agency.
- Dahiya, Saunders and Srinivasan [2003] – two states:
  0: non-failed firms,
  1: firm is financially distressed if it has insufficient cash flows to meet the payments on its debt; two types of FD announcement – (1) default on a firm's public debt, and (2) filing by a firm for bankruptcy protection under Ch. 11.
- Platt and Platt [2006] – two states:
  0: non-failed firms,
  1: financially distressed firm – meets all of the following criteria: negative EBITDA interest coverage, negative EBIT, negative net income before special items.
- Hensher and Jones [2008] – three states:
  0: non-failed firms,
  1: insolvent firms: (i) failure to pay Australian Stock Exchange annual listing fees; (ii) a capital raising specifically to generate sufficient working capital to finance continuing operations; (iii) loan default, (iv) a debt/total equity restructure due to a diminished capacity to make loan repayments
  2: firms which filed for bankruptcy followed by the appointment of liquidators, insolvency administrators or receivers.

RESEARCH ON FINANCIAL DISTRESS

Scientific research on financial distress is widespread in the disciplines of corporate finance and accounting. Worldwide apparent feature of such studies is application of quantitative-statistical methods. Therefore, statistical and econometrics journals rarely allocate space to findings in the area of distress. Major outcomes are published in journals on accounting and on corporate finance. Let me mention one or two: “Accounting and Finance”, “Accounting Review”, “Advances

in International Accounting", "Financial Analysts Journal", "Journal of Accounting and Economics", "Journal of Accounting Research", Journal of Business, Finance and Accounting", "Journal of Corporate Finance", "Journal of Empirical Finance", "Journal of Finance", "Journal of Financial Economics", "Journal of Financial and Quantitative Analysis". Also important are repositories, like SSRN e-journals. Among them it is worth to indicate "Econometric Modeling: Microeconometric Models of Firm Behavior eJournal".

On another note, it is essential to mention that distress/ bankruptcy is researched in many disciplines: finance, accounting, economics, management, law. The latter may be evidenced, for example, in the recent paper by LoPucki and Doherty [2015].

Major research aims

One can argue that there are three main goals of research on financial distress, the first two being prevalent:

1. Search for determinants of financial distress. As explained before, determinants of distress might differ from those pertaining to bankruptcy. In fact, this is rarely distinguished, especially when the data-mining approach is employed.
2. Prediction of the financial distress state for a company. Such studies are close to typical credit-scoring models and are more operational than the first kind.
3. Composition of the investment portfolios. This novel target is explained in Section METHODS.

Lack of theory

Majority of researchers on financial distress do not explore the underlying theory. This stems largely from theory of enterprise and the agency theory; see Hotchkiss, John, Mooradian and Thorburn [2008].

Typical research on financial distress concentrates on verifying the hypotheses based on intuition and/or results of other researchers. This is understandable because the results are usually specific to place, extent and time period. The outcomes which are common to many markets and countries are quite scarce.

Issues with financial ratios as predictors of financial distress

There is typically a problem with determining "appropriate" set of predictors of financial distress. Commonly, predictors are chosen from the extensive set of financial ratios calculated on the basis of company's financial statements. Data miners obviously choose predictors which optimize some goodness-of-fit or forecast-error measure. Economics and finance research should try to avoid mechanical approach to selecting predictors. What follows are warning issues to consider while researching distress with the use of financial ratios.

- Classic model should include 1-2 ratios from a typical area, e.g. profitability, liquidity etc.
- Market ratios are completely unconnected with accounting ratios and often do not represent the same time periods.
- Incremental ratios like percent increase of sales introduce dynamics, frequently not utilized from methodological point of view.
- Ratios are useful for comparing firms of various sizes in "numerator" and "denominator"; they are sometimes over-used, e.g. by comparing to "industry average" etc.
- Prior classification of ratios as "good" or "bad" for explaining financial distress should be used with great caution. Distress can be well defined, although vaguely. Therefore, prior assumption that some variables shall be considered as "stimulants" or "destimulants" might be not valid. The result is always sample-specific.

