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EFFICIENCY OF INVESTMENT PORTFOLIOS DURING THE COVID-19 PANDEMIC AND THE WAR IN UKRAINE

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Purpose: The aim of the conducted research is to examine the efficiency of portfolios composed of companies listed on the Warsaw Stock Exchange in the subsequent quarters of 2018-2023.
Design/methodology/approach: The classical Markovitz approach and the TMAI measure, beta coefficient and Sharpe ratio were used to determine the shares of optimal portfolios. The expected rate of return, realized rate of return, portfolio risk and Sharpe ratio will be used to assess the efficiency of companies.
Findings: The analysis conducted allowed to build investment portfolios, assess their efficiency and indicate a portfolio that systematically gives a better result than the portfolio containing all the analyzed companies. The obtained results allowed us to state that in the analyzed period, the "best" portfolio is the portfolio based on the problem of maximizing the linear combination of Sharpe ratios. The outbreak of the Covid-19 pandemic and the war in Ukraine significantly affected the rates of return of investment portfolios. In the case of the strongest restrictions related to the pandemic, positive rates of return were brought by the portfolio that is a solution to the problem of minimizing the linear combination of beta coefficients.
Research limitations/implications: The financial condition of a company, estimated using the TMAI measure, is a variable that is not directly measurable. Its value is generated by observations of diagnostic variables, which are a subjective choice of the researcher. This choice should be made in a reliable manner, preceded by studies of the appropriate literature. The Sharpe ratio requires the assumption of the normality of the distribution of return rates, but in practice this assumption is rarely met. When determining the beta coefficient, the length of the period that should be used to estimate the Sharpe model equation should be determined, because as the number of observations increases, the assumption of linear dependence is not met.
Practical implications: The presented methods of determining company shares allow to indicate a portfolio that systematically gives a better result than the reference portfolio containing all analyzed companies. The existence of such a portfolio allows to use such measures as TMAI, beta or Sharpe to estimate optimal portfolios.
Social implications: What will be the impact on society of this research? How will it influence public attitudes? How will it influence (corporate) social responsibility or environmental issues? How could it inform public or industry policy? How might it affect quality of life? Not all papers will have social implications.

Originality/value: Showing that using the TMAI measure, beta coefficient and Sharpe ratio to build an investment portfolio even in "difficult" times, such as the COVID-19 pandemic or the outbreak of war in Ukraine, allows you to create a portfolio that gives better results than the reference portfolio. The methods used are useful for entrepreneurs and investors.
Keywords: investment portfolio, TMAI measure, Sharpe ratio, beta coefficient.
Category of the paper: research paper.

1. Introduction

The company's environment (both internal and external) is one of the main determinants of its functioning and development. The environment includes not only other entities related to the functioning of the company, but also phenomena and processes that are outside the company and over which the company has no influence. One of such unpredictable phenomena referred to as a "black swan" (Szczepański, 2020) was the outbreak of the Covid-19 pandemic. The pandemic has left a significant mark on the global economy. Its consequences in the form of restrictions, restrictions and sanitary regimes, as well as their subsequent loosening or lifting, have been and continue to be felt in various sectors of the economy. Already in 2020, many works appeared on the impact of the outbreak of the Covid-19 pandemic on socio-economic phenomena, i.e.: asset price and aggregate demand spirals and the supply shock associated with the Covid-19 virus (Caballero, Simsek, 2020), household consumption (Baker et al., 2020), real-time economic activity indicator in the United States (Lewis et al., 2020), changes in country credit ratings (Chodnicka-Jaworska, 2020).

Emotional factors accompanying the pandemic also had a significant impact on the decisions made by investors on financial markets. People's psychological conditions and the moods prevailing on the stock market play an important role in the decision-making process. Irrational investor behavior, especially herd effects, was particularly visible during the pandemic. In her research, Wiśniewska (2022) showed that the outbreak of the coronavirus pandemic did not reduce the activity of Polish investors, and caused a significant increase in interest in shares of companies listed on the Warsaw Stock Exchange. In the face of the developing pandemic, investor behavior and their attitude to risk changed, through the rapid purchase of discounted securities or rapid asset sales (Wiśniewska, 2022).

