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Market and Accounting Measures of Risk: The Case of the Frankfurt Stock Exchange

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Abstract: The main purpose of this study was to explore the relationship between market and accounting measures of risk and the profitability of companies listed on the Frankfurt Stock Exchange. An important aspect of the study was to employ accounting beta coefficients as a systematic risk measure. The research considered classical and downside risk measures. The profitability of a company was expressed as ROA and ROE. When determining the downside risk, two approaches were employed: the approach by Bawa and Lindenberg and the approach by Harlow and Rao. In all the analyzed companies, there is a positive and statistically significant correlation between the average value of profitability ratios and the market rate of return on investment in their stocks. Additionally, correlation coefficients are higher for the companies included in the DAX index compared with those from the MDAX or SDAX indices. A positive and in each case a statistically significant correlation was observed for all DAX-indexed companies between all types of market betas and corresponding accounting betas. Likewise, for the MDAX-indexed companies, these correlations were positive but statistical significance emerged only for accounting betas calculated on ROA. As regards the DAX index, not every correlation was positive and significant.

Keywords: accounting beta; ROA; ROE; downside risk; downside beta; semi-deviation; systematic risk; total risk; Frankfurt Stock Exchange

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1. Introduction

This research deals with accounting and market measures of risk and the profitability of companies listed on the Frankfurt Stock Exchange. An important aspect of this study was the application of accounting beta coefficients as measures of sensitivity. Accounting beta coefficients are measures of the systematic risk of a company, computed based on accounting profitability ratios. The study employed two basic ratios: return on assets (ROA) and return on equity (ROE). The concept of accounting beta coefficients was proposed by Hill and Stone (1980). Following Sharpe's single-factor model (Sharpe 1964), Hill and Stone designed a sensitivity metric describing changes in the accounting profitability of a listed company caused by changes in the profitability of a given market or sector. The principal and obvious objective of a company is to generate profit. It can be assumed that the market value of stocks of a given company is related to the earned profit and expectations regarding its future level. The dividend policy of the company is also important, with which managers build long-term investor confidence. It is reflected in the payments made from profit, which may be treated by the shareholders as a significant component of value. At the same time, there is a developed theoretical trend regarding the impact of the dividend policy on the value of an enterprise. Changeability and uncertainty as to the level of profit in the future, combined with the volatility of the parameters of the dividend policy, are the result of the risk to which each business activity and its owners are exposed (Szydłowski and Wojtowicz 2020). Of key importance here is the mechanism of sharing the risk between market players and the perception of market information (Włodarczyk and Szturo 2018). Changes in a company's profitability are one of the factors causing fluctuations in stock prices. This

phenomenon can be viewed in the context of total risk, i.e., variability (semi-variability) in both rates of return on financial markets, and from the perspective of the profitability of companies per se. On the other hand, there is systematic risk, which can be quantified with sensitivity metrics, both calculated from rates of return and profitability ratios. As with total risk, systematic risk can be calculated from classical measures of risk based on variance (standard deviation) and by applying downside risk measures. The downside risk measures used in this study originate from the concept of lower partial moments proposed and defined by Bawa (1975) and Fishburn (1977). Two approaches were employed in this study for the determination of downside risk: the approach by Bawa and Lindenberg (1977) and the approach by Harlow and Rao (1989).

The beta coefficient is a measure of the systematic risk of listed companies (Sharpe 1964). Betas from Sharpe's model can be applied only to companies listed on an equity market because they are derived from the prices of stocks (rates of return). In the following sections of this paper, they will be denoted as market betas, the same as other sensitivity metrics whose calculations rely on prices (rates of return) on an equity market.

The accounting-based beta was first proposed by Hill and Stone (1980), and it is determined analogously to the determination of a market-based beta. Market betas measure the sensitivity of the rate of return on stocks of a given company to changes in the profitability of the entire sector (market). It is assumed that accounting returns are generated by a stochastic process, which is structurally similar to the one generating rates of return on a stock exchange (Hill and Stone 1980).

The accounting beta can be used as an additional tool for the determination of the systematic risk of companies listed on the capital market. Nekrasov and Shroff (2009) suggested using accounting betas when it is impossible to calculate market risk measures. Accounting beta coefficients instead of market betas can be calculated for companies not listed on a stock exchange to assess their risk (Sarmiento-Sabogal and Sadeghi 2015). Stubelj and Laporšek (2021) used accounting betas to compare the level of systematic risk between different industries. The research was based on data of Slovenian capital firms, both listed and unlisted ones. Portfolios containing companies from one industry were taken into account and weighed by the value of equity. The ROE ratio was used as the measure of accounting profitability.

However, there are two major limitations here. One is the availability of accounting data, and the other one is the fact that financial reports are not published frequently enough. Data of at least quarterly frequency are best for the determination of accounting betas (see Nekrasov and Shroff 2009). For example, quarterly financial reports are available for the Frankfurt Stock Exchange and Warsaw Stock Exchange, whereas companies listed on the London Stock Exchange are not legally obligated to publish data every quarter of a year. Xing and Yan (2019) showed that better quality and availability of accounting data contribute to the lowering of systematic risk on capital markets. It is therefore important for investors to have access to current reliable financial and non-financial statements. A helpful instrument in this respect is the broadly understood audit, which in practice can significantly reduce the risk of false disclosures presented in the reports (Bartoszewicz and Rutkowska-Ziarko 2021).

Studies conducted by Nekrasov and Shroff (2009) as well as Sarmiento-Sabogal and Sadeghi (2015) demonstrated a connection between accounting betas and market betas for companies listed on stock exchanges in the United States. Amorim et al. (2012) discovered a relationship between accounting data and systematic risk in the Brazilian financial market.

The above-mentioned research considered accounting betas only in the contexts of symmetric measures of risk, such as standard deviation. In this study, the downside risk is also considered. The concept of downside accounting beta was proposed by Rutkowska-Ziarko and Pyke (2017). In this research, this measure of risk is compared to the accounting beta based on the standard deviation and to the market measures of sensitivity. Owing to the need for writing mathematical formulas to show the main features of the used

risk measures in this work, a broader description of downside risk measures and their application in the finance area is provided in the next section of the article.

