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DETERMINING THE INVESTOR'S STRATEGY DURING THE COVID-19 CRISIS BASED ON CVAR RISK MEASURE

Abstract: The realized investment operations of each investor are based on the analysis in such a way that a certain certainty of the invested financial amount and a satisfactory return is ensured during the implementation. Therefore, when investing, the investor decides which products or securities to invest in and chooses when the investor should make the chosen investment. In this way, the investor is faced with the question of the possible return of his investment strategy based on the optimization model of portfolio selection based on the CVaR risk measure. The investor decides based on certain assumptions, including the assumption of the emergence of a crisis, e.g., the crisis caused by the virus. The paper presents the impact of the crisis on investor decision-making through the CVaR risk measure, which was realized on historical data of the components of the Dow Jones Industrial Average (DJIA) stock index in both crisis and pre-crisis periods.

Keywords: Return, CVaR, Covid-19 Crisis

1. INTRODUCTION

The Covid-19 virus triggered a global crisis that directly affected national economies and stock markets, and the resulting losses were significant and painful for all investors. Its effects have caused a significant drop in the value of investments, which can be seen in the stock markets by a temporary decline in stock prices. However, every crisis is not only temporary, but in the end, it is always a great investment opportunity. Therefore, each investor should decide in which assets to invest. The investor does not know how to predict the future, but the investor should have an idea of how it could develop. The development of the stock market in 2020 proved to be unpredictable and proved the truth that the development of markets is impossible to predict with greater accuracy.

One approach to creating an effective stock portfolio is to use a Conditional Value at Risk (CVaR) optimization model. The decision-making assumptions may also include the current phenomenon, for example, the assumption of the emergence of a crisis, e.g., the crisis caused by the virus (currently Covid-19). The paper aims to present an effective portfolio construction analysis based on the optimization models of portfolio selection utilizing the CVaR risk measure. The analysis was performed on historical data of the components of the Dow Jones Industrial Average (DJIA) stock index during the crisis and the pre-crisis period.

2. SELECTION OF FINANCIAL ASSETS FOR PORTFOLIO CREATION

Different financial portfolios can be created by combining different financial assets. Financial assets generally represent cash in bank accounts or the value of securities, bonds, and other intangible assets of an individual or institution. Any investor can invest in any financial asset but should respect the fundamental intertwined factors of asset return, risk, and liquidity. The decision on how to distribute financial assets has a fundamental impact on the overall performance of the created portfolio.

The investor's decision on financial investments goes through stages of reviewing, finding, and subsequently realizing the optimal use of invested resources. At the same time, the implemented investment operations should be based on

analysis to ensure particular security of the invested amount and the corresponding satisfactory return. Its goal is to create a suitable portfolio. The return on the created portfolio can be calculated as a weighted average of the returns of the individual financial assets that make up the portfolio. The weights are formed by the shares of the individual types of financial assets.

Thus, in order for the investor not to monitor many different types of shares, the investor can focus on existing stock indices. Stock indices are generally an essential indicator of the development of the world economy. They provide information on the development of a particular part of the stock market or the market as a whole. They are also used to measure the average profitability of a particular market (benchmark). The stock index is a dimensionless indicator of the stock market, concentrating the movement of individual shares' prices into one aggregate number. It, therefore, has an information value about the trend of the entire market. Most stock exchanges have their own index.

To analyze the influence of Covid-19, the components of the price-weighted Dow Jones Industrial Average (DJIA) were selected as one of the world's best-known stock indices ("Dow Jones Industrial Average", 2022). The DJIA is a stock index of thirty US companies consisting of the largest and commonly publicly traded stocks in the United States (a price-weighted stock index means that the higher the company's stock price, the greater the weight in the index).

