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# *Building of F-Score-Like Models on the Example of the Polish Stock Market*

**Keywords:** F-Score; book-to-market; value investing; investment portfolio; scoring model

**JEL:** G11; G19; M21; M41

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**Abstract**

**Theoretical background:** Value investing is one of the most popular investing approaches. In their frame, there could be a high B/M investing strategy identified. F-Score, developed by Piotroski, is a scoring model applied to the sample of high B/M entities. Its purpose is to select companies with strong financial foundations and buy their shares for the investment portfolio to generate positive market-adjusted returns in the following periods. The effectiveness of this model was mostly empirically confirmed, especially regarding developed markets.
**Purpose of the article:** The main aim of the paper was to build F-Score-like models based on the data from the Polish stock market. The main hypothesis concerned the higher effectiveness of such models than F-Score, as the specificity of a given market should result in a better fit to the data.
**Research methods:** Building of the models based on the discriminant analysis and formation of the investment portfolios based on the indications of these models as well as F-Score. Finally, backtesting of the portfolios built to assess their effectiveness. The sample covered most of the Polish-listed companies. The period taken into account was 2012–2022.
**Main findings:** Models built (X-Score and Y-Score) were less efficient than F-Score. Moreover, they led to generating negative rates of return (both raw and market-adjusted). On the other hand, using of F-Score for the analyzed period seems to be purposeful due to the 1.35% mean annual market-adjusted return gen-

erated. Apart from the scoring models analyzed, the research partially confirmed the advisability of using a high B/M investing strategy. Generally, the results obtained are in line with the findings of most of other authors – regarding the F-Score effectiveness. However, an approach based on Mohanram's idea – using the differences between absolute values of a given variable and median from the sample – proved to be inadequate in the Polish stock market.

## Introduction

There are many different approaches to investing applied by investors. One of the most popular ones is value investing, including a high B/M (book-to-market ratio, the relation of the company's book value to its market value) strategy. F-Score, a model developed by Piotroski (2000), is a tool for value investors, mostly used for developed markets, for instance, the United States of America (Mohr, 2012; Safdar, 2016), the United Kingdom (Rathjens & Schellhove, 2011), Australia (Hyde, 2016), Germany (Pätäri, 2017), or Japan (Noma, 2010). However, this model is uncommonly recognized in emerging stock markets. Therefore, it was decided to analyze that model and its effectiveness on the example of the Polish stock market (an emerging market that was analyzed in terms of F-Score only regarding the sample of the largest entities) and build F-Score-like models, particularly better fit to the specificity of the domestic market.

The aim of the paper is to build F-Score-like models based on data from the Polish stock market. The purposefulness of modifying the F-Score or building models similar to Piotroski's model has already been noted by Mohanram (2005) and Nast (2017) – they pointed out, i.a., the instability of the results obtained by Piotroski (investment efficiency of the portfolios built in line with F-Score scoring) over time and space (taking into account markets other than the American one). Therefore, it was decided to attempt to build models based on a relatively large sample of companies from Poland, as an emerging market (that significantly differs from the US market, for instance, in terms of the ratio of stock market size to GDP, the share of dividend companies in the market, the level of transactional costs, etc.). Moreover, as the selection of companies to the investment portfolio (portfolio choice) is still an open issue (Puerto et al., 2020), developing such models can be generally seen as an attempt to create tools that are useful to investors, yet fairly simple to use.

Empirical research was designed in the following way – firstly, X-Score and Y-Score (models developed in the paper) were built, based on the discriminant analysis.[1] Then, the investment portfolios were constructed – they included shares of companies selected based on a scoring of developed models. Finally, the historical performance of the portfolios was tested and compared with F-Score-based results.

The research sample comprises of 225 companies listed on the Warsaw Stock Exchange (20% of entities with the highest B/M values in a given year were chosen,

[1] For the modelling purposes, there were used both variables included in Piotroski's paper and other indicators commonly used in the financial analysis.

in line with Piotroski's approach). The period under analysis was 2012–2022. The financial data (both book and market) was obtained from the Orbis database.

Section 1 is focused on the overview of the high B/M investing strategy, the F-Score model, and the previous papers aimed at the verification of its effectiveness as well as F-Score modifications. Section 2 is related to the design of the empirical research, which is presented in section 3. Section 4 comprises a discussion, while section 5 – conclusions.

## Literature review

Among investment strategies to be applied on the stock markets, there are often listed technical and fundamental analyses, which might be divided into value investing and growth investing. The general rule of the fundamental analysis is in line with Graham and Dodd's approach, which stated that the investing process should be focused on the identification of entities whose intrinsic value, based on their economic foundations, exceeds the market price at a given moment (Graham & Dodd, 1934).

Value investing was supported, *inter alia*, by Fama and French (1992) and Lakonishok et al. (1994), who explained the advantage of value investing over growth investing by behavioral factors. Fisher's approach was noticeably different – according to him, growth entities (characterized by a greater growth potential but also higher risk) were more favorable than value companies (Fisher, 1958). As there was no unified approach to value and growth investing, the papers aimed at the comparison of their effectiveness were developed. For instance, a systematic literature review focused on studies from the period 2007–2017 showed a partial reconciliation of the results of the research taken into account with the conclusions of value investing proponents, while the growth investing was not supported (Battisti et al., 2019). On the other hand, according, *inter alia*, to Perez (2018) and Hedau (2020), value investing did not lead to the outperformance of growth investing. Such heterogeneity confirms the purposefulness of research in this field.

Among value investing strategies, it could be mentioned, *inter alia*, high B/M strategy that is focused on the selection of entities with the lowest ratios of book to market values. As such a strategy is a foundation of the F-Score model, it is essential to refer to it.

### High B/M strategy

High B/M strategy concerned the ratio of book and market values of shares of a given entity. Companies with a B/M lower than 1 are usually considered undervalued. It is usually assumed that the market value of the vast majority of listed companies exceeds their book values. However, according to Barth et al. (2022), there were ca. 30% of undervalued entities (with B/M above 1), so the group of entities to which this strategy might be applied is quite numerous.

The purposefulness of selecting undervalued entities was pointed out by Graham and Dodd (1934), as mentioned above. The initial empirical confirmations of high B/M strategy effectiveness were made by Stattman (1980) and Rosenberg et al. (1985), based on the situation of the American stock market. Such a strategy was also supported by Fama and French (1992), who stated that lower-capitalized entities with minor B/M values generated on average higher yields than other companies. Therefore, it was purposeful to select undervalued entities for the investment portfolio. Also according to Chan et al. (1991), an investment portfolio consisting of stocks of high B/M entities noticeably outperformed the other ones.

The arguments of high B/M investing strategy proponents were empirically confirmed, *inter alia*, on the examples of South Africa (Auret & Sinclaire, 2006), Australia (O'Brien et al., 2010), Brazil (da Cunha Araújo & Veras Machado, 2018), Indonesia (Fahreza & Rizkianto, 2021), and United States of America (Barth et al., 2022). Based on these research, a high B/M investing strategy was considered effective both in the cases of value-weighted and equally-weighted portfolios. However, the correlation between B/M and future yields was rather moderate. On the other hand, the strategy was not supported, *inter alia*, by Syzdykov (2021).

## Piotroski's model

F-Score is considered as a scoring empirical model related to the high B/M strategy, used particularly by value investors. It was developed in 2000, however, its recognizability significantly increased after the occurrence of the global financial crisis. According to the American Association of Individual Investors, the usage of F-Score led to generating yields above 30%, while other investing strategies analyzed resulted in generating losses (Comparic, 2017). The financial ratios constituting the F-Score model are presented in Table 1.

**Table 1.** Variables of F-Score model

| Variable | Formula |
|---|---|
| ROA | $\frac{\text{Net income}_t - \text{extraordinary operations balance}_t}{\text{Total assets at the beginning of a period}_t}$ |
| CFO | $\frac{\text{Net operating cash flows}}{\text{Total assets at the beginning of a period}_t}$ |
| ΔROA | $\text{ROA}_t - \text{ROA}_{t-1}$ |
| ΔACCRUAL | $(\text{ROA} - \text{CFO})_t - (\text{ROA} - \text{CFO})_{t-1}$ |
| ΔLEVER | $\left(\frac{\text{Total liabilities}}{\text{Average total assets}}\right)_t - \left(\frac{\text{Total liabilities}}{\text{Average total assets}}\right)_{t-1}$ |
| ΔLIQUID | $\left(\frac{\text{Current assets}}{\text{Current liabilities}}\right)_t - \left(\frac{\text{Current assets}}{\text{Current liabilities}}\right)_{t-1}$ |

| Variable | Formula |
|---|---|
| EQ_OFFER | $\begin{cases} 1 & \text{for no issue of ordinary shares in a given period} \\ 0 & \text{otherwise} \end{cases}$ |
| ΔMARGIN | $\left(\frac{\text{Gross margin}}{\text{Sales revenues}}\right)_t - \left(\frac{\text{Gross margin}}{\text{Sales revenues}}\right)_{t-1}$ |
| ΔTURN | $\left(\frac{\text{Sales revenues}}{\text{Total assets at the beginning of a period}}\right)_t - \left(\frac{\text{Sales revenues}}{\text{Total assets at the beginning of a period}}\right)_{t-1}$ |

Source: Author's own study based on (Piotroski, 2000).

ROA, CFO, ΔROA, ΔACCRUAL relate to profitability, ΔLEVER, ΔLIQUID and EQ_OFFER to liquidity and financial leverage, while ΔMARGIN and ΔTURN – to the operating efficiency. ΔACCRUAL, ΔLEVER and EQ_OFFER are destimulants (their positive values are recognized with 0 scoring, while negative values – with 1 point) and other variables – stimulants. The final scoring of the F-Score for a given company is a sum of values for individual variables (0 or 1). Entities with the scoring of 8–9 points are selected for the investment portfolio (Piotroski, 2000).

