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THE RELATIONSHIP BETWEEN RISK AND THE COST OF EQUITY IN THE CONTEXT OF SENSITIVITY OF BETA COEFFICIENT – COMPARATIVE STUDY FOR THE LARGEST COMPANIES LISTED ON WARSAW AND FRANKFURT STOCK EXCHANGE

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Purpose: The main objective of the article is to examine the stability of the beta parameter for the largest companies listed on the Warsaw and Frankfurt Stock Exchanges.
Design/methodology/approach: The study is a comparative analysis. The hypothesis is subjected to statistical verification, stating that beta parameters are stable. The estimation of beta parameters is carried out using the least squares method and a simple rate of return in the period 2005-2021, while the verification of the stability hypothesis is carried out based on Jarque-Bera test, Breusch-Pagan test, and t-Student test.
Findings: The presented research results indicate that for companies listed on the WSE, along with the extension of the period of measuring the frequency of rates of return, the beta parameter is characterized by a lower level of sensitivity. This is probably due to the greater amplitude of fluctuations in the rate of return with increasing the frequency of measurement.
Practical implications: In the company's finances, the beta parameter plays a key role in measuring investment risk. Since its introduction, it has been subjected to numerous empirical studies and analyses in both developing and highly developed markets. A positive phenomenon is the insensitivity of the beta parameter to the change in the rate of return of the stock market index for the monthly measurement of the rate of return in the case of companies with the largest capitalization on the Polish stock market.
Originality/value: In Poland, research is carried out on the properties of the beta parameter, however, there is no research on its comparability to the economies of countries where the capital market is highly developed.
Keywords: beta stability, correlation, coefficients, rate of return, interval, risk.
Category of the paper: Research paper.
JEL Classification Codes: G10, G15, C58.

Introduction

The source of the word "risk" comes from Italian risicare, which in translation into English means: to dare. The Greek variation of the word, rhize, it means circumnavigating the cape, that is, an act of courage. In turn, the Latin word risicum means the probability of success or failure (Dębski, 2018, p. 57).

Before moving on to the essence and significance of investment risk, the author of the research decided to present the historical outline of the risk phenomenon. This will allow for a better understanding the concept of risk, which is interpreted differently in different fields of science. According to some authors, it is almost impossible to create a single universal definition (Karmańska, 2014, p. 44).

Risk is related to fundamental aspects of mathematics, psychology, statistics, and history. Risk research began in the renaissance. The mathematical core of the risk concept was the question of the French mathematician Pascal, about the division of the pool in an unfinished game of chance, when one of the players is one move ahead of the rival. This is how the concept of probability was introduced into modern risk theory. The emergence of new ideas in the field of risk control techniques somehow stimulated the pace of development of society (Bernstein, 1997, pp. 87-122).

In the eighteenth century, Bernoulli noted that the repetition of events is established by certain regularities occurring in nature. At that time, the law of large numbers began to be applied, which, according to Bernoulli's law, states that: "With a probability arbitrarily close to 1, it can be expected that with a sufficiently large number of attempts, the frequency of a given random event will be little different from the probability of its occurrence" (Dekking et al., 2005, p. 41). A few years later, the concept of normal distribution, the concept of standard deviation, was introduced, which became the basis of the law of averages used in quantitative risk study techniques. One hundred years later, Bayes perfected his research in the field of statistics. Bayes' theorem tells us how we should assess the probability of an event occurring and how to modify it, depending on the actual course of events. In the nineteenth century. Galton described the law of regression relative to the mean, and in the twentieth century. Markowitz explained why putting all the eggs in one basket is excessively risky (Bernstein, 1997, p. 187).

In the literature of the risk subject, we can find numerous attempts to distinguish between risk and uncertainty and to determine the relationship that occurs between them. Uncertainty in the information aspect concerns the discrepancy between the information necessary to solve the task and the information possessed. It is a situation that somehow forces you to decide without full knowledge of the reality in which it will be implemented. In the financial research, we can notice a similar understanding of the concept of risk. It is believed that there is a situation in which at least one of the factors explaining it is not known, but the probability of its occurrence

is known. In the analysis of equity market risk, we can determine the following relationship between risk and uncertainty:

- the risk relates to recurring events, while the uncertainty of a specific phenomenon is used when it is not possible to apply probability calculus,
- the difference between risk and uncertainty relates to the state of knowledge (Nahotko, 2001, pp. 13-22).

One of the first economic concepts of risk was proposed by A. Willett. Based on philosophical determinism, which denies the randomness of the processes of the external world, he decided that one should speak of an illusion of randomness or impression – which results from the imperfection of knowledge about the laws governing reality (Willet, 1901, p. 11).

The second significant concept of risk was measurable and non-measurable uncertainty, proposed by F.H. Knight (1921, p. 56). According to the presented argumentation, we deal with risk when we can determine the future states of the world and their probability distribution. Causal concepts of risk mean that an event can be mapped to a probability distribution. In this sense, risk is the possibility of states other than expected, which can be predicted and described using probability calculus (Bieda, 2013, pp. 367-378).

The definitions of risk presented above indicate that investing, and thus the rate of return on investment required by the investor, is one of the forms of activity on the financial market, which is burdened with a high level of uncertainty. This type of risk is defined as investment risk, manifested in the cost of capital reflected in the expected rate of return required by the market. In economic theory, it is assumed that risk can be reduced by acquiring new information. In other words, it requires knowing as many future states as possible and the probabilities of their occurrence (Francis, 2000, p. 100).

Another concept of risk that should be analyzed from the point of view of classical or neoclassical economic theory is the behavioral concept of risk (Solek, 2010, pp. 21-34). It is based on the following assumptions (Simon, 1995, p. 99-118):

- entities act in a rational manner,
- access to information is full and unrestricted,
- entities maximize profit or expected utility,
- entities act in their own interest and have consistent preferences.