Studies conducted on the SARS epidemic have shown that this epidemic led to a financial crisis in Asia, as a result of which investors suffered losses on the stock market estimated at USD 2 trillion (DeLisle, 2003). Other studies have shown that during various epidemics, investors were most often pessimistic about investment prospects, which could result in selling securities out of fear of more severe consequences of the epidemic (Bai, 2014; Baker, Wurgler, Yuan, 2012).

Haiyue Liu et al. (2020) found that the outbreak of the Covid-19 pandemic had a significant negative impact on the returns of stock indices in all the countries selected for the study. Asian markets responded faster to the outbreak of the epidemic, and some of them saw an improvement in the later stage of the pandemic. The authors showed that confirmed cases of the disease had a significant negative impact on the performance of the main stock indices. (Haiyue Liu et al., 2020)

However, the Jaworski study (2021) showed a statistically significant impact of the announcement of a national quarantine or its relaxation or lifting on global stock market indices, with a stronger reaction recorded in the case of the announcement of a quarantine than in the case of its relaxation.

The aim of the study was to assess the effectiveness of investment portfolios created from shares of companies included in the WIG30 and mWIG40 indices listed on the Warsaw Stock Exchange during the Covid-19 pandemic and the outbreak of war in Ukraine. In this way, an attempt will be made to answer the question of whether it is possible to build an optimal portfolio that gives better results than the reference portfolio built from all analyzed companies. In order to assess the effectiveness of the portfolios, the expected rate of return, the realized rate of return, portfolio risk and the Sharpe ratio will be used.

2. TMAI measure, Sharpe ratio, beta coefficient

The taxonomic measure of investment attractiveness TMAI proposed by W. Tarczyński (1994) is a linear ordering method based on a synthetic variable. Its values are estimated based on financial indicators describing companies. The estimated values of the synthetic variable allow for the arrangement of companies in terms of their financial condition. The following stages can be distinguished in the linear arrangement procedure: determining the nature of variables, determining the weights of variables, normalizing variables, determining the coordinates of the pattern in the case of pattern aggregation, pattern less or pattern aggregation, classification of ranked objects and recognition of development types (Bąk, 2016).

The construction of TMAI is based on estimating the distance of each object from the reference object using the formula (Tarczyński, 2002):

$$d_i = \left[\frac{\sum_{j=1}^{m} \left(y_{ij} - y_{0j} \right)^2}{m} \right]^{1/2}, \quad i = 1, ..., n; \tag{1}$$

where:

d_i – distance of the i-th object from the pattern object,

y_{0j} – pattern object, established on the basis of a formula.

$$y_{0j} = \max_i \{y_{ij}\}, \tag{2}$$

y_{ij}, m – as above.

The final step is TMAI normalization:

$$TMAI_i = 1 - \frac{d_i}{d_0}, \quad i = 1, \ldots, n; \tag{3}$$

where:

$TMAI_i$ – taxonomic measure of the attractiveness of the i-th object,

d_0 – norm that ensures that $TMAI_i$ take values from the interval $[0,1]$,

$$d_0 = \bar{d} + 2S_d, \tag{4}$$

$\bar{d}, S_d$ – arithmetic mean and standard deviation d_i.

One of the first measures of investment efficiency, proposed in 1966, is the Sharpe ratio, which is estimated as the ratio of the excess of the average rate of return over the risk-free rate to the standard deviation:

$$S = \frac{\bar{R} - R_f}{\sigma} \tag{5}$$

where:

$\bar{R}$ - average rate of return,

R_f - average risk-free rate,

σ - risk measured by standard deviation.

The Sharpe ratio requires the assumption of normality of the distribution of return rates, but in practice this assumption is rarely met (Bernardo, Ledoit, 2000). For this reason, many measures have been created that are modifications of the Sharpe ratio, based on a different construction or other assumptions regarding the risk measure (Pezier, White, 2006; Modigliani, Modigliani, 1997; Konno, Yamazaki, 1991; Watanabe, 2007; Le Sourd, 2007). However, research shows that many of these measures are correlated (Wiesinger, 2010; Żebrowska-Suchodolska,

The Sharpe model is one of the most popular models for capital market analysis, mainly due to the possibility of using the β coefficient as a measure of risk. The classic Sharpe model is of the form (Tarczyński, 1997):

$$R_{it} = \alpha + \beta \cdot R_{mt} + U_t \tag{6}$$

where:

R_{it} – share rate of return for the i-th company,

α, β – structural parameters of the model,

R_{mt} – market rate of return,

U_t – random component.