The empirical verification of F-Score's effectiveness by Piotroski showed that the mean annual market-adjusted return was 10.6%, taking a long position in shares of entities with F-Score not less than 5 (strong F-Score) and a short position regarding companies with scoring below 5 (weak F-Score). There was also a difference of 9.7 p.p. in favor of strong F-Score entities pointed out by the author (Piotroski, 2000).

It is worth noting that F-Score model applications include also, *inter alia*, its use as a benchmarking model for the synthetic assessment of the financial condition of public entities (Hamilton, 2013; Asmadi et al., 2021). This construct is also used as a prediction bankruptcy model – such an approach was applied, for instance, by Agrawal (2015) on the example of Indian entities and by Rahman et al. (2021) based on American public companies. Both studies indicated the purposefulness of using the F-Score model as a bankruptcy prediction construct, however, its effectiveness was lower than models built with the usage of F-Score's variables (Rahman et al., 2021). The advisability of using F-Score as a bankruptcy prediction model was also indicated by Korir (2019).

## Assessment of F-Score-type models efficiency

Many studies, especially based on the situation of developed stock markets, aimed at the assessment of the purposefulness of using F-Score. In general, the effectiveness of this model was empirically confirmed on the examples of Japan (Noma, 2010), the United Kingdom (Rathjens & Schellhove, 2011), the United States of America (Mohr, 2012; Krauss et al., 2015; Safdar, 2016; Turtle & Wang, 2017), several emerging markets (Hyde, 2013), India (Singh & Kaur, 2014; Tripathy & Pani, 2017), South Africa (Oyebode, 2016), Australia (Hyde, 2016), Germany (Pätäri, 2017), several European markets (Tikkanen & Äijö, 2018), Spain (Forner

& Vázquez Veira, 2018), set of emerging and developed stock markets (Walkshäusl, 2020). The comparisons of several investment strategies prepared, *inter alia*, by Almas and Duque (2008), Sareewiwatthana and Janin (2017) and Brindelid and Nilsson (2021) also show the effectiveness of the F-Score model (in some cases it was considered the most efficient from all analyzed models).

From the perspective of this research, it is essential to take into account the results of analyses aimed at the Polish stock market. The verification of F-Score was not a common subject of the research recently. However, some empirical insights were provided based on the papers focused on the relatively small samples. Kusowska (2021) took into account companies listed on WIG30 (30 largest Polish public companies). The research showed that use of Piotroski's model was justified during the period of 2014–2020, as high F-Score shares noticeably outperformed the whole portfolio of entities analyzed. However, it is worth noting that the period under review was significantly affected by the pandemic situation. Therefore, rates of return generated from all of the strategies analyzed were significantly negative, but while passive investing in the WIG30 index would result in the generation of a -40.8% loss, investing according to Piotroski's strategy to led to generating a loss of 37.3% (Kusowska, 2021).

Another attempt to verify the effectiveness of F-Score use based on the Polish market was made by Pilch (2021). His research concerned the period 2018–2020 and the set of entities from two industries – IT and video games. The results of this analysis were in line with the previously mentioned findings – an F-Score-based strategy led to generating rates of return at the level exceeding the benchmark – by 0.3 p.p. in 2018, 27.0 p.p. in 2019 and 48.5 p.p. in 2020. However, the results might be significantly affected by the choice of industries that are considered high-risky and even gain benefits from the COVID-related situation. Based on the above examples of research, it can be stated that no studies have been conducted in the case of a large group of Polish companies so far.

## F-Score modifications

Despite the relatively high efficiency of F-Score, as indicated above, there have been created several modifications of this model. These include, *inter alia*, G-Score, FS-Score, Piotroski Trfm, NF-Score, and B-Score. Piotroski Trfm and NF-Score were built using an exact set of variables as in the original Piotroski's research. Trfm uses 6 out of 9 financial indicators used by Piotroski, but with a reverse scoring regarding two of them (Nast, 2017). NF-Score is a neural model built using all 9 fundamental signals developed in F-Score (Gimeno et al., 2019). There is also a great similarity between F-Score and FS-Score – the differences between these models concerned free cash flow instead of operating cash flows and the difference between the number of own shares repurchased and shares issued instead of taking into account only the number of shares issued (Gray, 2015). G-Score uses only 3 variables (all from the profitability area) common with F-Score and 5 other indicators (relating to the profitability variance, sales dynamics, expenses on R&D and advertising, and capital expenditures). It is worth noting that scoring in G-Score was based on a comparison of the values for a given entity with medians from its industry (Mohanram, 2005). B-Score is a model developed for banks, therefore, their variables significantly differ from those included in F-Score, however, its form relates to Piotroski's model (Mohanram, 2017). As there were developed many F-Score-type models, it could be considered the manifestation of the belief that the F-Score can be improved, which applies also to this paper.

## Research methods

The empirical research is focused on a comparison of the performance of investment portfolios built based on X-Score and Y-Score (scoring models developed) and F-Score. X-Score and Y-Score were built from the variables that were selected based on discriminant analysis and mutual correlations. In the discriminant analysis, the value of the endogenous variable was set at 1, while the rate of return from shares of a given company in the year starting 6 months after the balance sheet date was positive – it applies to X-Score – or outperformed the Warsaw Stock Index (WIG) – regarding Y-Score – and 0 otherwise. For instance, rates of return for a year starting in six months after the fiscal date *k* refer to the financials from the fiscal year *k* (a year ending in *k*). Thus, yields for 1 July 2021 – 30 June 2022 (named "2022" further) were referred to the financials from 2020 (for income statement-based variables) and as of 31 December 2020 (for balance sheet-based variables), etc. 0 and rate of return from WIG were used as benchmarks, as mentioned above.

Individual variables were chosen based on such a procedure. There were also correlations between them analyzed to avoid the collinearity issue. X-Score and Y-Score consisted of variables selected based on discriminant analysis and correlations. These variables have an equal impact on the total models scoring (beta coefficients are 1 for each case). Shares of entities with high total scoring were chosen to the investment portfolios. Their effectiveness was assessed by using the backtesting method – the building of the portfolios based on historical data and calculating generated yields for past periods.

The main hypothesis (H0) assumes higher efficiency of X-Score and Y-Score than F-Score (assuming positive yields generated with using of both models).

The supporting hypotheses, developed based on the literature review and empirical research frame, are as follows:

H1: The differences between the distribution of the values of F-Score and X-Score and Y-Score are statistically significant.

H2: Most of the entities selected for the investment portfolio by F-Score generated positive yields.

H3: Most of the entities selected for the investment portfolio by X-Score and Y-Score generated positive returns.

H4: Yields of entities with higher scoring (according to F-Score) outperformed rates of return of low-scoring companies.

H5: Yields of entities with higher scoring (according to X-Score and Y-Score) outperformed rates of return of low-scoring companies.

H6: F-Score led to generating positive market-adjusted yields in total.

H7: X-Score and Y-Score on the example of the Polish stock market led to generating positive market-adjusted yields in total.

H1 relates to the independence of the assessment of the individual companies by models developed and F-Score. The very similar distributions of X-Score and Y-Score values in relation to the F-Score could suggest a lack of purposefulness of using developed models – then the use of the F-Score would be sufficient. H2 and H3 concerned the riskiness of the models – assuming a simple diversification (with a similar number of entities chosen to the investment portfolios in each year), lack of confirmation of these hypotheses leads to generating losses on the investment portfolios. H4 and H5 refer to the essence of scoring models analyzed – companies with a higher scoring should generate higher returns, otherwise, the models on which the strategies are based could be not useful. H6 and H7 concerned the verification whether it was more appropriate to invest in line with the models developed and F-Score or passively invest in a main stock market index (what was supported, for instance, by Chlebisz [2018] or Daniluk [2019]) without preparing time-consuming investment analyzes (calculating the values of models, selecting companies for the portfolios, etc.).

The supporting hypotheses (from the introduction) are to be validated in the following stages of the empirical research: H1 – comparison of histograms of F-Score and X-Score and Y-Score, H2 and H3 – analysis of descriptive statistics of yields of entities selected by the models, H4 and H5 – analysis of the association of scoring of given models and mean yields, H6 and H7 – backtesting of investment portfolios built.

**Sample**

The initial sample consists of 772 listed companies, from which 98 were excluded (as they operate in the financial industry – their financial statements are built differently and are not fully comparable). The following entities (out of 674 companies) were also removed from the sample:

– companies in the ongoing bankruptcy or restructuring processes,

– companies that debuted on the Warsaw Stock Exchange in 2021 or 2022,

– companies with no sufficient financial data.

From a set of entities created in that way, there were chosen companies with the highest B/M (20% of the total sample, in line with Piotroski's approach) in a given year. The breakdown of the final sample by industry is presented in Table 2.

**Table 2.** Sample breakdown by industry

| NACE code | Industry name | No. of entities | | Share | |
|---|---|---|---|---|---|
| | | Sample | Cases | Sample | Cases |
| C | Manufacturing | 64 | 264 | 28.4% | 30.2% |
| G | Wholesale and retail trade | 35 | 134 | 15.6% | 15.3% |
| M | Professional, scientific and technical activities | 22 | 70 | 9.8% | 8.0% |
| J | Information and communication | 21 | 71 | 9.3% | 8.1% |
| F | Construction | 17 | 60 | 7.6% | 6.9% |
| L | Real estate activities | 16 | 56 | 7.1% | 6.4% |
| D | Electricity, gas, steam and air conditioning supply | 12 | 69 | 5.3% | 7.9% |
| N | Administrative and support service activities | 7 | 14 | 3.1% | 1.6% |
| B | Mining and quarrying | 6 | 29 | 2.7% | 3.3% |
| S | Other service activities | 6 | 37 | 2.7% | 4.2% |
| – | Other industries | 19 | 69 | 8.4% | 7.9% |
| Total | | 225 | 873 | 100.0% | 100.0% |

Source: Author's own study based on the data from Orbis database.