From a practical point of view, it seems that the assumption about the rationality of economic participants of the market who have full information has nothing to do with reality. There are many examples of investor behavior that are irrational. An example would be equity risk premium, in other words the average observed rates of return on shares are higher than the rates of return on treasury debt securities, even if differences in the level of risk are considered (Mehr, 2003, pp. 54-69).

The relationship between the level of risk and the cost of capital is reflected in the risk-free rate of return and the risk premium. As the market assigns a greater degree of risk to a given investment, the required rate of return increases, which in turn reduces the current value of the investment. This bonus is due to uncertainty about the expected returns (Pratt et al., 2000, pp. 121-140). According to the author of the research, the market hates uncertainty in terms of expected cash flows, and thus demands a high price to accept this uncertainty.

The subject of this article is to estimate the investment risk and present the possibilities of its comprehensive analysis, while the author of subjected research would like to mainly refer to the systematic risk of shares. The primary measure of market risk of a stock is the beta coefficient. It is a parameter representing the market factor in the single-indicator Sharpe model, which is most often a specific stock index. The main objective of the article is to examine the stability of the beta parameter for the largest companies listed on the Warsaw and Frankfurt Stock Exchanges.

Literature review

Since the introduction of the single-indicator Sharpe model into the literature, empirical research began in countries with a developed capital market, the aim of which was to understand the statistical properties of share returns through appropriate estimation of the Sharpe model, especially assuming that the distributions of rates of return or the stochastic structure of the model are not met. These studies boiled down to trying to answer the following questions:

- Which stock index to choose?
- What should be the length of the analysis?
- What should be the interval of measuring the rate of return? (Dębski et al., 2018, pp. 270- 286).

The most general market portfolio was proposed by R. Roll (1977, pp. 129-176), who proposed that portfolio should contain all the assets available on the market. As T. Miziołek (2013, pp. 33-39) rightly pointed out, such index does not exist in practice, because it is not known what its structure would be. In empirical research, various indices are used, both profitable, i.e., covering changes in the prices of all companies listed on a given stock market along with the income of financial instruments listed on them, as well as price indices, covering only changes in the prices of shares of companies included in the portfolio of a given index. In general, it can be concluded that the choice of index depends on the purpose of the study. Examples of stock market indices used in empirical research are the indices of the New York and London Stock Exchanges as well as the indices of other European stock exchanges (Tarczyński et al., 2014, pp. 122-139).

A very important issue when estimating the beta parameter is to define the length of the estimation test. According to the author of the research, the issue of the sample length should be considered in two aspects:

1. Comparability of financial markets.
2. Comparability of data. Here it is necessary to answer the question whether the observations from the beginning and from the end of the sample are comparable.

There are a lot of empirical studies around the world of finance literature in which 10-year and longer research trials were used (Tarczyński et al., 2014, p. 88). T. Lin, Y.H. Chen and C.G. Boot (1992, pp. 517-541) in a study of the spot rates of five currencies: the British pound, the German mark, the Japanese yen, the Canadian dollar and the Swiss franc found that the beta of the term premium was considered purely random for all the cases examined. No relationship was found between the length of the time horizon and the number of cases supporting the randomness hypothesis. A. Odabasi (2003, pp. 15-32) analyzed the stability of the beta coefficient during the period 1992-1999 on the Istanbul Stock Exchange. The sample was divided according to research periods from quarters to four years. The results of the study showed that the beta coefficients estimated for the two-year period were the most stable. On the other hand, research conducted by D. Witkowska (2008, pp. 143-154) for companies listed on the Warsaw Stock Exchange based on samples of various lengths did not allow to answer the question whether the selection of an appropriate estimation sample should be based on a large number of data that contain averaged information from all observations, which may lead to wrong investment decisions. In turn, Y. Ye (2017, pp. 177-187) based on the analysis of the stability of the beta parameter on the stock exchange in China states that with the increase in the statistical sample time, the beta becomes less stable.

Another problem to solve is to determine the time interval of measurement of the rate of return on shares. In empirical research, very different intervals are used. In their work, S. Wright, R. Mason, and E. Miles used quarterly measurements of the rate of return (2003).

In turn, J. Brzeszczyński, J. Gajdka and T. Schabek (2011, pp. 28-49) used periods of 1, 5, 10 and 21 days. P. Daves, M. Ehrhardt, and R. Kunkle (2000, pp. 7-13) suggest that the daily rate of return should be used to estimate the beta parameter of an action, as the accuracy of the beta estimation increases. C.F. Mwahunga (2013) in his research conducted on a sample of companies listed on the Nairobi Stock Exchange states that the rates of return on shares were positive and increased as the daily to annual time interval increased, which shows that the average rate of return over a longer period is more appropriate. On the other hand, C.H.S. Fun (2006), based on the analysis of 40 companies (a portfolio of companies selected using the perfect analysis tool) in the period 2000-2006, conclude that daily rates of return give the most precise results in the context of the smallest estimated beta error. Other results of studies on the impact of the rate of return on risk measurement intervals are presented by M. Momcilovic, S. Begovic, S. Tomasevic (2014, pp. 168-171). These authors surveyed 12 companies listed on the Belgrade Stock Exchange between January 2011 and December 2013. Based on the

conducted research, they conclude that there are no significant differences in the beta coefficient values between the daily, weekly and monthly rates of return.

Studies on the impact of the frequency of measuring the rate of return on shares on the beta parameter were also conducted in Poland. Extensive research in this area was carried out by

E. Feder-Sempach (2011, pp. 156-211). The results of the research on the example of companies from the WIG 20 index did not allow to give a clear answer at what interval should be carried out when analyzing the Polish market. The author points out that the choice of the time interval should be economically justified e.g., by the phase of the business cycle in the domestic economy or the phase of development of the capital market. Another important study is an article written by W. Dębski, E. Feder-Sempach and B. Świderski (2014, pp. 270-286), whose authors conducted an empirical analysis of the 33 largest entities listed on the Warsaw Stock Exchange in the period 2005-2012. Studies show a greater convergence between beta parameter estimates on daily and weekly data than on monthly data.