Downside accounting betas were used in previous studies concerning the Warsaw Stock Exchange, the profitability and risk of Polish food, construction, and IT companies, as well as ones composing some of the WSE indices (WIG-20, WIG-40, and WIG-80). In each case, a positive correlation was observed between mean values of profitability ratios and average rates of return over a long period. In addition, a relationship was determined between market and accounting beta coefficients, which was stronger from downside risk than for risk assessed in the classical approach.

A question, therefore, arises as to whether the above relations also appear on other stock exchange markets. One of the biggest European stock exchanges, the Frankfurt Stock Exchange, was chosen for this study. The choice was dictated by the size of this market, its location in Europe, and the obligation to issue quarterly financial reports by issuers.

There is little research in the literature on the use of accounting betas in risk analysis, in particular those based on the downside risk. So, this study is a step towards filling this gap.

The main goal of this study was to verify whether there is a positive correlation between the systematic risk of listed companies and accounting beta coefficients. Other aims were:

- to check if such a relationship also appears regarding total risk and variability of profitability ratios; and
- to explore the connection between mean rates of return on the capital market and an average rate of relative profitability in the long term.

Considering the above goals, the following working hypotheses were put forth:

Hypothesis 1 (H1). *Listed companies with higher profitability ratios achieve higher rates of return in the long term.*

Hypothesis 2 (H2). *Total risk is positively correlated with variance (semi-variance) of accounting profitability.*

Hypothesis 3 (H3). *Market beta coefficients are correlated with accounting beta coefficients.*

Hypothesis 4 (H4). *Symmetric and downside risk metrics are mutually positively correlated.*

Hypothesis 5 (H5). *The profitability indicators ROA and ROE as well as risk metrics built on them are positively correlated.*

2. Risk Measures in the Classical and Downside Approaches

In this study, the risk was considered both in the context of the changeability of results and the sensitivity of these results to the overall situation on the market. This approach agrees with the division of risk metrics presented by Jajuga ([2007] 2019) and Kuziak (2011). The principal difference between sensitivity measures and variance measures lies in the fact that sensitivity measures take into account causes of risk, while variance metrics measure results of the occurrence of the risk. In this study, a result is understood as a rate of return and relative profitability measured with the help of ROA and ROE alternatively obtained by the investor.

Risk measures in this paper were divided according to three criteria (see Rutkowska-Ziarko 2020a):

- concept of risk: negative or neutral;
- measures of total and systematic risk; and
- measures based on rates of return (market) and profitability ratios (accounting).

Risk measures in the neutral approach will always be symmetrical measures of risk, such as standard deviation and other statistical measures of dispersion. We shall refer to

them in what follows as symmetrical risk measures. To express quantitatively the negative approach to risk, it is necessary to apply asymmetrical measures, accounting only for the left-hand side of the distribution of rates of return; an example of such measures is lower partial moments. Both the measures applying to results of risk and risk causes can be divided into symmetrical (classical) and downside ones.

2.1. Market Risk Measures

The classical risk measures are variance (S^2) and standard deviation (S). These statistical measures of dispersion were first applied to measure risk by Markowitz (1952). In that case, the random variable is the rate of return (R). The higher the value of these measures, the higher the risk that the achieved rate of return will differ from the expected one.

A value equal to zero means the absence of risk. Calculations of variance and standard deviation lead to attributing relatively more importance to large than to small deviations from the mean. This approach is suitable for investors with an aversion to risk.

A certain drawback of variance and standard deviation as risk measures is that negative and positive deviations from the expected rate of return are treated identically. In reality, negative deviations are undesirable while positive ones create an opportunity to gain a higher profit (Pla-Santamaria and Bravo 2013; Klebaner et al. 2017; Rutkowska-Ziarko and Pyke 2017). Measures devoid of these defects are semi-variance (${dS_i}^2$) and standard semi-deviation (dS_i). Their application is in accord with the so-called negative concept of risk. These measures were first defined by Markowitz (1959) with the help of the formulas:

$$ {dS_i}^2 = E\left\{\min[(R_{it} - \gamma), 0]^2\right\}, \tag{1} $$

$$ dS_i = \sqrt{E\left\{\min[(R_{it} - \gamma), 0]^2\right\}}, \tag{2} $$

where:

$t = 1, 2, \ldots, T$, T is the number of time units;

R_{it} is the rate of return achieved in the time t by the i-th company; and

γ is the target rate of return. It can equal the average rate of return or the rate of return arbitrarily chosen by the investor; often a risk-free rate is taken as a reference point.

Risk measures whose values take into account consequences of investment decisions are total risk measures. In essence, this second group of measures accounts for sources of risk, which are a derivative of systematic cyclical and economic factors. These measures, which are referred to in the literature as sensitivity measures, reflect the impact of the analyzed causes of risk on prices or rates of return generated by financial instruments. The higher the sensitivity of prices or rates of return to changes in systematic factors, the higher the so-called systematic risk of a given instrument. The single-index model by Sharpe assumes that rates of return of securities are in line with the tendency that dominates a given capital market.

In the classical CAPM model (a model for evaluation of capital assets), systemic risk is measured with a beta coefficient (β_i), which is usually calculated as follows (Barucci and Fontana 2017, p. 220):

$$ \beta_i = \frac{COV_{iM}}{{S_M}^2}, \tag{3} $$

where:

COV_{iM} is the covariance of the rate of return of the i-th company and market portfolio; and

${S_M}^2$ is the variance of the market portfolio.

The beta coefficient for this index equals 1 ($\beta_M = 1$). Securities that have the value of this coefficient higher than 1 are referred to as aggressive. During a bull market, the achieved profitability of such stocks is higher than that of the market index; during a bear market, a decline in the profitability of these stocks is greater than a decrease in the profitability of investment in the market index. Defensive stocks, i.e., the ones for which

the beta coefficient is within the range (0;1), respond to growths and fall on the market to a lesser degree than the market index. If security is characterized by a negative value of the beta coefficient, it means that the profitability rates it achieves are a reverse reaction to changes in the rates of return on the market index.