Table 2 includes entities that were among the highest B/M companies either once or several times. Therefore, the share of entities in the sample and by cases significantly differ – for instance, a random manufacturing company selected for the final sample occurred 4.13 times on average, while for wholesale and retail trade companies it was 3.83.

As it can be seen, there is a significant share of manufacturing entities among all the analyzed. There are also several industries with a 5–10% share in the final sample. Generally, the differentiation of the number of companies by individual industries seems to be quite noticeable. However, the breakdown of companies by industry by cases is similar to the distribution in the initial sample – for example, there were 14.9% of wholesale and retail trade entities among 672 companies listed on the Warsaw Stock Exchange and their share by cases is 15.3%. Therefore, it seems that sample breakdown by industry did not noticeably affect the results of the empirical research.

## Variables

The list of variables used is presented in Table 3. A significant part of them is based on Piotroski's approach. However, there were, *inter alia*, also other variables relating to profitability, liquidity, and debt (as major areas of the financial analysis) included.

**Table 3.** List of exogenous variables included in the research

| Variable | Formula | Area |
|---|---|---|
| Return on assets | $\mathrm{ROA} = \frac{\text{Net income} - \text{extraordinary operations balance}}{\text{Total assets at the beginning of a period}}$ | Profitability, operating efficiency |
| Return on equity | $\mathrm{ROE} = \frac{\text{Net income} - \text{extraordinary operations balance}}{\text{Equity at the beginning of a period}}$ | |
| Return on sales | $\mathrm{ROS} = \frac{\text{Net income} - \text{extraordinary operations balance}}{\text{Sales revenues}}$ | |
| Operating ROA[2] | $\mathrm{OROA} = \frac{\text{EBIT} - \text{extraordinary operations balance}}{\text{Total assets at the beginning of a period}}$ | |
| Operating ROE | $\mathrm{OROE} = \frac{\text{EBIT} - \text{extraordinary operations balance}}{\text{Equity at the beginning of a period}}$ | |
| Operating ROS | $\mathrm{OROS} = \frac{\text{EBIT} - \text{extraordinary operations balance}}{\text{Sales revenues}}$ | |
| Gross margin on sales | $\mathrm{MARGIN} = \frac{\text{Gross margin}}{\text{Sales revenues}}$ | |
| Sales turnover ratio | $\mathrm{TURN} = \frac{\text{Sales revenues}}{\text{Total assets at the beginning of a period}}$ | |
| Return on operating cash flows | $\mathrm{CFO} = \frac{\text{Net operating cash flows}}{\text{Total assets at the beginning of a period}}$ | |
| Relationship between ROA and CFO | $\mathrm{ACCRUAL} = \mathrm{ROA} - \mathrm{CFO}$ | |
| Current ratio | $\mathrm{LIQUID} = \frac{\text{Current assets}}{\text{Current liabilities}}$ | Liquidity |
| Quick ratio | $\mathrm{QR} = \frac{\text{Current assets} - \text{inventory}}{\text{Current liabilities}}$ | |
| Total debt ratio | $\mathrm{LEVER} = \frac{\text{Total liabilities}}{\text{Total assets}}$ | Debt |
| Current debt ratio | $\mathrm{CDR} = \frac{\text{Short} - \text{term liabilities}}{\text{Total assets}}$ | |
| Long-term debt ratio | $\mathrm{LDR} = \frac{\text{Long} - \text{term liabilities}}{\text{Total assets}}$ | |
| Natural logarithm of sales | $\mathrm{LNS} = \ln(\text{sales revenues})$ | Entity size |
| Natural logarithm of assets | $\mathrm{LNA} = \ln(\text{total assets at the beginning of the period})$ | |
| Issue of shares | $\mathrm{EQ\_OFFER} = \begin{cases} 1 & \text{for no issue of ordinary shares in a given period} \\ 0 & \text{otherwise} \end{cases}$ | Equity dilution |

Source: Author's own study based on (Piotroski, 2000; Sierpińska & Jachna, 2007; Hyde, 2016).

ROA, MARGIN, TURN, CFO, ACCRUAL, LIQUID, LEVER, and EQ_OFFER were chosen based on Piotroski's (2000) research. ROE and ROS are variables commonly used to assess the company's profitability, QR – liquidity, CDR and LDR – relative level of debt (i.a. Sierpińska & Jachna, 2007; Subramanyam, 2014; Pluskota et al., 2020). Operating ROA, ROE and ROS are used as ratios measuring operating profitability (Wawryszuk-Misztal, 2015; Jaworski & Czerwonka, 2017). LNS and LNA, variables related to the entity size, were selected in accordance with Hyde (2016), who stated that F-Score was more effective on the example of small entities.

Apart from the variables listed in Table 3, there were also their annual changes taken into account (similarly to ROA and ΔROA in the F-Score model)[3] – except the

[2] EBIT (earnings before interests and taxes) used as a measure of operating income.

[3] ΔTDR is equal to ΔLEVER.

EQ_OFFER variable, due to its nature. The variables analyzed do not have a normal distribution (based on Shapiro–Wilk and Jarque–Bera tests), which is typical for financial ratios or stock market data.

The calculation of the values of variables was based on the data from the Orbis database (https:\\orbis.bvdinfo.com). It was done using MS Excel, as well as the portfolios assessment. Discriminant analysis was conducted using Statistica software.

## Results

The empirical research was divided into the following steps: construction of F-Score-type models consisting of variables listed in the previous section and investment portfolios' building using the X-Score, Y-Score, and F-Score. The final part concerned backtesting – the assessment of historical yields of portfolios built.

## Building of F-Score-type models

The variables to be included in models were chosen based, *inter alia*, on partial Wilks' lambda – a measure used in discriminant analysis to separate different groups due to the different values of an endogenous variable (rates of return in the frame of this research). The higher the partial lambda is, the lower the discriminatory power of a given variable. Therefore, it is purposeful to choose financial ratios with the lowest values (generally, this measure's value range is 0–1). Partial Wilks' lambda values for variables included in the research are shown in Table 4.

**Table 4.** Partial Wilks' lambda for variables[4]

| Variable | Benchmark = 0 | | | Benchmark = WIG | | |
|---|---|---|---|---|---|---|
| | λ | *p*-value | Sign | λ | *p*-value | Sign |
| ROA | 0.9983 | 0.2301 | + | 1.0000 | 0.9240 | + |
| ΔROA | 0.9996 | 0.5408 | + | 0.9997 | 0.6360 | + |
| ROE | 0.9981 | 0.2034 | + | 0.9999 | 0.8004 | + |
| ΔROE | 0.9989 | 0.3337 | + | 0.9998 | 0.6844 | + |
| ROS | 0.9970 | 0.1091 | + | 0.9999 | 0.7322 | + |
| ΔROS | 0.9981 | 0.2015 | + | 0.9999 | 0.7690 | + |
| OROA | 0.9977 | 0.1602 | + | 1.0000 | 0.9919 | + |
| ΔOROA | 1.0000 | 0.9647 | + | 0.9999 | 0.7857 | + |
| OROE | 0.9992 | 0.4093 | + | 1.0000 | 0.8710 | + |
| ΔOROE | 0.9998 | 0.6850 | + | 1.0000 | 0.9548 | + |
| OROS | **0.9962** | **0.0688** | + | 0.9996 | 0.5553 | + |
| ΔOROS | **0.9965** | **0.0819** | + | 0.9996 | 0.5433 | + |
| MARGIN | **0.9941** | **0.0231** | + | 0.9996 | 0.5535 | + |

[4] Bold lambda values are statistically significant at $p < 0.10$.

| Variable | Benchmark = 0 | | | Benchmark = WIG | | |
|---|---|---|---|---|---|---|
| | λ | *p*-value | Sign | λ | *p*-value | Sign |
| ΔMARGIN | **0.9956** | **0.0503** | + | 0.9998 | 0.6722 | + |
| TURN | 0.9996 | 0.5646 | – | 0.9994 | 0.4688 | – |
| ΔTURN | 0.9990 | 0.3614 | + | 0.9999 | 0.7818 | + |
| CFO | 0.9999 | 0.7269 | + | 0.9992 | 0.4138 | + |
| ΔCFO | 0.9990 | 0.3574 | – | 0.9999 | 0.7908 | – |
| ACCRUAL | 1.0000 | 0.8730 | – | 0.9997 | 0.6327 | – |
| ΔACCRUAL | 0.9990 | 0.3577 | + | 0.9997 | 0.6287 | + |
| LIQUID | 1.0000 | 0.8804 | + | **0.9921** | **0.0089** | + |
| ΔLIQUID | 1.0000 | 0.8510 | + | **0.9918** | **0.0076** | + |
| QR | 0.9998 | 0.7045 | + | **0.9921** | **0.0088** | + |
| ΔQR | 1.0000 | 0.9347 | + | **0.9919** | **0.0080** | + |
| LEVER | 0.9999 | 0.7632 | + | 0.9993 | 0.4319 | + |
| ΔLEVER | 0.9987 | 0.2903 | – | 0.9996 | 0.5796 | – |
| CDR | 0.9975 | 0.1387 | – | 1.0000 | 0.9619 | – |
| ΔCDR | 0.9996 | 0.5383 | – | 0.9998 | 0.6850 | – |
| LDR | **0.9925** | **0.0109** | – | 0.9985 | 0.2494 | – |
| ΔLDR | 0.9991 | 0.3848 | + | 0.9999 | 0.7951 | + |
| LNS | 0.9999 | 0.8082 | – | **0.9841** | **0.0002** | – |
| ΔLNS | 0.9994 | 0.4685 | + | 0.9987 | 0.2944 | + |
| LNA | 0.9981 | 0.1934 | – | 0.9983 | 0.2192 | – |
| ΔLNA | 1.0000 | 0.8938 | – | 0.9997 | 0.6183 | – |
| EQ_OFFER | 0.9993 | 0.4257 | + | 0.9990 | 0.3570 | + |

"Sign" – a sign of the coefficient for a given variable ("+" means that higher absolute values of a given variable indicate a value of 1 (returns above the benchmark) of the explained variable in the discriminant analysis, etc.).
Source: Author's own study based on the data from Orbis database.