In our analysis, we selected the following stocks included in the Dow Jones Industrial Average (DJIA), namely Apple Inc. (AAPL), Boeing (BA), Caterpillar Inc. (CAT), Cisco Systems (CSCO), Chevron Corporation (CVX), The Walt Disney Company (DIS), General Electric Company (GE), Goldman Sachs (GS), The Home Depot (HD), IBM (IBM), Intel (INTC), Johnson & Johnson (JNJ), JPMorgan Chase (JPM), The Coca-Cola Company (KO), McDonald's (MCD), 3M (MMM), Merck & Co. (MRK), Microsoft (MSFT), Nike, Inc. (NKE), Pfizer Inc. (PFE), Procter & Gamble (PG), The Travelers Companies (TRV), UnitedHealth Group (UNH), Verizon Communications (VZ), Walmart (WMT), Exxon Mobil Corporation (XOM).

The composition of the DJIA index is currently not as industrial as the historical name of the index indicates. Its composition is decided by the board of the Wall Street Journal. The composition of the index, i.e., the selection of companies that make up the DJIA, is to some extent subjective. Two-thirds of the selected companies are manufacturers of industrial and consumer goods. Other industries are represented by various industries such as financial services, entertainment, and information technology. Although the choice of companies has changed since the index was founded in 1896, its purpose remains the same - to provide a simple and representative view of the US economy.

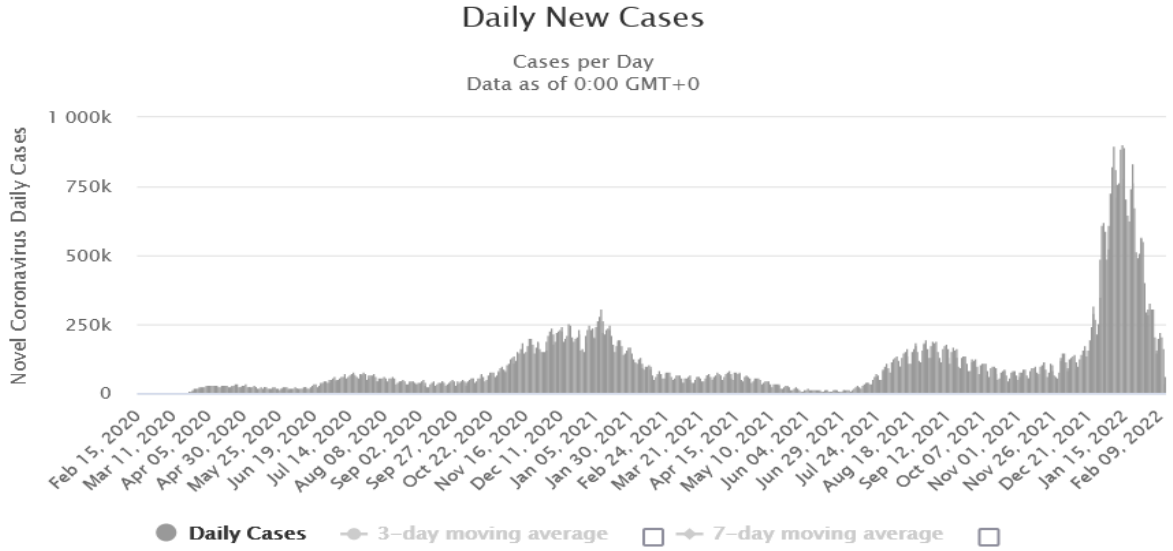
Based on the historical prices (weekly data) of selected stocks included in the DJIA stock index ("Data on individual stock", 2022), comparisons and analyzes of their behavior in the period before the arrival of the Covid-19 pandemic and during it in the USA were performed. Because the authors wanted to analyze the behavior of the DJIA stock index before and during the Covid-19 pandemic, they assumed two cases:

1. Input data for period one from 1.1.2018 to 31.12.2019 - before the occurrence of Covid-19.
2. Input data for period two from 1.1.2020 to 31.12.2021 - occurrence of Covid-19.

3. CONDITIONAL VALUE-AT-RISK

Choosing the right portfolio is a crucial investment idea. Every investor, of course, tries to maximize their return while minimizing risk. The risk represents the possibility that the actual return differs from the expected return, thus representing uncertainty about future income. This risk can be minimized by diversification, i.e., the risk of individual assets is spread over the portfolio and thus reduced.