Starting from the risk measures relating to risk effects in the downside approach, it is possible to characterize sensitivity measures that account for sources of risk, especially the market risk (Rutkowska-Ziarko et al. 2019). Quantification of the risk-to-profit ratio in the context of semi-metrics is based on lower partial moments, which were defined in several articles independently (Hogan and Warren 1974; Bawa and Lindenberg 1977; Fishburn 1977).

Downside risk measures account for only a certain deviation on the left side of the distribution of the rate of return. The so-called assumed benchmark rate of return γ (target point) is a significant concept for the downside beta coefficient. Reaching the rate of return below the threshold rate is understood as the realization of downside risk. Considering the risk of an investment as a possibility of having a loss, the proper measure of the sensitivity of a given security is the downside beta coefficient. In theory, there are many variants of downside beta coefficients, distinguished in terms of their formulas and target points. Relationships between different downside beta coefficients have been presented, inter alia, by Markowski (2018). The formulas for downside beta coefficients used in this study are written as given by Galagedera (2007). Bawa and Lindenberg (1977) took assumed rate of return as a risk-free rate of return, and the downside beta, in terms of expected values, is expressed as follows:

$$\beta_i^{BL} = \frac{E\left\{\left(R_{it} - R_f\right) \cdot \min[\left(R_{Mt} - R_f\right), 0]\right\}}{E\left\{\min[\left(R_{Mt} - R_f\right), 0]^2\right\}}, \tag{4}$$

where:

R_{Mt} is the rate of return achieved in the time t by the market portfolio; and

R_f is the risk-free rate.

One of the options is to take the risk-free rate (the minimum required rate of return) as the point where there are no losses and no profits (Żebrowska-Suchodolska and Karpio 2020). A special case of the above coefficient (10) where the target rate is zero (Nurjannah et al. 2012) can be written as follows:

$$\beta_i^{BL}\left(R_f = 0\right) = \frac{E[R_{it} \cdot \min(R_{Mt};\, 0)]}{E[\min(R_{Mt};\, 0)]^2}, \tag{5}$$

In another approach, market players treat downside risk as deviations from the average rate of return of the market portfolio as opposed to a risk-free rate. This approach was proposed by Harlow and Rao (1989), who defined the downside beta coefficient in the following way:

$$\beta_i^{HR} = \frac{E\left[\left(R_{it} - \overline{R}_i\right) \cdot \min\left(R_{Mt} - \overline{R}_M; 0\right)\right]}{E\left[\min\left(R_{Mt} - \overline{R}_M\right); 0)\right]^2}, \tag{6}$$

where:

$\overline{R}_i$, $\overline{R}_M$ are, respectively, the average rates of return of the ith company and the market portfolio.

It is possible to find works indicating that downside betas are better measures of systematic risk than classical beta coefficients (Harlow and Rao 1989; Estrada 2002; Post and van Vliet 2006; Galagedera and Brooks 2007; Markowski 2015; Markowski 2019; Markowski 2020). Numerous studies on developed financial markets show that downside measures surpass classical risk measures in explaining rates of return on stocks of listed companies (Post and van Vliet 2006; Ang et al. 2006; Chen et al. 2009; Tsai et al. 2014). Estrada (2002, 2007) observed the occurrence of a premium for downside risk. Ali (2019)

demonstrated that downside risk is important in the evaluation of assets on the Chinese stock market. Thuy and Kim (2018) found that downside risk is priced in asset pricing in the Korean stock market and that investors require compensation for bearing downside risk. Ayub et al. (2020) replaced the classical beta with the downside beta in the six-factor model. They tested this model on the Pakistan Stock Exchange. They found that the risk–return relationship is stronger for the downside beta model.

2.2. Accounting Risk Measures

To measure accounting profitability, return on equity (ROE) and return on assets (ROA) were used. The advantage of the ROA and ROE ratios is the possibility to compare the effectiveness of the company's operation between entities of different sizes. The disadvantage of ROE is that it is not possible to calculate this ratio when an enterprise has a negative value of equity. On the other hand, the new emission can make the ROE lower just by increasing the equity. ROA is sensitive to changes in the level of assets. For example, selling the ground or building makes the ROA higher when the ability to generate profit is on the same level.

In this study, accounting risk measures were considered in the context of total risk and systematic risk. Symmetric and downside measures of dispersion were adopted as risk measures. The systematic risk measures are accounting beta coefficients.

There is a great variety of concepts presented in the literature of how information from financial reports can be employed to analyze systematic risk. A broad review of different notions can be found in articles by Amorim et al. (2012) and Latif and Shah (2021). The accounting-based risk (ABR) model is also worth mentioning. This model, which was proposed by Toms (2012), replaces the market rate of return that features in the conventional CAPM with the accounting rate of return. An interesting compilation of downside risk with accounting information is the concept of accounting-based downside risk (Huang et al. 2021).

An important accounting measure of risk is Z-score. This measure is a different concept of risk compared with accounting beta; accounting beta and market beta are measures of sensitivity, while Z-score indicates the possibility of insolvency of the bank. Z-score is dedicated especially to financial institutions. The Z-score compares ROA ratios extended by the ratio of equity to total assets with a standard deviation of ROA. The higher the Z-score for a bank, the lower the risk of bankruptcy (Martínez-Malvar and Baselga-Pascual 2020). It would be interesting to compare the Z-score with the accounting risk measures used in this article. Although some limitations make it inapplicable, all accounting measures used in this study have their market equivalents; for example, market beta and accounting beta. This study aimed to compare the market and accounting measures of risk. There is no market equivalent for a Z-score. Additionally, the analysis was performed using two approaches based on ROA and ROE. The Z-score is defined only for ROA. In another dimension of the research, measures were considered in the downside and symmetrical approaches. However, the Z-score exists only in the symmetrical approach.

The term 'accounting beta' is sometimes used in a broader context and is understood by some authors as a regression coefficient standing at any variable of an accounting character (Beaver et al. 1970; Amorim et al. 2012; Latif and Shah 2021). Variables from financial reports were also captured in multi-factor models by Fama and French (2018).