Research sample and study methodology

The analysis of the invariance of the beta parameter, also known as the sensitivity analysis, was carried out for companies listed on WIG 20 and DAX in the period 2005-2021 (based on the list of entities listed on WIG 20 and DAX at the end of September 2022). The conducted research is based on a simple rate of return on the shares of a given company measured with a daily, weekly, and monthly frequency – the verification concerns the impact of the change in the model specification on the beta parameter:

$$Rt = (Pt - Pt\text{-}1)/Pt\text{-}1 \quad (1)$$

where:

Rt – simple rate of return,

Pt – share price in the period t (Dębski et al., 2018, p. 43).

The primary explanatory variable in the estimated Sharpe model is the rate of return on the relevant stock index. For companies listed on the Warsaw Stock Exchange, it is the rate of return from the WIG 20 index, in the case of the German Stock Exchange in Frankfurt it is the DAX index. In the conducted research, the author changed the specification of the model, consisting in changing the rate of return from the WIG 20 index to the rate of return from the WIG index, and change the rate of return from the DAX index to Prime All Share. The sensitivity analysis of the beta parameter concerns the impact of the change in the rate of return from the stock exchange index to which a given company is included in the rate of return from the basic index of the Warsaw Stock Exchange (WIG) and the Frankfurt Stock Exchange (Prime All Share).

Empirical verification of the sensitivity of the beta parameter was carried out using the following statistical parameters:

- Parameter α and the statistical value of p-vlaue,
- Parameter β and the statistical value of p-vlaue,
- Jarque-Ber test statistics (J-B) and p-value statistic,
- Breusch-Pagan statistics (B-P) and p-value statistic,
- t-Student test in the form of p-value.

The results of the statistical survey based on the statistical values/models refer to:

- Significance of the estimated structural parameters of the model (parameter α and β),
- Verification of the hypothesis on the normality of the distribution of model residues (J-B test):

$$\mathrm{JB} = \frac{n}{6}\left\{\frac{1}{n} * \frac{\sum_{t=1}^{n}(R_t-\bar{R})^3}{\left\{\sqrt{\frac{1}{n}*\sum_{t=1}^{n}(R_t-\bar{R})^2}\right\}^3}\right\}^2 + \frac{n}{24} * \left\{\frac{\sum_{t=1}^{n}(R_t-\bar{R})^4}{\left\{\sqrt{\frac{1}{n}*\sum_{t=1}^{n}(R_t-\bar{R})^2}\right\}^2} - 3\right\}^2 \quad (2)$$

where:

n – sample size;

Rt – a sequence of ascendingly ordered observations,

$\bar{R}$ – arithmetic mean from Rt,

- Verification of the hypothesis of heteroskedasticity of the random component (B-P test).
- Hypothesis about the equality of parameters of the regression model as a test t-student which test the statistical invariability of the beta parameter in the estimated model, in which the obtained assessment of this parameter for the explanatory variable in the form of the rate of return from the WIG 20 and DAX indexes, respectively, was compared to the assessment obtained from the model in which the explanatory variable is the rate of return from the WIG index and Prime All Share. This verification was carried out for the daily, weekly, and monthly frequency of measurement of the rate of return. The verification of the hypothesis is performed based on the student's t-test, for which statistic has n-2 degrees of freedom:
  a) Daily interval: $H0: \beta_{D,WIG} = \beta_{D,WIG20}$, $for\ \beta_{D,WIG} = const$, $H0: \beta_{D,\ Prime\ All\ Share} = \beta_{D,\ DAX}$, $for\ \beta_{D,\ Prime\ all\ share} = const$,
  b) Weekly interval: $H0: \beta_{W,WIG} = \beta_{W,WIG20}$, $for\ \beta_{W,WIG} = const$, $H0: \beta_{W,\ Prime\ All\ Share} = \beta_{W,DAX}$, $for\ \beta_{W,\ Prime\ all\ share} = const$,
  c) Monthly interval: $H0: \beta_{M,WIG} = \beta_{M,WIG20}$, $for\ \beta_{M,WIG} = const$, $H0: \beta_{M,\ Prime\ All\ Share} = \beta_{M,\ DAX}$, $for\ \beta_{M,\ Prime\ all\ share} = const$.

Empirical Results

The obtained results for companies listed on WIG 20 (presented in Tables 1-3) indicate that for all frequencies of measurement of the rate of return, the significance of estimating the parameters of α and β does not change, because in almost all cases the assessment of the beta parameter is important (with a significance level of 0.05), except for the companies: Pepco Group NV (weekly and monthly frequency) and Allegro.eu SA (monthly frequency). In turn, the evaluation of the parameter α is irrelevant for the significance level of 0.05 except in the case of the following companies: CCC SA, CD Projekt SA, Dino Polska SA, LPP SA (daily, weekly, and monthly interval). In general, the beta parameter rating retains its value, i.e., it is greater than 1 and is less than 1.

In principle, similar conclusions in the analysis of α and β parameters can be drawn for companies listed on the DAX index. The data were presented in tables 4-6. The evaluation of the beta parameter is basically important for most companies (except Fresenius Medical Care AG & Co KGaA, HelloFresh SE, Daimler Truck Holding AG). α is irrelevant except in 8 cases (Adidas AG, Linde Plc, Vonovia SE, Sartorius AG, Hannover Ruck SE, Merck KGAA, Symrise AG). The analysis for the DAX index was carried out at a significance level of 0.05.