As can be seen in Table 4, Wilks' lambdas are relatively high, but they are statistically significant in some cases. A set of variables for a given model was finally selected based on Wilks' lambdas as well as mutual correlations between variables[5] (to avoid the problem of collinearity). Please note that the correlation matrix for a set of variables was presented in the Appendix due to its size. Finally, there were chosen ROE, ΔROS, ΔMARGIN, TURN, CFO, ΔACCRUAL, QR, ΔLEVER, LDR, ΔLNS, and EQ_OFFER for X-Score and ΔROA, ROS, ΔMARGIN, TURN, CFO, ΔACCRUAL, ΔLIQUID, ΔLEVER, ΔCDR, ΔLNS, and EQ_OFFER for Y-Score. Thus, the final forms of these models are as follows:

$$\boldsymbol{X-Score} = F_{ROE} + F_{\Delta ROS} + F_{\Delta MARGIN} + F_{TURN} + F_{CFO} + F_{\Delta ACCRUAL} + F_{QR} + F_{\Delta LEVER} + F_{LDR} + F_{\Delta LNS} + F_{EQ\_OFFER} \tag{1}$$

[5] In the case of strongly correlated variables, one of them (the one with lower Wilks' lambda) was chosen to the model.

$$\boldsymbol{Y-Score} = F_{\Delta ROA} + F_{ROS} + F_{\Delta MARGIN} + F_{TURN} + F_{CFO} + F_{\Delta ACCRUAL} + F_{\Delta \mathrm{LIQUID}} + F_{\Delta LEVER} + F_{\Delta CDR} + F_{\Delta LNS} + F_{EQ\_OFFER} \quad (2)$$

where:
$F_i$ – binary value for a given variable.

Low scoring of X-Score and Y-Score was considered as 0–3 points, while high – 9–11 points. All of the variables used (except EQ_OFFER) were measured as a difference between the value for a given entity and the median for the whole sample, partially in line with Mohanram's (2005) approach. ΔLEVER, ΔCDR, LDR are destimulants, while other variables constituting models developed – stimulants. The distribution of scoring of the X-Score and Y-Score in that way as well as the F-Score, by a number of entities, is presented in Figures 1–3.

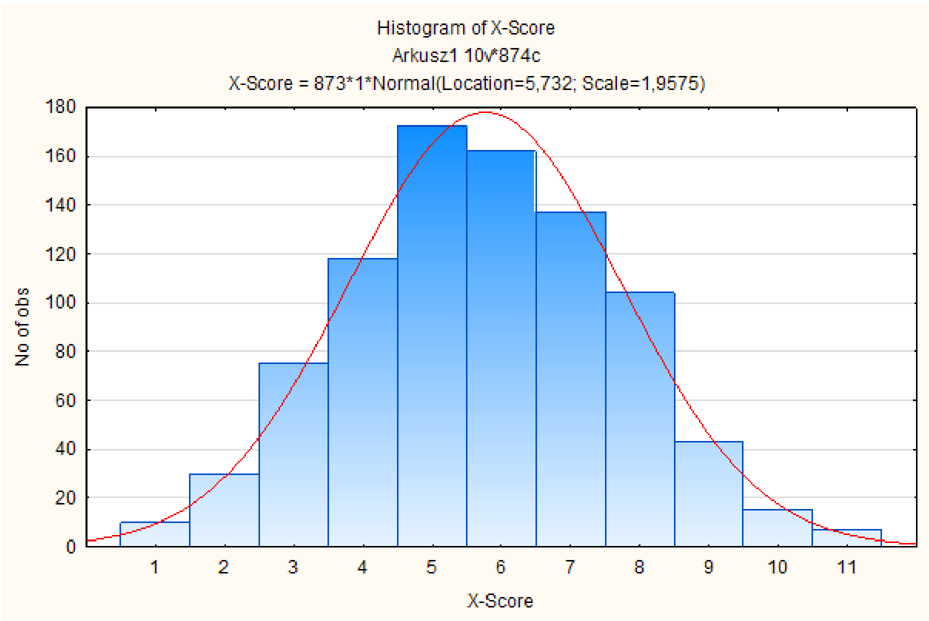


**Figure 1.** X-Score histogram

Source: Author's own study based on the data from Orbis database.

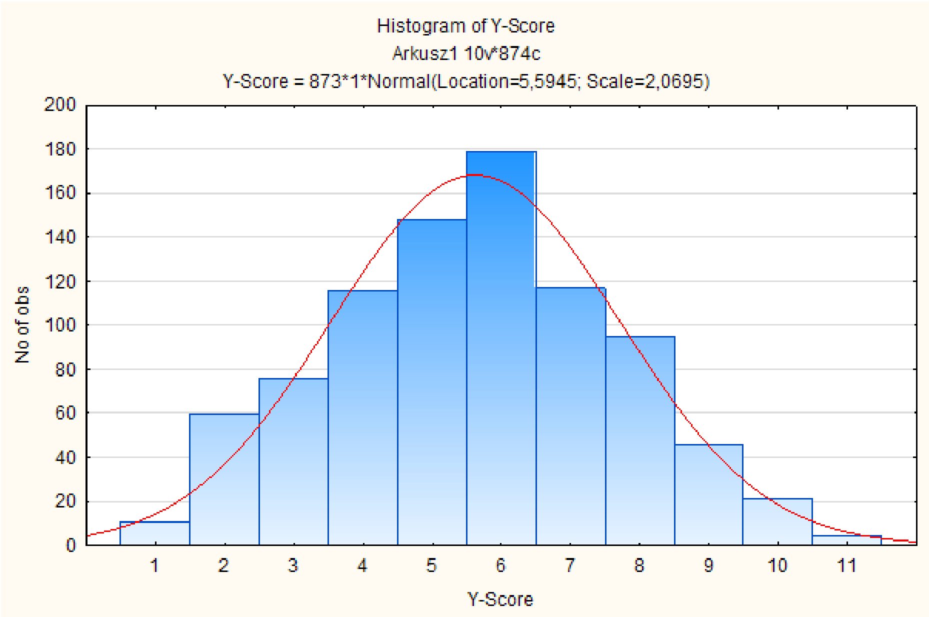


**Figure 2.** Y-Score histogram

Source: Author's own study based on the data from Orbis database.

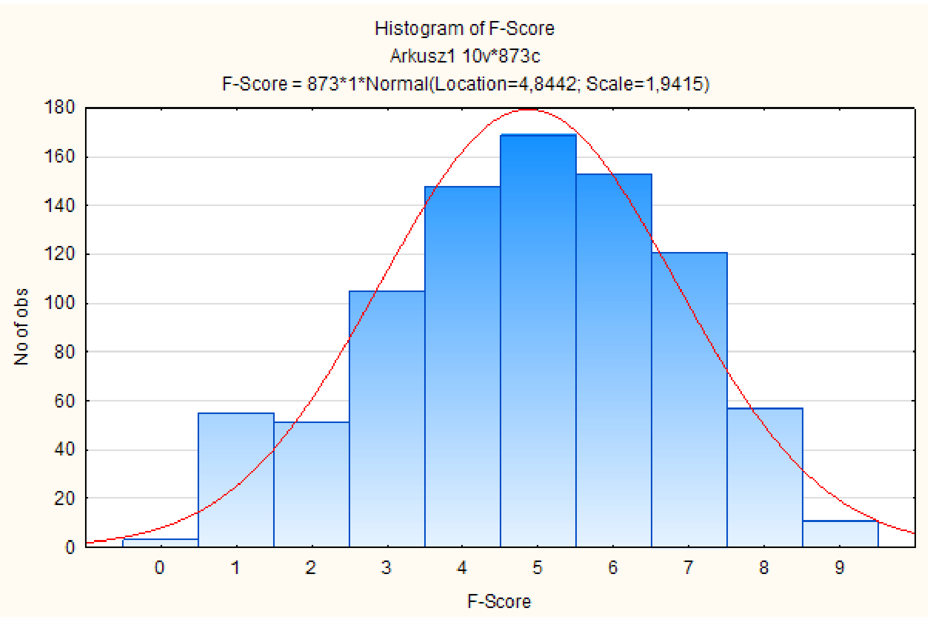


**Figure 3.** F-Score histogram

Source: Author's own study based on the data from Orbis database.