In this paper, the term 'accounting beta' is understood as a measure of sensitivity describing a change in the accounting profitability of a given company induced by a change in the accounting profitability of the appropriate sector or the market. According to Hill and Stone (1980), each beta coefficient calculated on the basis of a market price (β_i, β_i^{BL}, β_i^{HR}) can be named a market beta. By analogy, beta coefficients determined on the basis of accounting information are referred to as accounting betas. In our study, accounting betas were determined based on the rate of return on equity ($\beta(ROA)$, $\beta(ROE)$, $\beta_i^{BL}(ROA)$, $\beta_i^{BL}(ROE)$, $\beta_i^{HR}(ROA)$, $\beta_i^{HR}(ROE)$). Measures of total risk in the standard and downside

approaches were determined for these profitability ratios. The semi-deviation of the return on assets ($dS(ROA)$) was calculated as follows (Rutkowska-Ziarko 2015):

$$dS(ROA) = \sqrt{E\left\{\min[(ROA_{it} - \overline{ROA}_M), 0]^2\right\}}, \tag{7}$$

where:

ROA_{it} is the return on assets ratio of the ith company in time t; and

$\overline{ROA}_M$ is the long-term average rate of return on assets on the market (in the sector).

$$\overline{ROA}_M = \frac{1}{T}\sum_{t=1}^{T} ROA_{Mt}, \tag{8}$$

where:

ROA_{Mt} is the return on assets ratio on the market (in the sector) in time t; and

$\overline{ROA}_M$ is the long-term average rate of return on assets on the market (in the sector).

The profitability ratio of assets on the market (in the sector) in time t was determined as:

$$ROA_{Mt} = \sum_{i=1}^{N} ROA_{it} * \frac{MV_i}{\sum_{i=1}^{N} MV_i}, \tag{9}$$

where:

MV_i is the market value of the i-th company; and N is the number of companies, $i = 1, 2, \ldots, N$.

The semi-deviation for a given profitability ratio can be calculated in the same way.

The accounting beta coefficient for the profitability ratio of assets ($\beta_i(ROA)$) was derived from the formula:

$$\beta_i(ROA) = \frac{COV_{iM}(ROA)}{S_M(ROA)^2}, \tag{10}$$

where:

$COV_{iM}(ROA)$ is the covariance of the profitability ratio of the i-th company and the market portfolio (in practice, the index of the market or sector based on the given profitability ratio); and

$S_M(ROA)^2$ is the variance of the profitability ratio for the market (sector).

The notion of an accounting beta coefficient can be linked to the concept of a downside beta coefficient. The outcome is a downside risk measure, calculated based on accounting information, called a downside accounting beta (DAB) (Rutkowska-Ziarko and Pyke 2017).

By adapting Bawa and Lindberg's Formula (4) to the calculation of a downside accounting beta, risk-free rates should be replaced by another point of reference suitable for a given accounting measure. It could be a long-term average for a given profitability ratio in the sector or market. In addition, the market index for a given profitability ratio is needed. The basic solution is to use the average of this ratio (Hill and Stone 1980) and the easiest solution is to use the simple average of a given accounting variable (Kim and Ismail). This average can be weighted in a few ways. Beaver et al. (1970) suggested using the arithmetic mean or weighted average according to the market value. Another possibility is to build weights based on the volume of assets, equity, or volume of sales.

When using the formula developed by Bawa and Lindenberg for determination of an accounting beta for the profitability ratio of assets ($\beta_i^{BL}(ROA)$), the risk-free rate (R_f) was replaced by the average long-term return on assets for the market or sector ($\overline{ROA}_M$). This can be written as follows (Rutkowska-Ziarko 2020a; Rutkowska-Ziarko and Markowski 2020):

$$\beta_i^{BL}(ROA) = \frac{E\left\{(ROA_{it} - \overline{ROA}_M)\cdot\min[(ROA_{Mt} - \overline{ROA}_M), 0]\right\}}{E\left\{\min[(ROA_{Mt} - \overline{ROA}_M), 0]^2\right\}}. \tag{11}$$

Hallow and Rao's formula for the downside market beta was transformed in a similar manner to obtain the downside accounting beta $\beta_i^{HR}(ROA)$, as given below (Rutkowska-Ziarko 2020a):

$$\beta_i^{HR} = \frac{E\{(ROA_{it} - \overline{ROA}_i)\cdot\min[(ROA_{Mt} - \overline{ROA}_M), 0]\}}{E\left\{\min[(ROA_{Mt} - \overline{ROA}_M), 0]^2\right\}}, \tag{12}$$

where:

$$\overline{ROA}_i = \frac{1}{T}\sum_{t=1}^{T} ROA_{it}. \tag{13}$$

The downside accounting beta for any profitability ratio can be determined analogously.

The concept of a downside accounting beta was proposed in (Rutkowska-Ziarko and Pyke 2017) and later developed in subsequent papers (see Rutkowska-Ziarko 2020a).

Other concepts combining downside risk with accounting data can be found in earlier papers by other scholars (see Kim and Ismail 1998; Konchitchki et al. 2016). The most recent concept of accounting-based downside risk alongside an empirical analysis can be found in a paper authored by Huang et al. (2021).

Konchitchki et al. (2016) proposed a downside risk measure using accounting data and named it the accounting-based downside risk (ABDR). The measure of downside risk earnings is calculated using the ratio of the root of lower partial moments for ROA to the root of upper partial moments for ROA. In the cited work, the authors also used accounting beta coefficients for risk measured with variance. However, they did not use any sensitivity measures based on downside risk. Huang et al. (2021) employed the measure proposed by Konchitchki et al. (2016) to predict stock price falls on the Chinese market. They discovered a negative relation between ABDR and future stock price crash risk.

The model put forth by Kim and Ismail (1998) is closest to the concept of DAB. In the model suggested by Kim and Zumwalt (1979), the market rates of return were replaced by information from accounting reports. Earnings and cash flows were used as accounting variables. These researchers determined accounting betas separately for the up-market and down-market. Thus, they took advantage of the classical beta calculation, but divided accounting data time series into two subsets: up-market and down-market (see Kim and Ismail 1998; Kim and Zumwalt 1979), where 'up-market' refers to a situation when an increase in the market index determined for a given accounting variable (in this case, earnings or cash flow) reached a positive value, and 'down-market' refers to periods when this increase was negative. Betas are determined separately from the up-and-down markets.