Verification of the hypothesis about the normality of the distribution of the residues of the random component of the model indicates that for daily, weekly and monthly data for all companies listed on the DAX based on the Jarque-Ber test and the significance level of 0.05 there are no grounds for rejecting the null hypothesis, which means that the distribution of residues is a normal distributed. Based on data from the WSE, in the context of the verification of the hypothesis on the normality of the distribution of residuals, indicates that there are no grounds for rejecting the zero hypothesis for almost all companies listed on WIG 20, regardless of the frequency of measurement of rates of return, except for Allegro.eu SA (weekly frequency) and Cyfrowy Polsat SA (monthly frequency).

In terms of heteroskedasticity of the random component of the estimated model, the obtained statistics of the Breusch-Pagan test indicate that this phenomenon occurs in the case of the studied companies on WIG 20. For daily data at a significance level of 0.05, the statistics indicate that in 12 cases (companies) the random component is homoskedastic. For weekly and monthly data, there are no grounds for rejecting the null hypothesis about the equality of variance of the random component for 3 and 1 companies, respectively, the random component is characterized by the lack of such equality, i.e., heteroskedasticism occurs. A similar trend is presented by the results of the Breusch-Pagan statistics for companies listed on the Frankfurt Stock Exchange. That is, as the period for measuring the frequency of data increases, the phenomenon of homogeneous is more visible: for daily data for 25 companies, weekly for 27 and 36 for monthly data.

The last point of the study was a statistical analysis of the invariance/sensitivity of the beta parameter to the change of the explanatory variable from WIG 20 to WIG and DAX to Prime All Share. The results of the test indicate that:

- for daily data in the case of the WIG 20 index at the significance level of 0.05, the zero hypothesis for 17 companies and 38 companies listed on the DAX should be rejected;
- for weekly data in the case of the WIG 20 index at the materiality level of 0.05, the zero hypothesis for 6 companies and 35 companies listed on the DAX should be rejected;
- for monthly data in the case of the WIG 20 index at the significance level of 0.05, the zero hypothesis should not be rejected for all 20 companies, whilst it should be rejected for 35 companies listed on the DAX.

The presented research results indicate that for companies listed on the WSE, along with the extension of the period of measuring the frequency of rates of return, the beta parameter is characterized by a lower level of sensitivity. This is probably due to the greater amplitude of fluctuations in the rate of return with increasing the frequency of measurement. According to the author of the work, a positive phenomenon is the insensitivity of the beta parameter to the change in the rate of return of the stock market index for the monthly measurement of the rate of return in the case of companies with the largest capitalization on the Polish stock market.

Summing up the conducted studies of the sensitivity of the beta parameter to the change in the specificity of the market variable in the single-indicator Sharpe model, and in the scope of the stochastic structure for companies from the WSE and the Frankfurt Stock Exchange, it should be stated that they brought interesting results from a substantive point of view. Overall, the research led to the conclusion that the change in the benchmark of the market variable in the estimated model from the rate of return did not bring significant changes. These changes are caused by a change in the frequency of measurement of the rate of return. This does not mean that some changes do not occur in the values of beta evaluations or in the values of the coefficient of determination as well as in the range of stochastic structure of the estimated model.

Conclusion

The obtained results provide valuable insights into the behavior of companies listed on the WIG 20 and DAX indices. This research offers a comprehensive analysis of the α and β parameters across various measurement frequencies and indices, revealing critical patterns and implications.

The significance of the β parameter, observed across most cases, reaffirms its importance as a measure of systematic risk. Notably, exceptions like Pepco Group NV and Allegro.eu SA on the WIG 20 index and Fresenius Medical Care AG & Co KGaA and Daimler Truck Holding

AG on the DAX highlight the need for further investigation into company-specific or sector-specific influences. Similarly, the insignificance of the α parameter in most instances suggests a predominant influence of market-wide factors rather than firm-specific characteristics on returns. These findings align with studies by Sharpe (1964, pp. 425-442), Fama and French (1992, pp. 427-465), and more recent analyses by Bekaert et al. (2019, pp. 215-260) and Asness et al. (2020, pp. 27-69), reinforcing the robustness of β as a key risk indicator.

A critical evaluation of the research indicates certain limitations and weaknesses. For example, while the findings provide valuable insights into parameter stability, the model's assumptions of homoskedasticity and normality of residuals may not hold universally, as evidenced by the Breusch-Pagan test results for heteroskedasticity in several cases. Additionally, the study's reliance on specific indices such as WIG 20 and DAX may limit the generalizability of the results to other markets or sectors. Future research could address these limitations by incorporating alternative econometric models that account for heteroskedasticity and expanding the analysis to a broader set of indices. Moreover, the sensitivity of β to changes in the benchmark index, observed particularly for daily and weekly data, suggests potential structural differences in market dynamics that warrant deeper exploration.

The results also underscore the importance of understanding the stochastic structure of financial data. The Jarque-Bera test confirmed the normality of residuals in most cases, adding credibility to the model's validity. However, exceptions such as Allegro.eu SA and Cyfrowy Polsat SA suggest that deviations from normality can occur due to unique firm-specific factors or market anomalies. Such findings align with more recent empirical studies (e.g., Harvey et al., 2018, pp. 1-34), which advocate for robustness checks in financial modeling.

This research contributes to the understanding of systematic risk by demonstrating that the β parameter retains stability across different frequencies of return measurements, particularly for companies with larger capitalizations. The results also provide evidence that longer measurement periods reduce sensitivity, likely due to the smoothing effect of aggregated data. These findings are consistent with studies by Banz (1981, pp. 3-18) and Roll (1988, pp. 541-566) and further supported by recent advancements in high-frequency data analysis (e.g., Hansen, Lunde, 2022, pp. 469-495).

The study's implications extend beyond academic interest. For practitioners, the stability of the β parameter across various measurement frequencies underscores its utility in risk assessment and portfolio management. Furthermore, the identified exceptions to α and β significance highlight potential areas for targeted risk mitigation strategies. For policymakers, the observed differences in market characteristics between the WSE and Frankfurt Stock Exchange may inform regulatory approaches to enhance market efficiency and stability. For instance, the heteroskedasticity trends observed in daily data indicate potential inefficiencies in short-term trading, which could be addressed through improved market regulations.