The parameters α, β are estimated using the least squares method. When using the above model, the length of the period that should be used to estimate the equation should be determined, because as the number of observations increases, the key assumption of linear dependence in the Sharpe model is not met. Tarczyński (2009) proposes a period of 10 last quotations using a confirmatory procedure based on the analysis of the R^2 coefficient, the R^2 increment and the Student's t-test.

3. Optimal investment portfolios

The basic characteristics describing stock portfolios are the expected portfolio rate of return and portfolio risk, calculated using the formulas:

$$R_p = \sum_{i=1}^{m} x_i R_i \,, \tag{7}$$

$$S_p^2 = \sum_{i=1}^{m} x_i^2 S_i^2 + 2\sum_{i=1}^{m-1} \sum_{j=i+1}^{m} x_i x_j S_i S_j \rho_{ij} \,, \tag{8}$$

where:

R_p – expected rate of return of the portfolio of m shares,

S_p – risk of the portfolio of ma shares,

R_i – expected rate of return of the i-th share,

S_i – standard deviation of the i-th share,

ρ_{ij} – correlation coefficient of i-th stock with j-th stock,

x_i - share of i-th share in the portfolio,

$$\sum_{i=1}^{m} x_i = 1, \quad x_i \geq 0, \quad i = 1,...,m, \tag{9}$$

m – number of shares in the portfolio.

The shares of stocks in the portfolio are usually determined based on the H. Markowitz model (Markowitz, 1952), so as to minimize the risk of this portfolio (Problem 1). Another frequently used approach is the task of maximizing the expected rate of return (Problem 2).

Problem 1

$$minS_p^2$$

subject to:

$$R_p \geq R_0$$

$$\sum_{i=1}^{n} x_i = 1$$

$$x_i \geq 0, i = 1, 2, \ldots, n$$

Problem 2

$$maxR_p$$

subject to:

$$\sum_{i=1}^{n} S_i x_i \leq S_0$$

$$\sum_{i=1}^{n} x_i = 1$$

$$x_i \geq 0, i = 1, 2, \ldots, n$$

where: R_0– expected rate of return, other symbols as above.

To determine the shares of financial instruments in the optimal portfolio, linear ordering methods can be used, i.e. the relative development level index (RDI), the generalized distance measure (GDM) and the synthetic development measure (TMAI).

Problem 3

$$max \sum_{i=1}^{n} TMAI_i x_i$$

subject to:

$$R_p \geq R_0$$

$$\sum_{i=1}^{n} S_i x_i \leq S_0$$

$$\sum_{i=1}^{n} x_i = 1$$

$$x_i \geq 0, i = 1, 2, \ldots, n$$

where: symbols as above.

The following optimization problems based on the beta coefficient (Problem 4) and the Sharpe ratio (Problem 5) were also used in the study:

Problem 4

$$min \sum_{i=1}^{n} \beta_i x_i$$

subject to:

$$R_p \geq R_0$$

$$\sum_{i=1}^{n} S_i x_i \leq S_0$$

$$\sum_{i=1}^{n} x_i = 1$$

$$x_i \geq 0, i = 1, 2, \ldots, n$$

where: symbols as above.