The distribution of the models analyzed (X-Score, Y-Score, F-Score) seems to be similar to the Gauss distribution, which is, however, not confirmed by the Shapiro–Wilk test applied. The share of low-scored entities (0–3 points for X-Score and Y-Score and 0–2 for F-Score) accounted for 13% of the total sample for X-Score, 17% for Y-Score, and 12% for F-Score, while the share of high-scored companies (9–11 points for X-Score and Y-Score, 8–9 points for F-Score) – 7%, 8%, 8%, respectively. Therefore, it could be stated that the models' indications seem to be restrictive, which might be considered an advantage. The companies with high scores were chosen to the investment portfolios built.

For the purposes of H1 verification, Pearson's chi-square test was employed. Regarding X-Score, the hypothesis about the compatibility distribution with F-Score was rejected (*p*-value amounted to 0.022), however, it was not true for Y-Score (*p*-value ~1.000). As a result, H1 might be considered partially confirmed. Nevertheless, testing investment portfolios built in line with both X-Score and Y-Score still seem to be valuable to compare X-Score and Y-Score (despite the similar distributions of Y-Score and F-Score).

## Investment portfolios building

Yields generated by the companies selected for the investment portfolios based on the models' indications significantly differed. Descriptive statistics for a such variable are presented in Table 5.

**Table 5.** Descriptive statistics for rates of return of shares selected by a given model

| Statistics | X-Score | Y-Score | F-Score |
|---|---|---|---|
| Arithmetic mean | 3.5% | 5.3% | 10.0% |
| Standard deviation | 44.1% | 48.1% | 54.1% |
| Coefficient of variation | 1246.2% | 905.5% | 539.4% |
| Quartile 1. | -21.5% | -20.3% | -20.7% |
| Median | -4.8% | -4.8% | 0.3% |
| Quartile 3. | 22.2% | 17.2% | 25.2% |
| Minimum | -66.2% | -79.4% | -89.2% |
| Maximum | 190.6% | 190.6% | 234.3% |

Source: Author's own study based on the data from Orbis database.

The mean rate of return was positive for companies chosen by each model analyzed. However, most of the entities selected for the portfolios by X-Score and Y-Score generated negative yields but it was not true regarding F-Score. Therefore, H2 is empirically confirmed, while H3 – not. 25% of units from the portfolios generated at least 17%, 22%, 25% yields regarding Y-Score, X-Score, F-Score, respectively. Piotroski's model was also less risky than the ones built by the author, based especially on the coefficient of variation.

At a first glance, based on descriptive statistics, the F-Score model seems to outperform X-Score and Y-Score. However, it is essential to both provide insight into the association between the scoring of given models and yields generated and backtest investment portfolios built. Suitable results are presented in Tables 6 and 7, sequentially.

**Table 6.** Raw and market-adjusted yields by scoring of the models analyzed

| Scoring | X-Score | | Y-Score | | F-Score | |
|---|---|---|---|---|---|---|
| | R | M | R | M | R | M |
| 0 | - | - | - | - | 14.59% | 11.83% |
| 1 | -2.60% | -5.36% | 0.51% | -2.25% | 16.02% | 13.26% |
| 2 | 10.71% | 7.95% | 10.60% | 7.84% | 3.31% | 0.55% |
| 3 | 1.91% | -0.85% | 21.17% | 18.41% | 15.51% | 12.75% |
| 4 | 31.38% | 28.62% | 22.33% | 19.57% | 17.98% | 15.22% |
| 5 | 20.38% | 17.62% | 24.30% | 21.54% | 25.61% | 22.85% |
| 6 | 31.21% | 28.45% | 12.60% | 9.84% | 8.39% | 5.63% |
| 7 | 5.08% | 2.32% | 22.00% | 19.24% | 20.19% | 17.43% |
| 8 | 3.90% | 1.14% | 5.66% | 2.90% | 7.61% | 4.85% |
| 9 | 8.72% | 5.96% | 4.04% | 1.28% | 22.57% | 19.81% |
| 10 | -5.19% | -7.95% | -0.30% | -3.06% | n/a | n/a |
| 11 | -9.59% | -12.35% | 49.12% | 46.36% | n/a | n/a |
| HML | -4.11% | -6.87% | -3.73% | -6.49% | -0.16% | -2.92% |

R – rate of return on the portfolio in a given year; M – market-adjusted (compared to WIG[6]) rate of return on the portfolio in a given year; HML – the difference between mean yield generated by entities with scoring at the level of 9–11 points and 0–2 points (for X-Score and Y-Score) and 8–9 points and 0–2 points (for F-Score), respectively.

Source: Author's own study based on the data from Orbis database.

Based on Table 6, entities with higher scoring generally do not outperform other companies, especially those considered weak in terms of their financial situation. Thus, H4 and H5 are not empirically confirmed. It seems that there were more purposeful to invest in high B/M entities with moderate scoring of X-Score and Y-Score – companies with 4–9 points generated mean market-adjusted rates of return at a significant positive level. Regarding F-Score, mean market-adjusted yields were positive for entities with each scoring.

The results of the aforementioned analysis are quite astounding. However, it is worth pointing out that mean yields might be not fully comparable due to the different number of entities with each scoring. Hence, investment portfolios based on the original models' assumptions were built and their yields analyzed, which is shown in Table 7.

[6] WIG – Warsaw Stock Index, used as a benchmark of the stock exchange.

**Table 7.** Rates of return generated from the investment portfolios built based on F-Score-type models indications

| | | X-Score | Y-Score | F-Score |
|---|---|---|---|---|
| 2013 | R | -6.3% | -3.3% | 29.8% |
| | M | -15.9% | -13.0% | 20.1% |
| | N | 3 | 2 | 1 |
| 2014 | R | -21.7% | -13.8% | -17.2% |
| | M | -37.7% | -29.8% | -33.2% |
| | N | 2 | 4 | 3 |
| 2015 | R | 16.5% | -2.6% | -13.0% |
| | M | 13.8% | -5.3% | -15.7% |
| | N | 5 | 7 | 7 |
| 2016 | R | 23.5% | -35.5% | -8.7% |
| | M | 39.6% | -19.4% | 7.4% |
| | N | 4 | 3 | 5 |
| 2017 | R | 3.4% | 47.6% | 50.6% |
| | M | -33.0% | 11.2% | 14.2% |
| | N | 5 | 8 | 8 |
| 2018 | R | -34.5% | -33.7% | -21.5% |
| | M | -26.2% | -25.4% | -13.2% |
| | N | 6 | 5 | 5 |
| 2019 | R | 15.8% | -2.2% | -5.5% |
| | M | 8.3% | -9.8% | -13.0% |
| | N | 6 | 6 | 8 |
| 2020 | R | 34.8% | 45.8% | 65.5% |
| | M | 52.5% | 63.5% | 83.2% |
| | N | 13 | 11 | 10 |
| 2021 | R | 6.3% | -5.1% | -0.5% |
| | M | -27.0% | -38.4% | -33.8% |
| | N | 10 | 9 | 7 |
| 2022 | R | -27.8% | -8.3% | -4.8% |
| | M | -8.9% | 10.7% | 14.1% |
| | N | 11 | 16 | 14 |
| Cumulative R | | -14.19% | -36.44% | 49.55% |
| Mean annual R | | -1.52% | -4.43% | 4.11% |
| Cumulative M | | -45.46% | -67.71% | 18.28% |
| Mean annual M | | -4.28% | -7.19% | 1.35% |

N – number of entities selected for the portfolio in a given year.
Source: Author's own study based on the data from Orbis database.

The buy-and-hold strategy applied to F-Score for the period July 2012 – June 2022 led to generating a mean annual yield of 1.35% above the market, while it was noticeably negative for X-Score and Y-Score. Therefore, H6 is considered empirically confirmed, while H7 – not at all. Moreover, the main hypothesis (H0) was also not supported.

Please note that there was a growing number of entities selected by given models in time, there were also generated negative yields by the companies selected for the portfolio in 2013–2014 (for X-Score) and 2013–2016 (Y-Score), which could partially explain the weakness of these models. The models' indications were quite consistent for F-Score and Y-Score in individual years – in 9 out of 10 years the signs of raw returns generated by the portfolios built based on these models were the same, while it was 5 between X-Score and F-Score and 6 between X-Score and Y-Score.

In general, the results obtained seem to be astonishing, as X-Score and Y-Score were built based on the situation of the Polish stock market. On the other hand, as mentioned above, it might be more appropriate to invest in moderate-scored entities according to these models. F-Score was found to be effective, it also outperformed the benchmark.

**Discussions**

Generally, the effectiveness of the F-Score model was empirically confirmed in the example of the Polish stock market, similarly, as in the cases of European, American and Asian markets previously analyzed (i.a. Noma, 2010; Rathjens & Schellhove, 2011; Hyde, 2013; Safdar, 2016; Tripathy & Pani, 2017; Tikkanen & Äijö, 2018; Walkshäusl, 2020). Comparing the results of the research with the previous studies focused on the Polish market, by Kusowska (2021) and Pilch (2021), it could be stated that the effectiveness pointed out by them was empirically confirmed based on a significantly larger sample and timeframe taken into account.

Considering individual variables, the results of the discriminant analysis were generally in line with the findings of Piotroski (2000) – there were confirmed significant positive associations between most of the variables selected to the models (for instance, ΔMARGIN, ΔACCRUAL, ΔROA, ΔLIQUID, and EQ_OFFER – variables that were chosen to X-Score or Y-Score and constitute F-Score) and future yields. However, a negative association between rates of return from the future period and ΔLEVER was identified. These results differ from those obtained by Nast (2017), regarding the reverse scoring of ΔLEVER postulated by him.

Based on the research made, higher scoring of both F-Score as well as X-Score and Y-Score was not associated with higher future yields. It could be deemed the opposite with the findings of, *inter alia*, Piotroski (2000), Rathjens and Schellhove (2011), Tripathy and Pani (2017) and Walkshäusl (2020).