3. Data

This research included some of the companies listed on the Frankfurt Stock Exchange, contained in the DAX, MDAX, and SDAX indices. Until 19 September 2021, the DAX was composed of the 30 largest German companies in terms of book value and market capitalization, and since 20 September 2021, it has encompassed 40 companies. The subsequent 60 companies arranged in terms of size compose the MDAX index, called the index of medium companies. The following 70 companies, referred to as 'small caps', are included in the SDAX index. In total and until 19 September 2021, the three indices accounted for 160 of the biggest companies listed on the Frankfurt Stock Exchange. An earlier study on the WSE demonstrated that the relationship between profitability ratios versus mean rates of return and market and accounting betas are stronger among large and medium companies than among small ones. To verify whether the same relationships appear on the FSE, the three mentioned indices were analyzed separately.

The study covered the years 2010–2019. The choice of this research period was a compromise between the number of companies for which stock exchange data and financial data were available and the duration of the time series. Eventually, the study included 18 companies from the DAX index, 31 from the MDAX index, and 37 from the SDAX

index. The analyzed companies are referred to in what follows as 'large' (DAX), 'medium' (MDAX), and 'small' (SDAX). Furthermore, the period selected for the study intentionally excludes the crises that struck the financial markets in 2008 and 2020. Raw data consisted of daily closing prices and quarterly ROA and ROE profitability ratios. Based on daily quotations, quarterly simple rates of return were determined according to the rollover method, having assumed that an investment could be made on any trading day. The research data are panel data, where research objects are individual companies listed on the FSE, while observations of the analyzed variables are time series. All data used in the study were obtained from the Thomson Reuters Refinitiv Eikon database.

4. Empirical Results and Discussion

The analyses proceeded through two steps. Firstly, the measures of profitability and risk were calculated based on time series. Secondly, using cross-sectional data, correlations between variables were found. For each of the analyzed companies, market betas and accounting betas were determined according to two approaches: risk measures by standard deviation and downside risk. Downside betas were determined in two ways, according to Bawa and Lindenberg (1977) and according to Harlow and Rao (1989). DABs were determined based on the modification of these approaches for profitability ratios (Rutkowska-Ziarko 2020a). The research results presented in this paper mainly refer to the same risk metrics previously determined for the Warsaw Stock Exchange (WSE), which involved companies from the WIG30 (corresponding to DAX), WIG40 (corresponding to MDAX), and WIG80 (corresponding to SDAX) indices. However, the analyses concerning the WSE covered the years 2010–2017 (Rutkowska-Ziarko 2020a), while those of the FSE included data from 2010 to 2019. The downside accounting beta coefficients were first defined in (Rutkowska-Ziarko and Pyke 2017).

4.1. Descriptive Statistics of Profitability and Risk Measures

Tables 1–3 present descriptive statistics of the analyzed profitability and risk measures for companies included in the DAX, MDAX, and SDAX indices. Average quarterly rates of return ($\overline{R}$) were the lowest for large companies. This was true for mean, median, and minimum and maximum values. Meanwhile, the total risk of these companies measured by the variance in rates of return in both the symmetrical and downside approaches was the lowest. The mean and median of the conventional beta coefficient (β) for companies included in the DAX index are less than 1, being higher for companies in the MDAX and SDAX indices. None of the analyzed companies displayed a negative value of this coefficient. Considering β^{BL} and β^{HR}, no distinct differences were discernible between companies in the different indices.

In respect of ROA, the most profitable on average were the SDAX companies, while ROE was the highest for companies from the MDAX index. Large companies were less differentiated in terms of the level of profitability ratios compared with medium and small companies. Meanwhile, the distribution of ROA and ROE for companies from the DAX index was left-skewed, while that for companies from the MDAX and SDAX indices was right-skewed. Mean rates of return for companies listed on the DAX index were on a level similar to the one previously recorded on the Warsaw Stock Exchange. However, the MDAX and SDAX companies were more profitable for investors. For companies listed on the WSE, the average value of the rate of return on equity was close to the average quarterly rate of return (Rutkowska-Ziarko 2020a). As for companies listed on the FSE, a similar dependence was observed for the MDAX companies. The average rates of return for the DAX companies were lower than the average ROE. For the SDAX-indexed companies, the average rate of return in the long term was higher than the average rate of return on equity in the long term.

Table 1. Descriptive statistics of profitability and risk measures for companies included in the DAX index.

Variable	Mean	Median	Min	Max	Std. Dev.	Skewness
$\overline{R}$	0.028	0.029	−0.029	0.057	0.019	−1.379
S	0.120	0.115	0.091	0.161	0.024	0.534
dS	0.069	0.062	0.047	0.123	0.020	1.220
β	0.973	0.964	0.487	1.407	0.311	−0.081
β^{BL}	0.884	1.000	0.075	1.782	0.450	−0.036
β^{HR}	0.939	1.004	0.408	1.332	0.313	−0.293
$\overline{ROA}$	0.013	0.014	0.000	0.025	0.006	−0.233
$S(ROA)$	0.789	0.759	0.092	1.974	0.488	0.770
$dS(ROA)$	0.543	0.471	0.079	1.126	0.356	0.547
$\beta(ROA)$	0.731	0.693	−1.488	2.315	0.828	−0.647
$\beta^{BL}(ROA)$	1.113	1.304	−2.601	5.171	2.326	0.123
$\beta^{HR}(ROA)$	0.840	0.615	−2.219	2.643	1.119	−0.682
$\overline{ROE}$	0.034	0.037	−0.001	0.050	0.012	−1.638
$S(ROE)$	2.298	2.122	0.482	4.967	1.257	0.518
$dS(ROE)$	1.612	1.380	0.326	4.441	1.033	1.196
$\beta(ROE)$	0.796	0.800	−2.162	2.403	1.019	−1.171
$\beta^{BL}(ROE)$	1.144	0.665	−2.443	6.609	2.277	1.070
$\beta^{HR}(ROE)$	0.889	0.729	−2.636	3.000	1.322	−0.650

Source: own research. Notes: $\overline{R}$, β, β^{HR}, β^{BL}, $S, dS, \overline{ROA}, \overline{ROE}, \beta(ROA), \beta(ROE), \beta^{HR}(ROA)$, $\beta^{HR}(ROE)$,$\beta^{BL}(ROA), \beta^{BL}(ROE), S(ROA), S(ROE), dS(ROA), dS(ROE)$, denote the average rate of return, beta coefficient, Harlow and Rao downside beta, Bawa and Lindenberg downside beta, standard deviation of the rate of return, semi-deviation of the rate of return, average value of profitability ratio return on assets, average value of profitability ratio return on equity, accounting beta for ROA, accounting beta for ROE, Harlow and Rao downside accounting beta for ROA, Harlow and Rao downside accounting beta for ROE, Bawa and Lindenberg downside accounting beta for ROA, Bawa and Lindenberg downside accounting beta for ROE, standard deviation of ROA, semi-deviation of ROA, standard deviation of ROE, and semi-deviation of ROE, respectively.