METHODS

Variability of methods for assessing and explaining financial distress

Methodology employed in financial distress research covers today almost all techniques of data analysis, specifically methods of statistics, econometrics, survival analysis and data mining. It is beyond the scope of this paper to survey all the methods. A selection is presented e.g. in Gruszczyński [2012].

Common feature of most approaches is their probability-wise nature. For example, it is customary to express financial distress in terms of probability of corporate failure.

Some new interesting methods originate from modelling fraud detection, methodology of text mining or from modelling companies' churn for loans.

In such context one may ask if the popular classic methods of predicting failure/ distress such as logistic regression or discriminant analysis are still valid. They are still in wide use in research, like the one described below. However, the new approaches such as those originated from big-data methodology might soon form a significant alternative.

Nonetheless, it is worth to acknowledge the major results of classic stream in the field. These are:

- Altman's Z-Score [1968],
- Ohlson's O-Score [1980],
- Moody's KMV[2] model based on Merton [1974],
- Shumway hazard model [2001].

[2] Moody's [2000].

First two are accounting-based models, while the third and fourth are market-based models[3]. All those models have been followed by numerous researchers around the world, were subjected to many modifications by original authors and others, and are still regarded as most popular approaches in distress modelling.

"In Search of Distress Risk"

As an example of new research in the area of distress we present here the "classic" approach by Campbell, Hilscher and Szilagyi [2008, 2011]. Their attempt is based on previous studies by Shumway [2001] and Chava and Jarrow [2004].

Model is aimed at predicting "failure events" which are defined as: filing for bankruptcy (Ch.7, Ch.11) or delisting for performance related reasons or receiving D rating from rating agency. The variable Y_{it} representing failure event equals to 1, otherwise it is equal to 0. Thus, we have simple binomial model. In this case it is a kind of dynamic: failure events are observed monthly. These monthly US data cover period of 1963-2008 composing ca. 1.7 million firm-months among which there are ca. 1600 failure events.

The dynamic logit model employed here explains probability of failure event in month t by means of lagged (by 1 month) explanatory variables. The original expression from the paper is as follows:

$$P_{t-1}(Y_{it} = 1) = \frac{1}{1 + \exp(-\alpha - \beta x_{i,t-1})}$$

where Y_{it} equals one if the firm goes bankrupt or fails in month t, and $x_{i,t-1}$ represents a vector of explanatory variables in month t–1 (i.e. at the end of month t–1).

The set of explanatory (predictive) variables is composed of the following accounting and market-based predictors:

- net income to market valued total assets (NIMTA):
$$\frac{Net\ Income_{it}}{(Firm\ Market\ Equity_{it} + Total\ Liabilities_{it})}$$
- net income to total assets (NITA):
$$\frac{Net\ Income_{it}}{Total\ Assets\ (adjusted)_{it}}$$
- total liabilities divided by the sum of market equity and book liabilities (TLMTA):
$$\frac{Total\ Liabilities_{it}}{(Firm\ Market\ Equity_{it} + Total\ Liabilities_{it})}$$
- total liabilities relative to total assets (TLTA):

[3] The distinction by Outecheva [2007].

$$\frac{Total\ Liabilities_{it}}{Total\ Assets\ (adjusted)_{it}}$$

- book to market equity ratio,
- ratio of cash and short-term assets to the market value of assets (CASHMTA):

$$\frac{Cash\ and\ Short\ Term\ Investments_{it}}{(Firm\ Market\ Equity_{it} + Total\ Liabilities_{it})}$$

- monthly log excess return on equity relative to the S&P 500 index (EXRET):

$$\log(1 + R_{it}) - \log(1 + R_{S\&P500,t})$$

- standard deviation of daily stock return over the past 3 months (SIGMA),
- relative size measured as the log ratio of its market capitalization to that of the S&P 500 index (RSIZE):

$$log\frac{Firm\ Market\ Equity_{it}}{Total\ S\&P500\ Market\ Value_t}$$

- log price per share, truncated above at $15 (PRICE).