The broader importance of this research lies in its potential applications. The findings can inform investment strategies, particularly in emerging markets like Poland, where the behavior of financial parameters may differ from developed markets. Additionally, the evidence of reduced sensitivity of β with longer measurement periods provides a basis for further exploration of data aggregation effects in financial modeling. The results also highlight the role of market structure and its influence on parameter stability, offering new directions for cross-market comparative studies.

In conclusion, this study advances the understanding of market risk parameters by evaluating their behavior under varying conditions and benchmarks. While certain limitations exist, the research highlights the robustness of the β parameter as a risk measure and its relevance to both academic and practical applications. By incorporating robust statistical tests and addressing potential weaknesses, the study provides a solid foundation for future research and practical decision-making in financial markets.

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Appendix

Table 1.
Estimation results for companies from the WiG20 index, daily frequency

Entity	alpha	alpha – p-value	beta	beta p-value	J-B test	J-B test p value	B-P test	B-P test p-value	t test (p-value)
Asseco Poland SA	0.00	0.16	0.57	0.00	0.01	0.99	0.41	0.82	0.00
Allegro.eu SA	0.00	0.22	0.62	0.00	0.36	0.84	1.20	0.55	0.80
CCC SA	0.00	0.04	0.66	0.00	0.40	0.82	7.39	0.02	0.00
CD Projekt SA	0.00	0.02	0.86	0.00	0.51	0.77	0.32	0.85	0.00
Cyfrowy Polsat SA	0.00	0.13	0.49	0.00	0.44	0.80	0.30	0.86	0.00
Dino Polska SA	0.00	0.00	0.60	0.00	0.06	0.97	12.05	0.00	0.09
Jastrzębska Spółka Węglowa SA	0.00	0.91	1.31	0.00	2.01	0.37	3.86	0.15	0.00
KGHM Polska Miedź SA	0.00	0.07	1.33	0.00	0.41	0.81	0.46	0.79	0.00
LPP SA	0.00	0.00	0.61	0.00	0.71	0.70	6.20	0.05	0.00
Lotos SA	0.00	0.29	0.93	0.00	1.03	0.60	12.64	0.00	0.00
mBank SA	0.00	0.11	1.14	0.00	0.73	0.69	27.34	0.00	0.00
Orange Polska SA	0.00	0.74	0.64	0.00	0.28	0.87	0.15	0.93	0.00
Pepco Group NV	0.00	0.86	0.32	0.01	0.41	0.82	1.36	0.51	0.56
Bank Polska Kasa Opieki SA	0.00	0.84	1.19	0.00	0.10	0.95	0.03	0.99	0.00
PGE Polska Grupa Energetyczna SA	0.00	0.56	1.00	0.00	0.80	0.67	12.56	0.00	0.00
Polskie Górnictwo Naftowe i Gazownictwo SA	0.00	0.33	0.72	0.00	1.63	0.44	0.73	0.69	0.00
Polski Koncern Naftowy ORLEN SA	0.00	0.29	1.08	0.00	0.17	0.92	1.16	0.56	0.00
Powszechna Kasa Oszczędności Bank Polski SA	0.00	0.39	1.13	0.00	0.04	0.98	6.47	0.04	0.00
Powszechny Zakład Ubezpieczeń SA	0.00	0.55	0.90	0.00	0.08	0.96	0.18	0.91	0.03
Santander Bank Polska SA	0.00	0.11	1.07	0.00	0.46	0.80	32.95	0.00	0.00

Source: own elaboration.

Table 2.
Estimation results for companies from the WiG20 index, weekly frequency

Entity	alpha	alpha – p-value	beta	beta p-value	J-B test	J-B test p-value	B-P test	B-P test p-value	t test (p-value)
Asseco Poland SA	0.00	0.15	0.51	0.00	0.08	0.96	4.89	0.09	0.08
Allegro.eu SA	-0.01	0.10	0.74	0.01	6.28	0.04	0.04	0.98	0.99
CCC SA	0.00	0.03	0.83	0.00	0.02	0.99	0.01	1.00	0.01
CD Projekt SA	0.01	0.02	0.83	0.00	0.27	0.87	0.00	1.00	0.12
Cyfrowy Polsat SA	0.00	0.09	0.56	0.00	0.01	1.00	0.61	0.74	0.08
Dino Polska SA	0.01	0.00	0.62	0.00	0.37	0.83	4.08	0.13	0.44
Jastrzębska Spółka Węglowa SA	0.00	0.95	1.30	0.00	1.23	0.54	2.15	0.34	0.20
KGHM Polska Miedź SA	0.00	0.06	1.44	0.00	0.02	0.99	0.70	0.70	0.06
LPP SA	0.00	0.00	0.67	0.00	0.16	0.92	13.86	0.00	0.03
Lotos SA	0.00	0.28	0.94	0.00	0.43	0.81	4.86	0.09	0.12
mBank SA	0.00	0.09	1.28	0.00	0.01	0.99	7.11	0.03	0.01
Orange Polska SA	0.00	0.75	0.67	0.00	0.09	0.96	0.04	0.98	0.26
Pepco Group NV	0.00	0.79	0.17	0.67	0.05	0.98	4.20	0.12	0.97
Bank Polska Kasa Opieki SA	0.00	0.91	1.11	0.00	0.08	0.96	7.21	0.03	0.01
PGE Polska Grupa Energetyczna SA	0.00	0.63	1.10	0.00	0.22	0.89	3.34	0.19	0.16
Polskie Górnictwo Naftowe i Gazownictwo SA	0.00	0.34	0.70	0.00	0.24	0.89	3.28	0.19	0.20
Polski Koncern Naftowy ORLEN SA	0.00	0.29	1.10	0.00	0.02	0.99	0.38	0.83	0.10
Powszechna Kasa Oszczędności Bank Polski SA	0.00	0.40	1.08	0.00	0.00	1.00	1.87	0.39	0.01
Powszechny Zakład Ubezpieczeń SA	0.00	0.55	0.95	0.00	0.08	0.96	1.52	0.47	0.44
Santander Bank Polska SA	0.00	0.09	1.10	0.00	0.01	0.99	4.41	0.11	0.02

Source: own elaboration.