Table 2. Descriptive statistics of profitability and risk measures for companies included in the MDAX index.

Variable	Mean	Median	Min	Max	Std. Dev.	Skewness
$\overline{R}$	0.037	0.031	−0.026	0.106	0.031	0.318
S	0.145	0.144	0.088	0.272	0.037	1.183
dS	0.081	0.078	0.038	0.160	0.031	0.788
β	1.029	1.037	0.549	1.635	0.282	0.280
β^{BL}	1.057	0.978	0.164	2.106	0.540	0.495
β^{HR}	0.929	0.873	0.264	2.037	0.472	1.013
$\overline{ROA}$	0.012	0.009	−0.012	0.072	0.015	2.299
$S(ROA)$	1.185	1.071	0.052	4.545	0.976	1.963
$dS(ROA)$	0.869	0.642	0.028	3.441	0.749	1.766
$\beta(ROA)$	0.741	0.374	−0.295	4.244	1.005	1.818
$\beta^{BL}(ROA)$	0.642	0.619	−7.080	7.394	2.667	0.041
$\beta^{HR}(ROA)$	0.731	0.194	−0.850	5.748	1.462	1.997
$\overline{ROE}$	0.035	0.035	−0.037	0.011	0.031	0.361
$S(ROE)$	4.143	2.867	0.479	14.967	3.620	1.637
$dS(ROE)$	3.084	1.966	0.347	13.270	3.170	2.007
$\beta(ROE)$	0.244	0.041	−0.157	3.055	0.648	3.264
$\beta^{BL}(ROE)$	0.284	0.103	−0.667	3.035	0.748	2.192
$\beta^{HR}(ROE)$	0.257	0.028	−0.270	3.039	0.678	2.907

Source: own research.

Table 3. Descriptive statistics of profitability and risk measures for companies included in the SDAX index.

Variable	Mean	Median	Min	Max	Std. Dev.	Skewness
$\overline{R}$	0.035	0.034	−0.018	0.073	0.026	−0.262
S	0.162	0.162	0.070	0.270	0.053	0.343
dS	0.087	0.084	0.044	0.141	0.027	0.372
β	1.013	1.018	0.195	1.754	0.376	0.043
β^{BL}	0.941	0.889	−0.338	2.108	0.591	0.020
β^{HR}	0.836	0.747	−0.272	1.633	0.477	−0.088
$\overline{ROA}$	0.015	0.013	−0.002	0.070	0.014	2.064
$S(ROA)$	1.747	1.419	0.245	6.762	1.349	1.720
$dS(ROA)$	1.149	0.829	0.181	3.429	0.801	0.927
$\beta(ROA)$	0.369	0.135	−2.413	7.944	1.652	3.102
$\beta^{BL}(ROA)$	1.398	1.319	−6.594	6.766	2.307	−0.812
$\beta^{HR}(ROA)$	0.600	0.516	−2.122	6.007	1.331	1.723
$\overline{ROE}$	0.029	0.028	−0.006	0.110	0.022	1.239
$S(ROE)$	4.140	3.416	0.527	13.888	2.989	1.252
$dS(ROE)$	2.816	2.046	0.373	7.029	2.014	0.730
$\beta(ROE)$	0.336	0.071	−2.400	6.994	1.715	2.885
$\beta^{BL}(ROE)$	1.364	0.861	−5.943	6.905	2.516	−0.007
$\beta^{HR}(ROE)$	0.603	0.558	−3.103	6.472	1.598	1.148

Source: own research.

Accounting beta coefficients for the DAX and SDAX companies achieve the highest values for β^{BL} and are shaped similarly for both ROE and ROA. Approximately the same situation was observed in the case of companies listed on the WSE (Rutkowska-Ziarko 2020a). For the companies listed on the MDAX index, sensitivity measures calculated based on ROA were much higher than the ones based on ROE, in both the classical and downside approach. Comparison of values of accounting beta coefficients for the FSE indicates that they tend to be much higher than those calculated for the WSE (Rutkowska-Ziarko 2020a).

4.2. Pearson's Correlation Coefficient between Profitability and Risk Measures

The second stage of the study aimed to explore the relationship between the previously determined variables according to the division of companies included in the three stock exchange indices. In particular, profitability and risk measures based on market rates of return were compared to ones based on accounting profitability measures (Table 4). Next, classical measures of sensitivity and total risk were compared to their downside counterparts (Table 5). In addition, correlations between accounting risk and profitability measures were investigated for the two analyzed profitability indicators (ROE and ROA) (Table 6).

The Pearson's linear correlation coefficients between market and accounting profitability and risk measures are specified in Table 4. Three statistical significance levels were taken into account in all the tables, namely 10%, 5%, and 1%. Critical values in a two-tailed test for adequate numbers are given under Table 4.

Table 4. Correlations between market and accounting measures of profitability and risk.