Problem 5

$$max \sum_{i=1}^{n} S_i x_i$$

subject to:

$$R_p \geq R_0$$

$$\sum_{i=1}^{n} x_i = 1$$

$$x_i \geq 0, i = 1, 2, \ldots, n$$

4. Empirical study

The study covered 51 companies listed on the Warsaw Stock Exchange, included in the WIG30 and mWIG40 indices in the period from 1 October 2018 to 31 March 2023. The study excluded companies from the financial sector and companies that were not listed throughout the period under consideration or had missing data. The following companies were taken into account: Amica, Amrest, Asbis, Assecopol, Azoty, Benefit, Bogdanka, Boryszew, Budimex, Bumech, CDProjekt, Ciech, CIGames, Comarc, Cormav, CyfPolsat, Datawalk, Develia, DinoPL, Domdevel, Echo, Enea, Energa, EuroCash, Forte, GPW, Grenevia, GTC, Intercars, JSW, Kernel, Kety, KGHM, KrukSA, LiveChat, Mercator, Mobruk, Neuca, OrangePL, Pak, Pep, PGE, PKNOrlen, PKPCargo, Playway, Polimex, Stalprod, Tauron, Trakcja, TSGames, VRG.

In order to determine the TMAI measure for each company, financial indicators were taken into account for each quarter in the period from 1.10.2018 to 1.4.2023 (18 quarters). The study used the following indicators from the Notoria database: operating profit margin, gross profit margin, net profit margin, return on equity (ROE), return on assets (ROA), current liquidity ratio, quick liquidity ratio, increased liquidity ratio, receivables turnover, inventory turnover, operating cycle, liabilities turnover, cash conversion cycle, current assets turnover, asset turnover, asset coverage ratio, debt ratio.

In each quarter in the period from 1.10.2018 - 31.03.2023 5 optimal portfolios were constructed, which were solutions to the optimization problems 1-5 (90 portfolios) and one reference portfolio containing shares of all companies covered by the study in a given quarter (18 portfolios). Each portfolio was purchased on the 1st day of the quarter and sold on the 1st day of the following quarter at closing prices. The following were used to assess the portfolios: expected rate of return, portfolio risk, realized rate of return, Sharpe ratio. Since estimating the Sharpe ratio requires knowledge of the risk-free interest rate for each period, its value was assumed at the level of the 3M WIBOR rate on the day of construction of subsequent portfolios.

Table 1 presents the expected rates of return for portfolios constructed in subsequent quarters of the years 2018-2023. Expected rates of return that were higher than the expected rate of return of the reference portfolio in a given quarter are marked in bold.

Table 1.
Expected rates ofreturn of the constructed portfolios

	01.01.2019	**01.04.2019**	**01.07.2019**	**01.10.2019**	**01.01.2020**	**01.04.2020**	**01.07.2020**	**01.10.2020**	**01.01.2021**
max Sharpe	-0,09%	**0,38%**	**0,44%**	**0,31%**	**0,69%**	**0,50%**	**1,22%**	**0,58%**	**0,92%**
min Beta	-0,06%	**0,21%**	**0,00%**	**0,09%**	**0,17%**	**-0,14%**	**0,64%**	**0,16%**	**0,36%**
max TMAI	**-0,06%**	**0,30%**	**0,07%**	**0,13%**	**0,25%**	**-0,03%**	**0,64%**	**0,16%**	**0,33%**
max Rp	**0,32%**	**0,78%**	**0,49%**	**0,36%**	**0,71%**	**0,56%**	**1,24%**	**0,78%**	**0,92%**
min Sp	-0,06%	**0,18%**	**0,05%**	**0,03%**	**0,17%**	**-0,09%**	**0,64%**	**0,16%**	0,29%
reference portfolio	-0,06%	0,17%	-0,01%	-0,07%	0,15%	-0,35%	0,61%	0,15%	0,29%

	01.04.2021	**01.07.2021**	**01.10.2021**	**01.01.2022**	**01.04.2022**	**01.07.2022**	**01.10.2022**	**01.01.2023**	**01.04.2023**
max Sharpe	**0,73%**	**0,59%**	**0,46%**	**0,22%**	**0,07%**	**0,40%**	**0,10%**	**0,62%**	**0,47%**
min Beta	0,16%	0,13%	**0,15%**	**0,02%**	0,02%	**0,08%**	-0,10%	**0,23%**	0,06%
max TMAI	0,16%	0,13%	**0,15%**	**0,07%**	0,02%	**-0,09%**	-0,10%	**0,30%**	**0,40%**
max Rp	**0,74%**	**0,59%**	**0,67%**	**0,29%**	**0,65%**	**0,56%**	**0,43%**	**0,69%**	**0,53%**
min Sp	0,16%	0,13%	**0,15%**	**-0,03%**	0,02%	**-0,09%**	**-0,02%**	**0,23%**	0,06%
reference portfolio	0,16%	0,13%	0,14%	-0,06%	0,03%	-0,08%	-0,10%	0,22%	0,07%

Source: own elaboration.