Partially confirmed were the findings of Auret and Sinclaire (2006), O'Brien et al. (2010), da Cunha Araújo and Veras Machado (2018), Fahreza and Rizkianto (2021), and Barth et al. (2022), regarding the effectiveness of high B/M investing strategy (simultaneously, the conclusions of Syzdykov (2021) were not positively validated). Mean rates of return were mostly positive among the sample analyzed, regardless of the scoring of given entities.

It is worth noting that the building of X-Score and Y-Score was made with the usage of Mohanram's (2005) method (including not absolute values of indicators but their differences compared to the medians). As the effectiveness of these models was lower than F-Score, moreover, their usage led to generating negative both raw and market-adjusted yields, based on the backtesting, such an approach might be considered imperfect.

It is also worth to underline that the inclusion of periods of COVID-19 pandemic and several months after the war in Ukraine beginning significantly affected the results obtained. Generally, after the outbreak of both these events, financial markets noted significant declines and the market volatility noticeably increased (Czech et al., 2020; Basdekis et al., 2022). According to Mielus (2022), the impact of the Ukrainian war outbreak on the financial markets was even stronger than the shock caused by the pandemic beginning, on the example of European countries. It could noticeably impact the results of the research, as companies in a good financial situation in the periods preceding these events could be selected by the scoring models for investment portfolios, while their share prices in the following period fell due to the occurrence of the aforementioned shocks.

## Conclusions

The main aim of the paper was to build F-Score-type models on the example of the Polish stock market, which was done in the frame of the empirical research made. However, models built (X-Score and Y-Score) were less effective than F-Score – investment portfolios built based on their indications led to generating negative rates of return in total, which was not true for F-Score. It could be astounding to some extent as there were mostly similar variables (also without reversal scoring) regarding Y-Score and F-Score. However, it might be affected by the procedure applied to X-Score and Y-Score variables – there were the differences between the values of variable for a given entity and the median in the sample analyzed taken into account instead of absolute variables' values.

Based on the above conclusions, the main hypothesis, according to which X-Score and Y-Score were more efficient than F-Score, could not be empirically confirmed. On the other hand, the results obtained emphasize the purposefulness of using the F-Score.

Generally, the research pointed out the advisability of using high a B/M strategy, as most of the mean yields for undervalued entities were positive. However, using scoring like the one adopted in F-Score seems to be not a suitable approach on the example of the Polish stock market – the companies with higher scoring did not outperform other entities. Moreover, low-scored entities generated better historical results on average – it applies to all models taken into account.

Implications of the research made mostly concerned investors – based on the results obtained, investing in line with the high B/M strategy as well as using F-Score seems to be purposeful. Moreover, the building of F-Score-like models based on the situation of a specific market and using them for the investment portfolios construction do not necessarily led to outperforming F-Score, as it could be wrongly assumed.

Among the limitations of the research, it could be indicated both data inaccessibility and the disadvantages of the methodology applied, including both building and testing the models based on the historical data (backtesting), which is, however, a common approach. It is also worth pointing out that the exclusion of the companies from the financial industry (due to the different forms of their financial statements) might noticeably disrupt the results.

Regarding the suggestions for future research, building of the models based on the example of the Polish stock market, without using Mohanram's approach but in line with the original Piotroski's one (including absolute values of variables), is worth undertaking. Moreover, other F-Score-type models should be analyzed as well as other timeframes taken into account, especially bearing in mind the current and potential future economic situation of the European countries, emphasizing the results of the COVID-19 outbreak and war in Ukraine, but also taking into account the periods of high inflation and potential noticeable economic slump in the following years. Due to the significant volatility in stock markets due to the pandemic or war in Ukraine, the analysis focused on shorter periods and more frequent portfolio rebalancing (for instance, based on quarterly financial data) should also be taken into consideration.

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## Appendix

Correlation matrix for the initial set of explanatory variables*

| Variables | ROA | dROA | ROE | dROE | ROS | dROS | OROA | dOROA | OROE | dOROE | OROS | dOROS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ROA** | 1.0000 | -0.0007 | **0.8807** | **0.3243** | 0.0700 | 0.0527 | **0.1609** | -0.0015 | **0.1074** | **0.0985** | 0.0157 | 0.0039 |
| **dROA** | -0.0007 | 1.0000 | -0.0004 | **-0.8807** | -0.0013 | 0.0008 | -0.0638 | **1.0000** | -0.0158 | **-0.6165** | -0.0037 | -0.0011 |
| **ROE** | **0.8807** | -0.0004 | 1.0000 | **0.3590** | 0.0622 | 0.0470 | **0.2898** | -0.0010 | **0.5397** | **0.4298** | 0.0765 | 0.0594 |
| **dROE** | **0.3243** | **-0.8807** | **0.3590** | 1.0000 | 0.0246 | 0.0312 | **0.1451** | **-0.8813** | **0.1925** | **0.7001** | 0.0329 | 0.0260 |
| **ROS** | 0.0700 | -0.0013 | 0.0622 | 0.0246 | 1.0000 | **0.8879** | 0.0144 | -0.0014 | 0.0176 | 0.0136 | **0.1377** | **0.1376** |
| **dROS** | 0.0527 | 0.0008 | 0.0470 | 0.0312 | **0.8879** | 1.0000 | -0.0161 | 0.0006 | 0.0046 | 0.0039 | **0.1175** | **0.1645** |
| **OROA** | **0.1609** | -0.0638 | **0.2898** | **0.1451** | 0.0144 | -0.0161 | 1.0000 | -0.0630 | **0.5960** | **0.4174** | **0.1440** | 0.0810 |
| **dOROA** | -0.0015 | **1.0000** | -0.0010 | **-0.8813** | -0.0014 | 0.0006 | -0.0630 | 1.0000 | -0.0153 | **-0.6160** | -0.0036 | -0.0010 |
| **OROE** | **0.1074** | -0.0158 | **0.5397** | **0.1925** | 0.0176 | 0.0046 | **0.5960** | -0.0153 | 1.0000 | **0.7520** | **0.1578** | **0.1246** |
| **dOROE** | **0.0985** | **-0.6165** | **0.4298** | **0.7001** | 0.0136 | 0.0039 | **0.4174** | **-0.6160** | **0.7520** | 1.0000 | **0.1175** | **0.0928** |
| **OROS** | 0.0157 | -0.0037 | 0.0765 | 0.0329 | **0.1377** | **0.1175** | **0.1440** | -0.0036 | **0.1578** | **0.1175** | 1.0000 | **0.9892** |
| **dOROS** | 0.0039 | -0.0011 | 0.0594 | 0.0260 | **0.1376** | **0.1645** | 0.0810 | -0.0010 | **0.1246** | **0.0928** | **0.9892** | 1.0000 |
| **MARGIN** | 0.0141 | -0.0038 | 0.0129 | 0.0087 | **0.2675** | **0.2337** | 0.0495 | -0.0038 | 0.0182 | 0.0093 | **0.8716** | **0.8634** |
| **dMARGIN** | -0.0093 | 0.0023 | -0.0062 | -0.0030 | **0.2622** | **0.2706** | -0.0751 | 0.0021 | -0.0202 | -0.0225 | **0.8503** | **0.8722** |
| **TURN** | -0.0042 | 0.0067 | 0.0254 | 0.0048 | 0.0393 | 0.0261 | **0.1798** | 0.0067 | **0.1235** | 0.0429 | 0.0749 | 0.0799 |
| **dTURN** | -0.0019 | **1.0000** | -0.0014 | **-0.8814** | -0.0014 | 0.0007 | -0.0638 | **1.0000** | -0.0157 | **-0.6162** | -0.0036 | -0.0008 |
| **CFO** | 0.0678 | 0.0196 | **0.1179** | 0.0199 | 0.0177 | -0.0415 | **0.4940** | 0.0200 | **0.2747** | **0.1645** | 0.0602 | 0.0319 |
| **dCFO** | 0.0032 | **-0.9995** | 0.0038 | **0.8819** | 0.0018 | -0.0015 | 0.0731 | **-0.9995** | 0.0213 | **0.6217** | 0.0046 | 0.0014 |
| **ACCRUAL** | **0.0996** | -0.0301 | **0.1496** | 0.0639 | **0.1155** | **0.1212** | **0.2279** | -0.0299 | **0.1655** | **0.1283** | -0.0034 | -0.0274 |
| **dACCRUAL** | -0.0018 | **1.0000** | -0.0014 | **-0.8814** | -0.0014 | 0.0007 | -0.0639 | **1.0000** | -0.0159 | **-0.6166** | -0.0037 | -0.0011 |
| **LIQUID** | 0.0607 | 0.0033 | 0.0493 | 0.0060 | 0.0635 | 0.0563 | -0.0071 | 0.0033 | -0.0021 | 0.0015 | -0.0705 | -0.0662 |
| **dLIQUID** | 0.0796 | 0.0265 | 0.0637 | 0.0054 | 0.0746 | 0.0401 | -0.0109 | 0.0264 | -0.0040 | -0.0151 | -0.0244 | -0.0361 |
| **QR** | 0.0606 | 0.0028 | 0.0489 | 0.0061 | 0.0626 | 0.0559 | -0.0112 | 0.0028 | -0.0040 | 0.0008 | -0.0723 | -0.0677 |
| **dQR** | 0.0798 | 0.0236 | 0.0637 | 0.0078 | 0.0748 | 0.0401 | -0.0110 | 0.0235 | -0.0045 | -0.0138 | -0.0244 | -0.0363 |
| **LEVER** | -0.0518 | -0.0033 | -0.0305 | 0.0031 | 0.0453 | 0.0228 | -0.0345 | -0.0032 | 0.0339 | 0.0253 | **0.0912** | 0.0749 |
| **dLEVER** | -0.0283 | **-0.0987** | 0.0615 | **0.1105** | -0.0170 | -0.0028 | -0.0424 | **-0.0987** | **0.1318** | **0.1902** | 0.0009 | -0.0055 |
| **CDR** | -0.0656 | -0.0272 | -0.0564 | 0.0218 | 0.0287 | 0.0188 | -0.0712 | -0.0272 | -0.0073 | 0.0208 | 0.0640 | 0.0563 |
| **dCDR** | -0.0628 | **-0.0905** | 0.0177 | **0.0895** | -0.0147 | -0.0008 | -0.0694 | **-0.0905** | **0.1004** | **0.1581** | 0.0165 | 0.0109 |
| **LDR** | 0.0088 | 0.0333 | 0.0303 | -0.0259 | 0.0329 | 0.0105 | 0.0448 | 0.0333 | 0.0655 | 0.0117 | 0.0574 | 0.0419 |
| **dLDR** | 0.0706 | -0.0078 | 0.0813 | 0.0321 | -0.0032 | -0.0037 | 0.0571 | -0.0078 | 0.0511 | 0.0474 | -0.0310 | -0.0319 |
| **LNS** | -0.0453 | 0.0136 | 0.0086 | 0.0030 | **0.1303** | 0.0832 | **0.1602** | 0.0136 | **0.1433** | 0.0645 | **0.2558** | **0.2272** |