Variables		Companies Belonging to a Given Frankfurt Stock Exchange Index		
		DAX	**MDAX**	**SDAX**
$\overline{R}$	$\overline{ROA}$	0.658 ***	0.307 *	0.314 *
$\overline{R}$	$\overline{ROE}$	0.684 ***	0.335 *	0.405 **
β	$\beta(ROA)$	0.401 *	0.020	−0.132
β	$\beta(ROE)$	0.550 **	0.116	−0.054
β^{HR}	$\beta^{HR}(ROA)$	0.512 **	0.191	−0.072
β^{HR}	$\beta^{HR}(ROE)$	0.548 **	0.197	0.043
β^{BL}	$\beta^{BL}(ROA)$	0.604 ***	0.372 **	0.306 *
β^{BL}	$\beta^{BL}(ROE)$	0.525 **	0.163	0.326 **
S	$S(ROA)$	−0.133	0.477 ***	0.059
S	$S(ROE)$	0.105	0.165	0.175
dS	$dS(ROA)$	−0.304	0.450 **	0.024
dS	$dS(ROE)$	0.070	0.210	0.241
Sample size		18	31	37

Source: own research. Notes: *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. The critical value of the Pearson's correlation coefficient for the significance level of 10%, 5%, and 1% for the (a) 18, (b) 31, and (c) 37 companies is, respectively: (a) 0.4000, 0.4683, and 0.5897, (b) 0.3009, 0.3550, and 0.4556, and (c) 0.2746, 0.3246, and 0.4182.

Table 5. Correlations between risk measures in the variance and downside approaches.

Variables		Companies Belonging to a Given Frankfurt Stock Exchange Index		
		DAX	**MDAX**	**SDAX**
β	β^{HR}	0.990 ***	0.633 ***	0.795 ***
β	β^{BL}	0.916 ***	0.725 ***	0.869 ***
$\beta(ROA)$	$\beta^{HR}(ROA)$	0.852 ***	0.936 ***	0.392 **
$\beta(ROA)$	$\beta^{BL}(ROA)$	0.169	0.514 ***	0.901 ***
$\beta(ROE)$	$\beta^{HR}(ROE)$	0.937 ***	0.990 ***	0.828 ***
$\beta(ROE)$	$\beta^{BL}(ROE)$	0.749 ***	0.950 ***	0.404 **
S	dS	0.884 ***	0.833 ***	0.758 ***
$S(ROA)$	$dS(ROA)$	0.918 ***	0.976 ***	0.900 ***
$S(ROE)$	$dS(ROE)$	0.922 ***	0.982 ***	0.847 ***
Sample size		18	31	37

Source: own research. Notes: *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. The critical value of the Pearson's correlation coefficient for the significance level of 10%, 5%, and 1% for the (a) 18, (b) 31, and (c) 37 companies is, respectively: (a) 0.4000, 0.4683, and 0.5897, (b) 0.3009, 0.3550, and 0.4556, and (c) 0.2746, 0.3246, and 0.4182.

Table 6. Correlations between measures of profitability and risk based on ROE and ROA.

Variables		Companies Belonging to a Given Frankfurt Stock Exchange Index		
		DAX	**MDAX**	**SDAX**
$\overline{ROA}$	$\overline{ROE}$	0.771 ***	0.770 ***	0.939 ***
$\beta(ROA)$	$\beta(ROE)$	0.722 ***	0.584 ***	0.967 ***
$\beta^{HR}(ROA)$	$\beta^{HR}(ROE)$	0.776 ***	0.611 ***	0.952 ***
$\beta^{BL}(ROA)$	$\beta^{BL}(ROE)$	0.884 ***	0.663 ***	0.951 ***
$S(ROA)$	$S(ROE)$	0.763 ***	0.399 **	0.872 ***
$dS(ROA)$	$dS(ROE)$	0.789 ***	0.449 ***	0.787 ***
Sample size		18	31	37

Source: own research. Notes: *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively. The critical value of the Pearson's correlation coefficient for the significance level of 10%, 5%, and 1% for the (a) 18, (b) 31, and (c) 37 companies is, respectively: (a) 0.4000, 0.4683, and 0.5897, (b) 0.3009, 0.3550, and 0.4556, and (c) 0.2746, 0.3246, and 0.4182.

For companies listed on the DAX, MDAX, and SDAX indices, there is a positive and statistically significant correlation between the mean value of profitability metrics (ROA and ROE) and rates of return on investing in these companies' stocks. This attests to the results of earlier studies on Polish listed companies (Rutkowska-Ziarko 2015, 2020a, 2020b; Rutkowska-Ziarko and Pyke 2018). This correlation is on a moderate level and is distinctly higher for the profitability measure of equity than the profitability measure of assets. A similar superiority of ROE over ROA in explaining how average rates of return on the WSE are shaped has been observed for construction (Rutkowska-Ziarko and Pyke 2018) and IT companies (Rutkowska-Ziarko 2020b), as well as for WIG-20, WIG-40, and WIG-80 companies (Rutkowska-Ziarko 2020a). On the FSE, these correlations were stronger for the companies included in the DAX index than the ones in the MDAX and SDAX indices. As for the WSE-listed companies, it was noticed that the relationship between returns for investors and profitability ratio is stronger for companies with higher market capitalization than for ones with lower market capitalization.

A positive and invariably statistically significant correlation was observed for all DAX-indexed companies between all types of market betas and the corresponding accounting betas. Likewise, these correlations were positive for all MDAX-indexed companies, but statistically significant only in the case of $\beta^{BL}(ROA)$. Regarding companies included in the SDAX index, negative correlation coefficients between market betas and accounting betas appeared on three occasions, but the results were not statistically significant. As for the SDAX index, a positive and statistically significant correlation between market and accounting beta coefficients appeared only in the case of accounting betas determined from the formula by Bawa and Lindenberg. It can be observed that for the FSE-listed companies, regardless of which index they belong to, the downside measures of sensitivity depend more strongly on downside beta coefficients determined according to the formula developed by Bawa and Lindenberg.

As regards companies listed on the WSE (Rutkowska-Ziarko 2020a), a positive dependence was determined between accounting and market total risk measures although it was not always statistically significant. The correlation coefficients determined for the FSE-listed companies were either positive or negative; however, overall, they were not significant statistically. It was only in the case of MDAX-indexed companies and ROA that a statistically significant correlation between variability of rates of return and variability of profitability ratios was determined.