A comparison of the expected rates of return obtained for the individual portfolios with the expected rate of return of the reference portfolio indicates that during the period under review, the max Sharpe (solution to problem 5) and max Rp (solution to problem 2) portfolios had a higher expected rate of return than the reference portfolio seventeen times. The max TMAI portfolio (solution to problem 3) had a higher expected rate of return than the reference portfolio 14 times, and the min Beta (solution to problem 4) and min Sp (solution to problem 1) portfolios 12 times.

Table 2 presents the risk of portfolios constructed in subsequent quarters of the years 2018-2023. The risk of portfolios that were lower than the risk of the reference portfolio in a given quarter is marked in bold.

Table 2.
Risk of the constructed portfolios

	01.01.2019	**01.04.2019**	**01.07.2019**	**01.10.2019**	**01.01.2020**	**01.04.2020**	**01.07.2020**	**01.10.2020**	**01.01.2021**
max Sharpe	16,23%	14,74%	15,64%	14,44%	14,38%	20,78%	18,87%	18,07%	17,93%
min Beta	17,52%	**13,77%**	**15,36%**	14,43%	14,91%	**14,59%**	**17,54%**	**15,61%**	19,44%
max TMAI	**15,82%**	**14,28%**	**14,41%**	**11,44%**	**10,78%**	**17,14%**	**18,03%**	**16,47%**	17,91%
max Rp	15,86%	21,69%	15,69%	14,44%	14,38%	20,76%	18,85%	18,06%	17,93%
min Sp	**11,81%**	**9,74%**	**8,52%**	**8,45%**	**7,63%**	**11,61%**	**14,41%**	**11,49%**	**11,53%**
reference portfolio	15,84%	14,59%	15,45%	14,28%	14,18%	20,54%	18,73%	17,98%	17,70%

	01.04.2021	**01.07.2021**	**01.10.2021**	**01.01.2022**	**01.04.2022**	**01.07.2022**	**01.10.2022**	**01.01.2023**	**01.04.2023**
max Sharpe	15,88%	15,02%	15,23%	16,07%	19,06%	17,11%	17,03%	16,14%	14,96%
min Beta	**13,16%**	16,79%	**13,47%**	18,94%	20,35%	**15,65%**	16,86%	**13,53%**	**12,67%**
max TMAI	**15,40%**	15,04%	15,16%	16,10%	19,09%	17,11%	17,02%	16,11%	**14,26%**
max Rp	15,88%	15,02%	15,23%	16,07%	19,00%	17,07%	17,02%	16,14%	14,94%
min Sp	**9,31%**	**8,45%**	**9,33%**	**7,50%**	**11,39%**	**9,82%**	**9,53%**	**10,67%**	**8,61%**
reference portfolio	15,72%	14,79%	15,14%	15,86%	18,85%	16,83%	16,82%	15,90%	14,71%

Source: own elaboration.

Based on the data presented in Table 2, it can be seen that the min Sp portfolio was characterized by a lower risk level than the reference portfolio 18 times, while the min Beta and max TMAI portfolios were characterized by a lower risk level than the reference portfolio 10 times. The max Rp portfolio had a higher risk level than the reference portfolio in each quarter.

Table 3 presents the realised rates of return for portfolios constructed in subsequent quarters of the years 2018-2023. The realised rates of return that were higher than the realised rate of return of the reference portfolio in a given quarter are marked in bold.