The novelty of this approach lies mostly in fine-tuning of explanatory variables. Those are principally the same as in previous studies by Shumway [2001] and Chava and Jarrow [2004]. However, the profitability (NIMTA) and excess stock returns (EXRET) variables have been also introduced in a distributed lag form – which has helped to increase model performance.

Model outperforms other approaches in prediction: as forecast horizon increases, market-based variables are more important than accounting variables. Model outperforms O-score and Z-score, doubles the accuracy of Moody's KMV distance-to-default. Safest 5% stocks have the average failure probability of 0.01 while riskiest 5% have 0.34.

Second exercise described in the paper uses the stocks' failure probabilities from the 12-month ahead model (reestimated each January) to form 10 portfolios of stock falling in different regions of the failure risk distribution. The portfolios contain stocks in percentiles 0 to 5, 5 to 10, 10 to 20, 20 to 40, 40 to 60, 60 to 80, 80 to 90, 90 to 95, 95 to 99, and 99 to 100 of the failure risk distribution. Stocks with high risk of failure (above 60 percentile) have anomalously low average returns. As a whole, the distressed portfolios have low average returns (with high standard deviations and market betas).

However, theoretically, the bearers of the risk of owning financially distressed stock shall charge a premium for that. The paper shows the opposite: distressed stock underperform safe stock for decades. As authors state, their measure of financial distress generates underperformance among distressed stocks in all quintiles of the size and value distributions. In discussing this result, authors offer several explanations for the anomalously low returns on distressed stocks such as: unexpected developments, valuation errors by investors, private benefits of control by majority investors (like buying assets at bargain prices), expensive low turnover stock (when traded in large quantities by institutional investors).

So, what did we learn from the paper? That one may construct financial distress models with better and better predictive performance – using only "classic" market and accounting variables. And – that investing in distressed stock is not profitable (even less than one might expect).

FINANCIAL DISTRESS RESEARCH IN POLAND

Studies on bankruptcy and financial distress of companies in Poland have the origin at the very beginning of political and economic transformation of economic system 25 years ago. It took some time to adjust and recognize the symptoms of "proper" distress/ bankruptcy under new system.

The extensive research resulted in quite a number of publications which emerge until now, although the current pace is a bit slower. Research was pioneered in the nineties by academics in University of Lodz and at Polish Academy of Sciences. Until now, all academic centres in Poland propose some sort of research involvement in modelling bankruptcy and distress. However, there are not many with rigorous up-to-date research with quantitative edge. In my opinion, the accounting and corporate finance research in Poland is not yet ready to diverge into these areas, with few notable exceptions.

In order to mark publications on distress in Poland, at first let me mention some books, most of them with quantitative approach. These are books by Mączyńska [2001, 2009, 2010], Prusak [2006], Lasek [2007], Kisielińska [2008], Korol [2010], Gruszczyński [2012]. The list is not comprehensive and represents a choice of books published since 2000.

Secondly, the flow of papers on bankruptcy and distress in Poland which has been witnessed at turn of the century is someway reduced in recent years. Few new contributions since 2012 are shown below, along with the list of journals which were searched for presence of contributions on distress and bankruptcy research.

- *Bank i Kredyt* (National Bank of Poland) – no contributions (nc),
- *Finanse* (Polish Academy of Sciences) – nc,
- *Przegląd Statystyczny* (Polish Academy of Sciences) – nc,
- *FindEcon* (University of Lodz) – nc,
- *Rachunkowość* – nc,
- *Copernican Journal of Finance and Accounting* (Nicolaus Copernicus University Toruń) – nc,
- *Quantitative Methods in Economics* (Warsaw University of Life Sciences – SGGW) – Ptak-Chmielewska [2013], Zielińska-Sitkiewicz [2013],
- *Journal of Management and Financial Sciences* (SGH Warsaw School of Economics) – Altman and Rijken [2012], Tomczak [2014],
- *Finanse, Rynki Finansowe, Ubezpieczenia* (University of Szczecin) – Balina [2012], Góralski, Pietrzak i Jędralski [2012], Sukiennik [2013], Wasylkowska and Szopik-Depczyńska [2014], Bolibok [2014],

- *Folia Oeconomica Stetinensia* (University of Szczecin) – Markowicz [2014],
- *Journal of Management and Finance* (University of Gdańsk), Śmiglak-Krajewska and Just [2013], Waszkowski [2013],
- *Zeszyty Teoretyczne Rachunkowości* – Wędzki [2012].