| **Variables** | **ROA** | **dROA** | **ROE** | **dROE** | **ROS** | **dROS** | **OROA** | **dOROA** | **OROE** | **dOROE** | **OROS** | **dOROS** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **dLNS** | -0.0807 | -0.0536 | -0.0284 | 0.0230 | **0.2623** | **0.2711** | -0.0108 | -0.0535 | 0.0688 | 0.0604 | **0.3254** | **0.3642** |
| **LNA** | -0.0389 | 0.0109 | -0.0133 | -0.0134 | 0.0099 | -0.0037 | 0.0778 | 0.0109 | 0.0660 | 0.0225 | 0.0651 | 0.0526 |
| **dLNA** | -0.0458 | **-0.7008** | 0.0019 | **0.5398** | -0.0003 | -0.0831 | **0.1381** | **-0.7006** | **0.1083** | **0.4645** | 0.0609 | 0.0390 |
| **EQ_OFFER** | 0.0140 | **0.1022** | 0.0547 | -0.0731 | -0.0006 | -0.0478 | 0.0158 | **0.1023** | 0.0824 | 0.0125 | 0.0006 | -0.0089 |
| **Variables** | **MARGIN** | **dMARGIN** | **TURN** | **dTURN** | **CFO** | **dCFO** | **ACCRUAL** | **dACCRUAL** | **LIQUID** | **dLIQUID** | **QR** | **dQR** |
| **ROA** | 0.0141 | -0.0093 | -0.0042 | -0.0019 | 0.0678 | 0.0032 | **0.0996** | -0.0018 | 0.0607 | 0.0796 | 0.0606 | 0.0798 |
| **dROA** | -0.0038 | 0.0023 | 0.0067 | **1.0000** | 0.0196 | **-0.9995** | -0.0301 | **1.0000** | 0.0033 | 0.0265 | 0.0028 | 0.0236 |
| **ROE** | 0.0129 | -0.0062 | 0.0254 | -0.0014 | **0.1179** | 0.0038 | **0.1496** | -0.0014 | 0.0493 | 0.0637 | 0.0489 | 0.0637 |
| **dROE** | 0.0087 | -0.0030 | 0.0048 | **-0.8814** | 0.0199 | **0.8819** | 0.0639 | **-0.8814** | 0.0060 | 0.0054 | 0.0061 | 0.0078 |
| **ROS** | **0.2675** | **0.2622** | 0.0393 | -0.0014 | 0.0177 | 0.0018 | **0.1155** | -0.0014 | 0.0635 | 0.0746 | 0.0626 | 0.0748 |
| **dROS** | **0.2337** | **0.2706** | 0.0261 | 0.0007 | -0.0415 | -0.0015 | **0.1212** | 0.0007 | 0.0563 | 0.0401 | 0.0559 | 0.0401 |
| **OROA** | 0.0495 | -0.0751 | **0.1798** | -0.0638 | **0.4940** | 0.0731 | **0.2279** | -0.0639 | -0.0071 | -0.0109 | -0.0112 | -0.0110 |
| **dOROA** | -0.0038 | 0.0021 | 0.0067 | **1.0000** | 0.0200 | **-0.9995** | -0.0299 | **1.0000** | 0.0033 | 0.0264 | 0.0028 | 0.0235 |
| **OROE** | 0.0182 | -0.0202 | **0.1235** | -0.0157 | **0.2747** | 0.0213 | **0.1655** | -0.0159 | -0.0021 | -0.0040 | -0.0040 | -0.0045 |
| **dOROE** | 0.0093 | -0.0225 | 0.0429 | **-0.6162** | **0.1645** | **0.6217** | **0.1283** | **-0.6166** | 0.0015 | -0.0151 | 0.0008 | -0.0138 |
| **OROS** | **0.8716** | **0.8503** | 0.0749 | -0.0036 | 0.0602 | 0.0046 | -0.0034 | -0.0037 | -0.0705 | -0.0244 | -0.0723 | -0.0244 |
| **dOROS** | **0.8634** | **0.8722** | 0.0799 | -0.0008 | 0.0319 | 0.0014 | -0.0274 | -0.0011 | -0.0662 | -0.0361 | -0.0677 | -0.0363 |
| **MARGIN** | 1.0000 | **0.9710** | 0.0484 | -0.0036 | 0.0491 | 0.0045 | 0.0097 | -0.0038 | -0.0337 | 0.0147 | -0.0352 | 0.0147 |
| **dMARGIN** | **0.9710** | 1.0000 | **0.0915** | 0.0028 | 0.0064 | -0.0023 | -0.0477 | 0.0023 | -0.0279 | -0.0005 | -0.0291 | -0.0005 |
| **TURN** | 0.0484 | **0.0915** | 1.0000 | 0.0082 | **0.3765** | 0.0018 | **-0.2854** | 0.0066 | -0.0678 | -0.0345 | -0.0685 | -0.0343 |
| **dTURN** | -0.0036 | 0.0028 | 0.0082 | 1.0000 | 0.0217 | **-0.9994** | -0.0324 | **1.0000** | 0.0029 | 0.0259 | 0.0024 | 0.0231 |
| **CFO** | 0.0491 | 0.0064 | **0.3765** | 0.0217 | 1.0000 | 0.0026 | **-0.6662** | 0.0193 | -0.0166 | -0.0010 | -0.0168 | -0.0007 |
| **dCFO** | 0.0045 | -0.0023 | 0.0018 | **-0.9994** | 0.0026 | 1.0000 | 0.0139 | **-0.9995** | -0.0033 | -0.0263 | -0.0028 | -0.0234 |
| **ACCRUAL** | 0.0097 | -0.0477 | **-0.2854** | -0.0324 | **-0.6662** | 0.0139 | 1.0000 | -0.0299 | **0.0901** | 0.0717 | 0.0868 | 0.0715 |
| **dACCRUAL** | -0.0038 | 0.0023 | 0.0066 | **1.0000** | 0.0193 | **-0.9995** | -0.0299 | 1.0000 | 0.0033 | 0.0264 | 0.0028 | 0.0235 |
| **LIQUID** | -0.0337 | -0.0279 | -0.0678 | 0.0029 | -0.0166 | -0.0033 | **0.0901** | 0.0033 | 1.0000 | **0.9583** | **0.9991** | **0.9592** |
| **dLIQUID** | 0.0147 | -0.0005 | -0.0345 | 0.0259 | -0.0010 | -0.0263 | 0.0717 | 0.0264 | **0.9583** | 1.0000 | **0.9585** | **0.9993** |
| **QR** | -0.0352 | -0.0291 | -0.0685 | 0.0024 | -0.0168 | -0.0028 | 0.0868 | 0.0028 | **0.9991** | **0.9585** | 1.0000 | **0.9600** |
| **dQR** | 0.0147 | -0.0005 | -0.0343 | 0.0231 | -0.0007 | -0.0234 | 0.0715 | 0.0235 | **0.9592** | **0.9993** | **0.9600** | 1.0000 |
| **LEVER** | 0.0727 | 0.0638 | **0.2889** | -0.0034 | 0.0124 | 0.0031 | -0.0524 | -0.0032 | **-0.1563** | -0.0643 | **-0.1477** | -0.0631 |
| **dLEVER** | -0.0239 | -0.0235 | **-0.1155** | **-0.0995** | -0.0020 | **0.0983** | -0.0487 | **-0.0986** | -0.0048 | -0.0290 | -0.0027 | -0.0242 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CDR** | 0.0472 | 0.0545 | **0.4037** | -0.0273 | -0.0379 | 0.0271 | -0.0352 | -0.0272 | **-0.1311** | -0.0586 | **-0.1230** | -0.0559 |
| **dCDR** | -0.0021 | -0.0035 | **-0.1417** | **-0.0915** | -0.0450 | **0.0893** | -0.0215 | **-0.0904** | -0.0172 | -0.0420 | -0.0143 | -0.0343 |
| **LDR** | 0.0512 | 0.0263 | **-0.1030** | 0.0332 | 0.0739 | -0.0334 | -0.0351 | 0.0333 | -0.0680 | -0.0213 | -0.0656 | -0.0233 |
| **dLDR** | -0.0409 | -0.0376 | 0.0617 | -0.0074 | 0.0852 | 0.0095 | -0.0496 | -0.0079 | 0.0250 | 0.0280 | 0.0231 | 0.0220 |
| **LNS** | **0.2390** | **0.2148** | **0.3677** | 0.0136 | **0.1236** | -0.0132 | -0.0120 | 0.0136 | **-0.1732** | -0.0842 | **-0.1747** | -0.0844 |
| **Variables** | **MARGIN** | **dMARGIN** | **TURN** | **dTURN** | **CFO** | **dCFO** | **ACCRUAL** | **dACCRUAL** | **LIQUID** | **dLIQUID** | **QR** | **dQR** |
| **dLNS** | **0.3930** | **0.4665** | **0.2730** | -0.0512 | **0.1079** | 0.0551 | **-0.1351** | -0.0535 | **-0.2951** | **-0.3190** | **-0.2968** | **-0.3198** |
| **LNA** | 0.0480 | 0.0381 | **0.1540** | 0.0106 | 0.0609 | -0.0118 | -0.0163 | 0.0109 | -0.0422 | -0.0153 | -0.0420 | -0.0154 |
| **dLNA** | 0.0129 | -0.0080 | -0.0086 | **-0.7021** | 0.0441 | **0.6944** | 0.0578 | **-0.7004** | -0.0175 | -0.0321 | -0.0152 | -0.0295 |
| **EQ_OFFER** | 0.0028 | -0.0002 | 0.0274 | **0.1024** | 0.0639 | **-0.1013** | -0.0415 | **0.1022** | 0.0251 | 0.0188 | 0.0235 | 0.0184 |