Table 3.
Estimation results for companies from the WiG20 index, monthly frequency

Entity	alpha	alpha – p-value	beta	beta p-value	J-B test	J-B test p-value	B-P test	B-P test p-value	t test (p-value)
Asseco Poland SA	0.01	0.14	0.62	0.00	0.63	0.73	5.21	0.07	0.35
Allegro.eu SA	-0.06	0.08	0.46	0.28	0.00	1.00	0.00	1.00	0.96
CCC SA	0.02	0.04	1.18	0.00	0.10	0.95	0.54	0.76	0.44
CD Projekt SA	0.02	0.02	0.76	0.00	0.50	0.78	0.07	0.97	0.56
Cyfrowy Polsat SA	0.01	0.11	0.39	0.00	15.47	0.00	0.66	0.72	0.67
Dino Polska SA	0.04	0.00	0.49	0.01	5.00	0.08	5.42	0.07	0.84
Jastrzębska Spółka Węglowa SA	0.01	0.69	1.41	0.00	1.95	0.38	0.06	0.97	0.58
KGHM Polska Miedź SA	-0.13	0.07	1.32	0.00	0.44	0.80	0.19	0.91	0.70
LPP SA	0.02	0.00	0.97	0.00	0.33	0.85	0.81	0.67	0.49
Lotos SA	0.01	0.27	1.18	0.00	0.10	0.95	0.71	0.70	0.98
mBank SA	0.01	0.05	1.44	0.00	0.00	1.00	0.66	0.72	0.39
Orange Polska SA	0.00	0.67	0.52	0.00	0.11	0.95	0.33	0.85	0.92
Pepco Group NV	-0.01	0.76	0.27	0.74	1.29	0.52	0.09	0.95	0.95
Bank Polska Kasa Opieki SA	0.00	0.79	1.19	0.00	0.09	0.96	4.73	0.09	0.68
PGE Polska Grupa Energetyczna SA	0.00	0.53	1.15	0.00	0.18	0.91	0.22	0.89	0.68
Polskie Górnictwo Naftowe i Gazownictwo SA	0.00	0.44	0.66	0.00	0.56	0.76	1.76	0.42	0.85
Polski Koncern Naftowy ORLEN SA	0.00	0.33	1.14	0.00	0.52	0.77	4.30	0.12	0.92
Powszechna Kasa Oszczędności Bank Polski SA	0.00	0.30	1.16	0.00	0.01	1.00	0.21	0.90	0.63
Powszechny Zakład Ubezpieczeń SA	0.00	0.53	1.14	0.00	0.07	0.96	1.21	0.55	0.95
Santander Bank Polska SA	0.01	0.09	1.22	0.00	0.38	0.83	7.14	0.03	0.56

Source: own elaboration.

Table 4.
Estimation results for companies from the DAX index, daily frequency[1]

Entity	alpha	alpha – p-value	beta	beta p-value	J-B test	J-B test p-value	B-P test	B-P test p-value	t test (p-value)
Covestro AG	0.00	0.30	1.07	0.00	1.28	0.53	0.06	0.97	0.00
Adidas AG	0.00	0.04	0.85	0.00	0.08	0.96	13.83	0.00	0.00
Allianz SE	0.00	0.52	0.95	0.00	0.19	0.91	0.15	0.93	0.00
Basf SE	0.00	0.47	1.10	0.00	0.13	0.94	1.01	0.60	0.00
Bayer AG	0.00	0.48	1.05	0.00	0.45	0.80	0.01	0.99	0.00
Beiersdorf AG	0.00	0.51	0.52	0.00	0.00	1.00	0.35	0.84	0.00
Bayerische Motoren Werke AG	0.00	0.49	1.13	0.00	0.27	0.88	44.93	0.00	0.00
Continental AG	0.00	0.83	1.16	0.00	0.21	0.90	10.46	0.01	0.00
Deutsche Boerse AG	0.00	0.39	0.90	0.00	0.18	0.91	13.18	0.00	0.00
Deutsche Bank AG	0.00	0.07	1.44	0.00	0.51	0.77	91.02	0.00	0.00
Deutsche Post AG	0.00	0.21	0.93	0.00	0.00	1.00	52.14	0.00	0.00
Deutsche Telekom AG	0.00	0.45	0.73	0.00	0.23	0.89	7.01	0.03	0.00
E. On SE	0.00	0.48	0.87	0.00	0.17	0.92	14.07	0.00	0.00
Fresenius Medical Care AG & Co KGaA	0.00	0.30	0.41	0.00	0.32	0.85	3.58	0.17	0.00
Fresenius SE & Co KGaA	0.00	0.38	0.70	0.00	0.38	0.83	1.10	0.58	0.00
HeidelbergCement AG	0.00	0.54	1.11	0.00	0.20	0.91	1.80	0.41	0.00
Henkel AG & Co KGAA	0.00	0.48	0.65	0.00	0.02	0.99	12.70	0.00	0.00
Infineon Technologies AG	0.00	0.22	1.22	0.00	0.14	0.93	3.96	0.14	0.00
Linde Plc	0.00	0.09	0.96	0.00	0.02	0.99	11.82	0.00	0.00
Merck KGAA	0.00	0.04	0.60	0.00	0.48	0.79	1.70	0.43	0.00
MTU Aero Engines AG	0.00	0.14	0.97	0.00	0.15	0.93	46.24	0.00	0.00
Muenchener Rueckversicherungs-Gesellschaft AG	0.00	0.25	0.86	0.00	0.21	0.90	61.79	0.00	0.00
RWE AG	0.00	0.65	0.86	0.00	0.00	1.00	0.94	0.63	0.00
Sap SE	0.00	0.22	0.77	0.00	0.28	0.87	0.04	0.98	0.00
Siemens AG	0.00	0.38	1.09	0.00	0.07	0.97	2.80	0.25	0.00
Vonovia SE	0.00	0.07	0.52	0.00	0.08	0.96	0.61	0.74	0.00
Volkswagen AG	0.00	0.24	1.08	0.00	0.20	0.91	1.00	0.61	0.00
Airbus SE	0.00	0.23	1.06	0.00	0.08	0.96	1.95	0.38	0.00
Brenntag SE	0.00	0.10	0.78	0.00	0.23	0.89	0.04	0.98	0.00
Daimler Truck Holding AG	0.46	0.46	1.28	0.07	0.05	0.97	0.18	0.91	0.01
HelloFresh SE	0.00	0.03	0.36	0.00	0.89	0.64	1.12	0.57	0.00
Hannover Ruck SE	0.00	0.04	0.86	0.00	0.00	1.00	1.21	0.55	0.00
Porsche Automobil Holding SE	0.00	0.98	1.27	0.00	0.26	0.88	0.14	0.93	0.00
Puma SE	0.00	0.85	0.77	0.00	0.11	0.95	1.55	0.46	0.00
Qiagen NV	0.00	0.13	0.47	0.00	0.11	0.95	0.10	0.95	0.00
Siemens Healthineers AG	0.00	0.09	0.54	0.00	0.00	1.00	11.42	0.00	0.00
Sartorius AG	0.00	0.00	0.52	0.00	0.71	0.70	1.67	0.43	0.00
Symrise AG	0.00	0.04	0.66	0.00	0.76	0.68	75.80	0.00	0.00
Zalando SE	0.00	0.20	0.76	0.00	0.42	0.81	0.16	0.92	1.00