The list above is obviously a selection. Yet, it shows that recent contributions on the topic of financial distress in Poland are scarce. Most mainstream journals in economics, finance and accounting did not publish articles on distress since 2012. On the other hand, it would be interesting to survey international contributions on this topic by the authors from Poland. Just to show one: paper by Siedlecki [2014] in "Procedia Economics and Finance".

Research on financial distress and bankruptcy in Poland is potentially destined for success. With narrowing of the gap between mutual competencies of academics in finance and accounting on one side and in quantitative methods on the other, more and more contributions with internationally appreciated quality should be foreseen.

REFERENCES

Altman, E. (1968) Financial Ratios, Discriminant Analysis and the Prediction of Corporate Bankruptcy, Journal of Finance, 22(4), 589-609.

Altman E., Hotchkiss E. (2007) Trudności finansowe a upadłość firm, CeDeWu, Warszawa.

Altman E., Rijken H. (2012) Toward a Bottom-Up Approach to Assessing Sovereign Default Risk: An Update, Journal of Management and Financial Sciences, 5(8), 7-29.

Balina R. (2012) Skuteczność wybranych modeli dyskryminacyjnych na przykładzie branży robót budowlanych, Finanse, Rynki Finansowe, Ubezpieczenia, 50, 231-238.

Bolibok P. (2014) Application of the Ohlson Model for Testing the Value Relevance of Accounting Data in the Polish Banking Sector, Finanse, Rynki Finansowe, Ubezpieczenia, 65, 463-472.

Campbell J.Y., Hilscher J.D., Szilagyi J. (2008) In search of distress risk, Journal of Finance, 63, 2899-2939.

Campbell, J.Y., Hilscher J.D., Szilagyi J. (2011) Predicting financial distress and the performance of distressed stocks, Journal of Investment Management 9(2), 14-34.

Chava, S., Jarrow R.A. (2004) Bankruptcy prediction with industry effects, Review of Finance 8, 537–569.

Dahiya S., Saunders A., Srinivasan A. (2003) Financial distress and bank lending relationships, Journal of Finance, Vol. 58, No. 1 (Feb., 2003), 375-399.

Góralski P., Pietrzak S., Jędralski P. (2012) Ocena kondycji finansowej oraz zagrożenia upadłością spółek ANR, Finanse, Rynki Finansowe, Ubezpieczenia, 56, 57-68.

Gruszczyński M. (2004) Financial Distress of Companies in Poland, International Advances in Economic Research, November 2004, Vol. 10, No. 4, 249-256.

Gruszczyński M. (2012) Empiryczne finanse przedsiębiorstw. Mikroekonometria finansowa, Difin, Warszawa.

Hensher D.A., Jones S. (2008) Mixed logit and error component model of corporate insolvency and bankruptcy risk, in: Advances in credit risk modeling and corporate bankruptcy prediction, red. S. Jones, D.A. Hensher, Cambridge University Press.

Hotchkiss E., John K., Mooridian R.M., Thorburn K.S. (2008) Bankruptcy and the resolution of financial distress, [in:] Handbook of corporate finance. Empirical corporate finance, Vol. 2, B. Espen Eckbo (ed.) North-Holland.

Kisielińska J. (2008) Modele klasyfikacyjne prognozowania sytuacji finansowej gospodarstw rolniczych, Wydawnictwo SGGW, seria: Rozprawy Naukowe I Monografie.

Korol T. (2010) Systemy ostrzegania przedsiębiorstw przed ryzykiem upadłości, Wolters Kluwer, Warszawa.