Table 3.
Realized rates of return of the constructed portfolios

	01.01.2019	**01.04.2019**	**01.07.2019**	**01.10.2019**	**01.01.2020**	**01.04.2020**	**01.07.2020**	**01.10.2020**	**01.01.2021**
max Sharpe	**11,69%**	**20,95%**	-3,29%	**34,67%**	**46,66%**	**73,26%**	**16,64%**	**25,27%**	**9,45%**
min Beta	**11,89%**	-19,06%	**14,94%**	8,12%	-14,79%	34,94%	**41,08%**	-4,80%	-5,00%
max TMAI	**30,54%**	**7,38%**	-2,54%	**34,96%**	**34,78%**	**68,82%**	**27,38%**	**9,28%**	-6,92%
max Rp	-13,23%	**30,98%**	**13,79%**	8,51%	**18,09%**	**64,31%**	**15,93%**	-5,52%	**9,45%**
min Sp	**23,95%**	**19,81%**	**3,26%**	**33,05%**	**23,80%**	**80,50%**	12,89%	0,10%	2,18%
reference portfolio	11,56%	-7,07%	2,28%	11,58%	-11,33%	39,41%	14,19%	8,54%	3,37%

	01.04.2021	**01.07.2021**	**01.10.2021**	**01.01.2022**	**01.04.2022**	**01.07.2022**	**01.10.2022**	**01.01.2023**	**01.04.2023**
max Sharpe	0,05%	**6,49%**	**-5,50%**	-29,91%	-14,33%	-14,48%	**18,73%**	-21,27%	**29,32%**
min Beta	2,79%	-5,80%	**-2,63%**	**6,26%**	**15,11%**	-23,08%	**39,05%**	11,87%	**31,71%**
max TMAI	-5,83%	-2,65%	**-4,03%**	-17,07%	-11,53%	**-0,97%**	**17,60%**	**26,40%**	-0,35%
max Rp	-8,18%	**6,49%**	-31,84%	-15,01%	-30,09%	**-7,40%**	**26,33%**	-15,08%	**29,53%**
min Sp	-5,74%	**8,98%**	-23,89%	-41,70%	-33,91%	-11,11%	**23,12%**	-17,57%	-2,64%
reference portfolio	6,33%	0,16%	-7,61%	-4,92%	-10,97%	-7,66%	13,49%	12,70%	12,69%

Source: own elaboration.

The analysis of realized rates of return showed that the max Sharpe portfolio achieved a higher rate of return than the reference portfolio 12 times, the max TMAI portfolio 11 times, and the max Rp portfolio 10 times. The remaining portfolios delivered a higher realized rate of return than the benchmark portfolio 10 times during the quarters under consideration.

Table 4 presents the cumulative rate of return, the geometric mean of realised rates of return and the average risk for portfolios constructed in subsequent quarters of the years 2018-2023. Values that were higher than the values obtained for the reference portfolio are marked in bold.

Table 4.
Cumulative rate of return, geometric mean rate of return and mean risk of the constructed portfolios

	cumulative rate of return	**geometric mean rate of return**	**mean risk**
max Sharpe	**346,97%**	**8,67%**	**16,53%**
min Beta	**200,10%**	**6,30%**	15,81%
max TMAI	**414,62%**	**9,53%**	15,64%
max Rp	66,32%	2,87%	**16,89%**
min Sp	39,27%	1,86%	9,99%
reference portfolio	107,70%	4,14%	16,33%

Source: own elaboration.

The analysis of cumulative rates of return (Table 4) showed that the max TMAI, max Sharpe and min Beta portfolios were characterized by a higher cumulative rate of return than the reference portfolio, in particular for the max TMAI portfolio this difference amounted to almost 307 percentage points. The max Rp and min Sp portfolios achieved the lowest cumulative rates of return, which were significantly lower than the cumulative rate of return for the reference portfolio. Based on the geometric average rates of return (Table 4), it can be seen that the max TMAI, max Sharpe and min Beta portfolios generated higher geometric average rates of return than the reference portfolio. The lowest geometric average was obtained for the min Sp portfolio, which was also characterized by the lowest average risk. However, it should be noted that the average risks obtained for the remaining portfolios are similar to each other and take values from the range (15.64%, 16.89%). The average level of risk was lower than the reference portfolio for the min Beta and max TMAI portfolios. The max TMAI portfolio, which had the highest cumulative realised rate of return and the highest geometric mean realised rate of return, had an average portfolio risk that was lower than the reference portfolio.