Table 5 shows Pearson's linear correlation coefficients between downside and classical risk measures. There is a positive relationship, often a very strong one, between symmetrical risk measures and their downside counterparts. This holds true for both sensitivity measures and total risk measures. This phenomenon appears in every case of risk measures derived from rates of return and for most risk measures calculated on the basis of profitability ratios. An exception to this rule is the lack of a linear correlation between $\beta(ROA)$ and $\beta^{BL}(ROA)$. It is worth recalling that there was a positive and statistically significant correlation between (ROA) and β^{BL} in the case of companies that belonged to any of the three analyzed FSE indices. Thus, downside measures do not always replicate the information provided by classical risk measures. It is, therefore, justifiable to assume that downside risk measures are a valuable addition to their symmetrical counterparts.

This study took into account two principal profitability measures that refer the earned profit to the value of assets and of equity. The question then arises as to what extent these two profitability measures provide similar information to stakeholders.

Table 6 shows correlations between accounting risk measures and profitability measures for the two profitability ratios analyzed in this study, i.e., ROA and ROE. In all cases, the Pearson's correlation coefficients are positive and statistically significant at the level of 1%. This brings us to an obvious conclusion that the indicator of the profitability of assets and the indicator of the profitability of equity provide a similar insight into the profitability and risk of IT companies listed on a stock exchange. In all cases, the Pearson's correlation coefficients are positive and statistically significant. The strongest linear correlation

between accounting measures of profitability and risk for ROA and ROE appears for the companies listed on the SDAX index. A similar situation was observed for companies listed on the WSE. Correlations between accounting profitability and risk measures were higher for the sWIG80 companies than for the WIG20 and mWIG40 ones (Rutkowska-Ziarko 2020a).

The empirical study enables us to verify the working hypotheses set out in this work.

Hypothesis 1 (H1), which maintains that companies with higher ROA and ROE profitability ratios, in the long run, achieve higher rates of return on a stock exchange, was verified for companies from all the analyzed FSE indices (see Table 4). This means that an increase in the market value of a company's equity in the long term is a consequence of the company's ability to generate profits.

Hypothesis 2 (H2), which states that total risk is positively correlated with the variance (semi-variance) of accounting profitability, cannot be confirmed or refuted unequivocally. In most cases, there was a positive correlation between total risk measured based on rates of return and in profitability ratios, but it was statistically significant only for companies from the MDAX index and variance measured with standard deviation (see Table 4).

Hypothesis 3 (H3), stating that market beta coefficients are correlated with accounting beta coefficients, was fully confirmed for companies that belong to the DAX index. For companies listed on the MDAX and SDAX indices, it can only be verified for downside betas determined from the formula developed by Bawa and Lindenberg. Although the correlations between market and accounting betas determined for the MDAX-indexed companies were always positive, they were not always statistically significant (see Table 4). Thus, it can be assumed that the relationship between accounting and market betas is more evident for large companies than for smaller ones. Additionally, it seems that the formula proposed by Bawa and Lindenberg is the most suitable one of all analyzed methods to determine systematic risk.

Hypothesis 4 (H4), in which we assumed that symmetrical and downside risk measures are positively correlated with each other, was confirmed for companies listed on any of the analyzed Frankfurt Stock Exchange indices. There was an exception, however, when DAX-indexed companies were analyzed for their $\beta(ROA)$ and $\beta^{BL}(ROA)$, in which the Pearson's linear correlation coefficient was 0.169, being statistically insignificant (see Table 5). This means that the downside measures may provide a different view of the enterprise's risk as compared with symmetric measures.

Hypothesis 5 (H5), which presumed that ROA and ROE profitability ratios, as well as risk measures built on these rates, are positively correlated with one another, was confirmed unequivocally. Nearly all correlation coefficients were significant at 1%, and in just one case—at the 5% significance level (see Table 6). This means that ROA and ROE are equally useful to stock exchange investors and other stakeholders in analyses of profitability and risk.

5. Conclusions, Future Research Directions, and Limitations

This study, based on a case study of the Frankfurt Stock Exchange, enabled us to observe the relationships that occur there between market and accounting measures of profitability and risk.

For all the analyzed companies, there is a positive and statistically significant correlation between the mean value of the profitability metrics (ROA and ROE) and rates of return on investment in these companies' stocks. This correlation is stronger for the rate of return on equity than for the rate of return on assets. Furthermore, correlation coefficients are higher for companies indexed the DAX than for ones indexed in the MDAX or SDAX.

The DAX-indexed companies were observed to present a positive and, in every case, statistically significant correlation between all types of market betas and the corresponding accounting betas. As with the MDAX index, these correlations were positive, but statistical significance was determined only for $\beta^{BL}(ROA)$. As for the SDAX index, there was a positive and statistically significant correlation between market and accounting beta

coefficients only in the case of beta coefficients calculated from Bawa and Lindenberg's formula.

However, the variability of profitability ratios did not always translate into the variability of the rates of return.

It was demonstrated that downside and symmetrical risk measures present mutual positive correlations although the strength of these correlations is sometimes very weak.

In conclusion, the Frankfurt Stock Exchange during the time period analyzed in this study displayed the following relationships:

- listed companies with higher profitability ratios achieve higher average rates of return in the long term;
- market beta coefficients are correlated with accounting beta coefficients, with the correlations being more distinctly demonstrated in the case of large companies, and with downside risk measures determined according to Bawa and Lindenberg's method;
- symmetrical and downside risk measures are mutually positively correlated; and
- the profitability metrics ROA and ROE as well as the risk measures built on them are positively correlated.

In the light of the findings presented above, it appears that downside risk measures, including downside accounting beta coefficients, can be useful risk measures for different groups of stakeholders active on the Frankfurt Stock Exchange.

The main limitation of applying accounting risk measures is the availability of accounting data, and the other one is the fact that financial reports are not published frequently enough. Data of at least quarterly frequency are best for the determination of accounting betas. Another problem, of a business and econometric nature, is taking into account the seasonality of the financial results of a company or industry. The question will arise as to whether such seasonal variability should be treated as a risk-increasing phenomenon or whether the assumption should be made that the long-term seasonality is predictable, and therefore the deviations should be calculated not from the average values but from the averages in a given season (e.g., quarter). The search for a solution to this problem marks one of the directions of future research. Another important issue seems to be the application of these accounting measures to the valuation of the risk and cost of capital of unlisted companies, e.g., companies preparing for the first issue of shares.

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