| Variables | LEVER | dLEVER | CDR | dCDR | LDR | dLDR | LNS | dLNS | LNA | dLNA | EQ_OFFER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **ROA** | -0.0518 | -0.0283 | -0.0656 | -0.0628 | 0.0088 | 0.0706 | -0.0453 | -0.0807 | -0.0389 | -0.0458 | 0.0140 |
| **dROA** | -0.0033 | **-0.0987** | -0.0272 | **-0.0905** | 0.0333 | -0.0078 | 0.0136 | -0.0536 | 0.0109 | **-0.7008** | **0.1022** |
| **ROE** | -0.0305 | 0.0615 | -0.0564 | 0.0177 | 0.0303 | 0.0813 | 0.0086 | -0.0284 | -0.0133 | 0.0019 | 0.0547 |
| **dROE** | 0.0031 | **0.1105** | 0.0218 | **0.0895** | -0.0259 | 0.0321 | 0.0030 | 0.0230 | -0.0134 | **0.5398** | -0.0731 |
| **ROS** | 0.0453 | -0.0170 | 0.0287 | -0.0147 | 0.0329 | -0.0032 | **0.1303** | **0.2623** | 0.0099 | -0.0003 | -0.0006 |
| **dROS** | 0.0228 | -0.0028 | 0.0188 | -0.0008 | 0.0105 | -0.0037 | 0.0832 | **0.2711** | -0.0037 | -0.0831 | -0.0478 |
| **OROA** | -0.0345 | -0.0424 | -0.0712 | -0.0694 | 0.0448 | 0.0571 | **0.1602** | -0.0108 | 0.0778 | **0.1381** | 0.0158 |
| **dOROA** | -0.0032 | **-0.0987** | -0.0272 | **-0.0905** | 0.0333 | -0.0078 | 0.0136 | -0.0535 | 0.0109 | **-0.7006** | **0.1023** |
| **OROE** | 0.0339 | **0.1318** | -0.0073 | **0.1004** | 0.0655 | 0.0511 | **0.1433** | 0.0688 | 0.0660 | **0.1083** | 0.0824 |
| **dOROE** | 0.0253 | **0.1902** | 0.0208 | **0.1581** | 0.0117 | 0.0474 | 0.0645 | 0.0604 | 0.0225 | **0.4645** | 0.0125 |
| **OROS** | **0.0912** | 0.0009 | 0.0640 | 0.0165 | 0.0574 | -0.0310 | **0.2558** | **0.3254** | 0.0651 | 0.0609 | 0.0006 |
| **dOROS** | 0.0749 | -0.0055 | 0.0563 | 0.0109 | 0.0419 | -0.0319 | **0.2272** | **0.3642** | 0.0526 | 0.0390 | -0.0089 |
| **MARGIN** | 0.0727 | -0.0239 | 0.0472 | -0.0021 | 0.0512 | -0.0409 | **0.2390** | **0.3930** | 0.0480 | 0.0129 | 0.0028 |
| **dMARGIN** | 0.0638 | -0.0235 | 0.0545 | -0.0035 | 0.0263 | -0.0376 | **0.2148** | **0.4665** | 0.0381 | -0.0080 | -0.0002 |
| **TURN** | **0.2889** | **-0.1155** | **0.4037** | **-0.1417** | **-0.1030** | 0.0617 | **0.3677** | **0.2730** | **0.1540** | -0.0086 | 0.0274 |
| **dTURN** | -0.0034 | **-0.0995** | -0.0273 | **-0.0915** | 0.0332 | -0.0074 | 0.0136 | -0.0512 | 0.0106 | **-0.7021** | **0.1024** |
| **CFO** | 0.0124 | -0.0020 | -0.0379 | -0.0450 | 0.0739 | 0.0852 | **0.1236** | **0.1079** | 0.0609 | 0.0441 | 0.0639 |
| **dCFO** | 0.0031 | **0.0983** | 0.0271 | **0.0893** | -0.0334 | 0.0095 | -0.0132 | 0.0551 | -0.0118 | **0.6944** | **-0.1013** |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **ACCRUAL** | -0.0524 | -0.0487 | -0.0352 | -0.0215 | -0.0351 | -0.0496 | -0.0120 | **-0.1351** | -0.0163 | 0.0578 | -0.0415 |
| **dACCRUAL** | -0.0032 | **-0.0986** | -0.0272 | **-0.0904** | 0.0333 | -0.0079 | 0.0136 | -0.0535 | 0.0109 | **-0.7004** | **0.1022** |
| **LIQUID** | **-0.1563** | -0.0048 | **-0.1311** | -0.0172 | -0.0680 | 0.0250 | **-0.1732** | **-0.2951** | -0.0422 | -0.0175 | 0.0251 |
| **dLIQUID** | -0.0643 | -0.0290 | -0.0586 | -0.0420 | -0.0213 | 0.0280 | -0.0842 | **-0.3190** | -0.0153 | -0.0321 | 0.0188 |
| **QR** | **-0.1477** | -0.0027 | **-0.1230** | -0.0143 | -0.0656 | 0.0231 | **-0.1747** | **-0.2968** | -0.0420 | -0.0152 | 0.0235 |
| **dQR** | -0.0631 | -0.0242 | -0.0559 | -0.0343 | -0.0233 | 0.0220 | -0.0844 | **-0.3198** | -0.0154 | -0.0295 | 0.0184 |
| **LEVER** | 1.0000 | **0.1633** | **0.7920** | **0.1536** | **0.5015** | 0.0054 | **0.4550** | 0.0438 | **0.2555** | 0.0287 | **-0.0924** |
| **dLEVER** | **0.1633** | 1.0000 | **0.1266** | **0.8673** | 0.0858 | **0.1776** | 0.0421 | **-0.1156** | 0.0489 | **0.1013** | -0.0079 |
| **CDR** | **0.7920** | **0.1266** | 1.0000 | **0.2063** | **-0.1311** | **-0.1683** | **0.2777** | 0.0216 | 0.0448 | 0.0086 | -0.0647 |
| **dCDR** | **0.1536** | **0.8673** | **0.2063** | 1.0000 | -0.0429 | **-0.3359** | 0.0267 | **-0.1118** | 0.0400 | 0.0879 | -0.0007 |
| **LDR** | **0.5015** | 0.0858 | **-0.1311** | -0.0429 | 1.0000 | **0.2472** | **0.3452** | 0.0405 | **0.3514** | 0.0344 | -0.0584 |
| **dLDR** | 0.0054 | **0.1776** | **-0.1683** | **-0.3359** | **0.2472** | 1.0000 | 0.0267 | 0.0023 | 0.0135 | 0.0179 | -0.0135 |
| **LNS** | **0.4550** | 0.0421 | **0.2777** | 0.0267 | **0.3452** | 0.0267 | 1.0000 | **0.2628** | **0.5363** | 0.0284 | 0.0006 |
| **Variables** | **LEVER** | **dLEVER** | **CDR** | **dCDR** | **LDR** | **dLDR** | **LNS** | **dLNS** | **LNA** | **dLNA** | **EQ_OFFER** |
| **dLNS** | 0.0438 | **-0.1156** | 0.0216 | **-0.1118** | 0.0405 | 0.0023 | **0.2628** | 1.0000 | 0.0213 | **0.1209** | -0.0193 |
| **LNA** | **0.2555** | 0.0489 | 0.0448 | 0.0400 | **0.3514** | 0.0135 | **0.5363** | 0.0213 | 1.0000 | 0.0369 | -0.0280 |
| **dLNA** | 0.0287 | **0.1013** | 0.0086 | 0.0879 | 0.0344 | 0.0179 | 0.0284 | **0.1209** | 0.0369 | 1.0000 | **-0.1030** |
| **EQ_OFFER** | **-0.0924** | -0.0079 | -0.0647 | -0.0007 | -0.0584 | -0.0135 | 0.0006 | -0.0193 | -0.0280 | **-0.1030** | 1.0000 |

* correlations in bold are statistically significant at $p < 0.10$

Source: Author's own study based on the data from Orbis database.