Table 5 presents the Sharpe ratios for the constructed portfolios. The Sharpe ratios that were higher than the Sharpe ratios of the reference portfolio in a given quarter are marked in bold.

Table 5.
Sharpe ratios of the constructed portfolios

	01.01.2019	**01.04.2019**	**01.07.2019**	**01.10.2019**	**01.01.2020**	**01.04.2020**	**01.07.2020**	**01.10.2020**	**01.01.2021**
max Sharpe	0,61	**1,30**	-0,32	**2,28**	**3,13**	**3,47**	**0,87**	**1,39**	**0,52**
min Beta	0,58	-1,51	**0,86**	0,44	-1,11	**2,31**	**2,33**	-0,32	-0,27
max TMAI	**1,82**	**0,40**	-0,30	**2,90**	**3,07**	**3,95**	**1,50**	**0,55**	-0,40
max Rp	-0,94	**1,35**	**0,77**	0,47	**1,14**	**3,04**	**0,83**	-0,32	**0,52**
min Sp	**1,88**	**1,86**	**0,18**	**3,71**	**2,90**	**6,83**	**0,88**	-0,01	0,17
reference portfolio	0,62	-0,60	0,04	0,69	-0,92	1,86	0,74	0,46	0,18

	01.04.2021	**01.07.2021**	**01.10.2021**	**01.01.2022**	**01.04.2022**	**01.07.2022**	**01.10.2022**	**01.01.2023**	**01.04.2023**
max Sharpe	-0,01	**0,42**	-0,38	-2,02	-1,00	-1,26	**0,68**	-1,75	**1,50**
min Beta	0,20	-0,36	-0,21	**0,20**	**0,51**	-1,93	**1,89**	**0,36**	**1,96**
max TMAI	-0,39	-0,19	-0,28	-1,22	-0,85	**-0,47**	**0,61**	**1,20**	-0,51
max Rp	-0,53	**0,42**	-2,11	-1,09	-1,83	**-0,85**	**1,12**	-1,37	**1,52**
min Sp	-0,64	**1,04**	-2,59	-5,90	-3,40	-1,85	**1,67**	-2,31	-1,11
reference portfolio	0,39	0,00	-0,52	-0,47	-0,84	-0,87	0,37	0,36	0,39

Source: own elaboration.

Based on the data presented in Table 5, it can be seen that the reference portfolio had a positive Sharpe ratio in 12 out of 18 analyzed quarters, which means that only in these years did it bring a rate of return higher than the risk-free rate. The constructed portfolios had a positive Sharpe ratio 9-12 times. The max Sharpe and max TMAI portfolios had a higher Sharpe ratio 11 times than the reference portfolio, of which 11 times this concerned positive values of the ratio for the max Sharpe portfolio and 9 times for the max TMAI portfolio. At the same time, the reference portfolio had a higher positive value of the ratio 4 times than the max Sharpe and max TMAI portfolio.

5. Summary

In The study assessed the efficiency of investment portfolios built from selected companies listed on the Warsaw Stock Exchange using 5 optimization tasks. Then, it was attempted to assess whether the selected optimization tasks allow for indicating a portfolio that systematically gives a better result than the reference portfolio containing all the analyzed companies. The conducted research allows for drawing the following conclusions:

- The obtained values of Sharpe ratios allow us to conclude that in the analyzed period the "best" portfolio is the max Sharpe portfolio, which is the solution to optimization problem 5.
- The analysis of geometric average rates of return of the constructed portfolios indicates that the max TMAI portfolio (solution to problem 3), maxSharpe (solution to problem 5), min Beta (solution to problem 4) portfolios brought higher geometric averages than the reference portfolio.
- Based on the conducted research, it can be seen that the outbreak of the Covid-19 pandemic and the war in Ukraine significantly affected the rates of return of investment portfolios. In the case of the strongest restrictions related to the pandemic, the Min beta portfolio, which is the solution to optimization problem 4, brought positive rates of return.

To sum up, it can be said that portfolios built on the basis of max Sharpe and max TMAI optimization problems allow for systematically achieving a higher rate of return than the reference portfolio.

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