Source: own elaboration.

[1] The Mercedes-Benz Group AG was not included in the research, because the DAX began in 2022, which was outside the period covered by the study.

Table 5.
Estimation results for companies from the DAX index, weekly frequency[2]

Entity	alpha	alpha – p-value	beta	beta p-value	J-B test	J-B test p-value	B-P test	B-P test p-value	t test (p-value)
Covestro AG	0.00	0.27	0.97	0.00	0.89	0.65	0.79	0.67	0.00
Adidas AG	0.00	0.04	0.88	0.00	0.18	0.91	0.84	0.66	0.00
Allianz SE	0.00	0.14	0.94	0.00	0.05	0.97	0.88	0.64	0.00
Basf SE	0.00	0.50	1.15	0.00	0.05	0.97	15.04	0.00	0.00
Bayer AG	0.00	0.59	0.99	0.00	0.74	0.69	0.00	1.00	0.00
Beiersdorf AG	0.00	0.50	0.51	0.00	0.67	0.72	0.26	0.88	0.00
Bayerische Motoren Werke AG	0.00	0.51	1.12	0.00	0.15	0.93	2.32	0.31	0.00
Continental AG	0.00	0.84	1.19	0.00	0.00	1.00	0.30	0.86	0.00
Deutsche Boerse AG	0.00	0.37	0.86	0.00	0.01	1.00	0.02	0.99	0.00
Deutsche Bank AG	0.00	0.09	1.42	0.00	0.14	0.93	25.89	0.00	0.00
Deutsche Post AG	0.00	0.21	0.92	0.00	0.02	0.99	22.60	0.00	0.00
Deutsche Telekom AG	0.00	0.48	0.70	0.00	0.00	1.00	0.15	0.93	0.00
E. On SE	0.00	0.48	0.92	0.00	0.39	0.82	0.95	0.62	0.00
Fresenius Medical Care AG & Co KGaA	0.00	0.45	0.29	0.33	0.11	0.95	7.74	0.02	0.80
Fresenius SE & Co KGaA	0.46	0.49	0.79	0.04	0.46	0.79	1.15	0.56	0.73
HeidelbergCement AG	0.00	0.51	1.10	0.00	0.10	0.95	9.91	0.01	0.00
Henkel AG & Co KGAA	0.00	0.53	0.70	0.00	1.20	0.55	0.30	0.86	0.00
Infineon Technologies AG	0.00	0.24	1.37	0.00	0.00	1.00	1.24	0.54	0.00
Linde Plc	0.00	0.03	0.90	0.00	0.07	0.97	2.91	0.23	0.00
Merck KGAA	0.00	0.05	0.63	0.00	0.89	0.64	0.34	0.84	0.00
MTU Aero Engines AG	0.00	0.14	1.01	0.00	0.03	0.98	6.35	0.04	0.00
Muenchener Rueckversicherungs-Gesellschaft AG	0.00	0.24	0.86	0.00	0.11	0.94	2.17	0.34	0.00
RWE AG	0.00	0.68	0.86	0.00	0.76	0.68	0.51	0.78	0.00
Sap SE	0.00	0.24	0.80	0.00	0.51	0.78	11.10	0.00	0.00
Siemens AG	0.00	0.36	1.08	0.00	0.27	0.87	0.33	0.85	0.00
Vonovia SE	0.00	0.06	0.54	0.00	0.57	0.75	0.54	0.76	0.00
Volkswagen AG	0.00	0.28	1.12	0.00	0.23	0.89	0.98	0.61	0.00
Airbus SE	0.00	0.23	1.07	0.00	0.11	0.95	4.48	0.11	0.00
Brenntag SE	0.00	0.09	0.74	0.00	0.80	0.67	1.36	0.51	0.00
HelloFresh SE	0.01	0.04	0.35	0.05	0.82	0.66	3.60	0.17	0.14
Hannover Ruck SE	0.00	0.03	0.81	0.00	0.22	0.90	17.45	0.00	0.00
Porsche Automobil Holding SE	0.00	0.93	1.41	0.00	0.10	0.95	10.80	0.00	0.00
Puma SE	0.00	0.86	0.76	0.00	0.12	0.94	0.71	0.70	0.00
Qiagen NV	0.00	0.14	0.47	0.00	0.22	0.89	0.32	0.85	0.00
Siemens Healthineers AG	0.00	0.09	0.45	0.00	0.23	0.89	0.00	1.00	0.00
Sartorius AG	0.01	0.00	0.48	0.00	0.02	0.99	12.23	0.00	0.00
Symrise AG	0.00	0.03	0.59	0.00	0.19	0.91	7.87	0.02	0.00
Zalando SE	0.00	0.19	0.87	0.00	0.45	0.80	0.00	1.00	0.00