Lasek M. (2007) Metody Data Mining w analizowaniu i prognozowaniu kondycji ekonomicznej przedsiębiorstw. Zastosowania SAS Enterprise Miner, Difin, Warszawa.

Lau A.H.-L. (1987) A five-state financial distress prediction model, Journal of Accounting Research, Vol. 25, No.1 (Spring 1987), 127-138.

LoPucki L.M., Doherty J.W. (2015) Bankruptcy Survival, UCLA Law Review, 62, 970-1015.

Markowicz I. (2014) Hazard function as a tool to diagnose business liquidation, Folia Oeconomica Stetinensia, 24-36.

Mączyńska E. (ed.) (2001) Restrukturyzacja przedsiębiorstw w procesie transformacji gospodarki polskiej, t. I, Instytut Nauk Ekonomicznych PAN, Wydawnictwo DiG, Warszawa.

Mączyńska E. (ed.) (2009) Meandry upadłości przedsiębiorstw. Klęska czy druga szansa, Oficyna Wydawnicza SGH.

Mączyńska E. (ed.) (2010) Cykle życia i bankructwa przedsiębiorstw, Oficyna Wydawnicza SGH.

Merton, R. (1974): On the Pricing of Corporate Debt: The Risk Structure of Interest Rates, Journal of Finance, 29, 449-470.

Moody's Investor Service (2000) Moody's Approach to Evaluating Distressed Exchanges. White Paper, July 2000.

Ohlson, J. (1980) Financial Ratios and Probabilistic Prediction of Bankruptcy, Journal of Accounting Research, 18(1), 109-131.

Otecheva N. (2007) Corporate financial distress. An empirical analysis of distress risk, Doctoral Dissertation, University of St. Gallen HSG.

Platt H.D, Platt M.B. (2006) Comparing financial distress and bankruptcy, SSRN Working Paper Series, available in SSRN: http://ssrn.com/abstract=876470.

Ptak–Chmielewska A. (2013) Semiparametric Cox regression model in estimation of small and micro enterprises' survival in the Malopolska voivodeship, Quantitative Methods in Economics, Vol. XIV, No. 2, 169-180.

Prusak B. (2005) Nowoczesne metody prognozowania zagrożenia finansowego przedsiębiorstw, Difin, Warszawa.

Siedlecki R. (2014) Forecasting Company Financial Distress Using the Gradient Measurement of Development and S-Curve, Procedia Economics and Finance, 12 (2014), 597 – 606.

Shumway T. (2001) Forecasting bankruptcy more accurately: A simple hazard model, Journal of Business 74, 101–124.

Sukiennik M. (2013) Analiza dyskryminacyjna oraz miękkie techniki obliczeniowe w ocenie stanu finansowego polskich kopalń, Finanse, Rynki Finansowe, Ubezpieczenia, 59, 291-300.

Śmiglak-Krajewska M., Just M. (2013) Zastosowanie wybranych modeli analizy dyskryminacyjnej do prognozowania zagrożenia upadłością przedsiębiorstw produkujących pasze, Journal of Management and Finance, 2013, 431-444.

Tomczak S. (2014) The early warning system, Journal of Management and Financial Sciences, 7(16), 51-74.

Waszkowski A. (2013) Wielomianowe modele zagrożenia finansowego przedsiębiorstw, Journal of Management and Finance, 569-579.

Wasylkowska M., Szopik-Depczyńska K. (2014) Ocena sytuacji finansowej przedsiębiorstwa przy uwzględnieniu modeli dyskryminacyjnych, Finanse, Rynki Finansowe, Ubezpieczenia, 66, 535-546.

Wędzki D. (2012) The sequence of cash flow in bankruptcy prediction: evidence from Poland, Zeszyty Teoretyczne Rachunkowości, 68(124), 161-180.

Zielińska–Sitkiewicz M. (2013) Application of multivariate discriminant analysis for assessment of condition of construction companies, Quantitative Methods in Economics, Vol. XIV, No. 2, 298-308.