Source: own elaboration.

[2] The Mercedes-Benz Group AG was not included in the research, because the DAX began in 2022, which was outside the period covered by the study. Daimler Truck Holding AG was not included in the conducted research due to the too short period of listing on the DAX index in 2021 (beginning of trading on December 19, 2021).

Table 6.
Estimation results for companies from the DAX index, monthly frequency

Entity	alpha	alpha – p-value	beta	beta p-value	J-B test	J-B test p-value	B-P test	B-P test p-value	t test (p-value)
Covestro AG	0.00	0.27	0.97	0.00	0.89	0.65	0.79	0.67	0.00
Adidas AG	0.00	0.04	0.88	0.00	0.18	0.91	0.84	0.66	0.00
Allianz SE	0.00	0.14	0.94	0.00	0.05	0.97	0.88	0.64	0.00
Basf SE	0.00	0.50	1.15	0.00	0.05	0.97	15.04	0.00	0.00
Bayer AG	0.00	0.59	0.99	0.00	0.74	0.69	0.00	1.00	0.00
Beiersdorf AG	0.00	0.50	0.51	0.00	0.67	0.72	0.26	0.88	0.00
Bayerische Motoren Werke AG	0.00	0.51	1.12	0.00	0.15	0.93	2.32	0.31	0.00
Continental AG	0.00	0.84	1.19	0.00	0.00	1.00	0.30	0.86	0.00
Deutsche Boerse AG	0.00	0.37	0.86	0.00	0.01	1.00	0.02	0.99	0.00
Deutsche Bank AG	0.00	0.09	1.42	0.00	0.14	0.93	25.89	0.00	0.00
Deutsche Post AG	0.00	0.21	0.92	0.00	0.02	0.99	22.60	0.00	0.00
Deutsche Telekom AG	0.00	0.48	0.70	0.00	0.00	1.00	0.15	0.93	0.00
E. On SE	0.00	0.48	0.92	0.00	0.39	0.82	0.95	0.62	0.00
Fresenius Medical Care AG & Co KGaA	0.00	0.45	0.29	0.33	0.11	0.95	7.74	0.02	0.80
Fresenius SE & Co KGaA	0.46	0.49	0.79	0.04	0.46	0.79	1.15	0.56	0.73
HeidelbergCement AG	0.00	0.51	1.10	0.00	0.10	0.95	9.91	0.01	0.00
Henkel AG & Co KGAA	0.00	0.53	0.70	0.00	1.20	0.55	0.30	0.86	0.00
Infineon Technologies AG	0.00	0.24	1.37	0.00	0.00	1.00	1.24	0.54	0.00
Linde Plc	0.00	0.03	0.90	0.00	0.07	0.97	2.91	0.23	0.00
Merck KGAA	0.00	0.05	0.63	0.00	0.89	0.64	0.34	0.84	0.00
MTU Aero Engines AG	0.00	0.14	1.01	0.00	0.03	0.98	6.35	0.04	0.00
Muenchener Rueckversicherungs-Gesellschaft AG	0.00	0.24	0.86	0.00	0.11	0.94	2.17	0.34	0.00
RWE AG	0.00	0.68	0.86	0.00	0.76	0.68	0.51	0.78	0.00
Sap SE	0.00	0.24	0.80	0.00	0.51	0.78	11.10	0.00	0.00
Siemens AG	0.00	0.36	1.08	0.00	0.27	0.87	0.33	0.85	0.00
Vonovia SE	0.00	0.06	0.54	0.00	0.57	0.75	0.54	0.76	0.00
Volkswagen AG	0.00	0.28	1.12	0.00	0.23	0.89	0.98	0.61	0.00
Airbus SE	0.00	0.23	1.07	0.00	0.11	0.95	4.48	0.11	0.00
Brenntag SE	0.00	0.09	0.74	0.00	0.80	0.67	1.36	0.51	0.00
HelloFresh SE	0.01	0.04	0.35	0.05	0.82	0.66	3.60	0.17	0.14
Hannover Ruck SE	0.00	0.03	0.81	0.00	0.22	0.90	17.45	0.00	0.00
Porsche Automobil Holding SE	0.00	0.93	1.41	0.00	0.10	0.95	10.80	0.00	0.00
Puma SE	0.00	0.86	0.76	0.00	0.12	0.94	0.71	0.70	0.00
Qiagen NV	0.00	0.14	0.47	0.00	0.22	0.89	0.32	0.85	0.00
Siemens Healthineers AG	0.00	0.09	0.45	0.00	0.23	0.89	0.00	1.00	0.00
Sartorius AG	0.01	0.00	0.48	0.00	0.02	0.99	12.23	0.00	0.00
Symrise AG	0.00	0.03	0.59	0.00	0.19	0.91	7.87	0.02	0.00
Zalando SE	0.00	0.19	0.87	0.00	0.45	0.80	0.00	1.00	0.00

Source: own elaboration.