Thus, the investor waives part of the expected return on the portfolio in favor of "insurance" against unexpected losses. Different levels of risk can be used to construct the standard role of the investor maximizing the expected return on the portfolio. One such measure is the conditional value at risk (CVaR) rate. Therefore, the aim is to formulate an investment strategy that will bring the investor, at the chosen expected level of appreciation at the end of the investment horizon, a minimum risk in the form of CVaR risk (Krokhmal, Uryasev, & Palmquist, 2002).



Picture 1: Number of new cases reported in the USA
Source: <https://www.worldometers.info/coronavirus/country/us/> Retrieved February 15, 2022

The most frequently used measure of risk is currently Value at Risk (VaR). However, this measure of risk is often criticized for not meeting the conditions of the so-called risk coherence (Artzner, et al., 1999), (Pflug, 2000). Also, VaR does not provide information on the distribution of extreme losses greater than the specified value (Yamai & Yoshida, 2002). For these reasons, the Conditional Value at Risk (CVaR), defined as the mean value of the loss exceeding the VaR at a given confidence level α , is increasingly used (Rockafellar, & Uryasev, 2002), (Xu, et al., 2016), (Liu, Chen, & Liu, 2018), (Pekár, Brezina, & Brezina, Jr. 2018), (Kang, Li, & Li, 2020), (Sun, et al., 2020).

4. CVAR-BASED PORTFOLIO SELECTION MODEL

Consider the construction of a portfolio that consists of n assets with yield vectors $\mathbf{r}_1, \mathbf{r}_2, \dots, \mathbf{r}_n$, representing discrete random variables. Let $E(\mathbf{r}_j)$ represent the expected return on the j -th asset. It will be also used the term E_j as the expected return on the portfolio. Let's assume that an investor invests in individual assets with a particular share represented by weights $\mathbf{w} = (w_1, w_2, \dots, w_n)^T$. Then the expected portfolio return is determined as $\sum_{j=1}^n w_j E(\mathbf{r}_j)$. Next, let

E_P denote the specified minimum portfolio return. Since the risk measure is used the Conditional value at risk (CVaR) in this case, in the next part we will discuss the construction of the portfolio selection model based on the CVaR risk measure. The aim of the constructed mathematical programming problem is to find such a value of optimal weights at which the value of risk expressed as CVaR will be as low as possible, this corresponds to the minimization type of objective function extremization. Because VaR value is used that is unknown, in the definition of CVaR, it must be included as a variable in the model, and therefore it must be reflected in the objective function. We will use variables z_t to implement the transformation to a linear problem, where $z_t \geq 0$ ($t = 1, 2, \dots, T$), which will acquire the value of the difference between the VaR and the return of the portfolio in state t , if the return is lower than the VaR or will be equal to zero.

Mathematical programming formulation of the problem can then be formulated as follows:

$$\begin{aligned}
 \min f(w_1, w_2, \dots, w_n, VaR_\alpha, z_1, z_2, \dots, z_T) &= VaR_\alpha + \frac{1}{\alpha} \sum_{t=1}^T p_t z_t \\
 z_t + \sum_{j=1}^n r_{jt} w_j + VaR_\alpha &\geq 0, t = 1, 2, \dots, T \\
 \sum_{j=1}^n E_j w_j &\geq E_P \\
 \sum_{j=1}^n w_j &= 1 \\
 w_1, w_2, \dots, w_n \geq 0, z_1, z_2, \dots, z_T &\geq 0
 \end{aligned} \tag{1}$$

By solving this task (Pekár, 2015), (Pfaff, 2016), (Pekár, Brezina & Reiff, 2019), the optimal weights of assets in the portfolio are determined at by decision maker given minimum value of the expected return while minimizing the CVaR risk function.

5. ANALYSIS OF THE IMPACT OF COVID-19 ON INVESTMENT STRATEGY

To compare the impact of Covid-19, the price-weighted stock index DJIA, which is one of the world's best-known stock indices, was selected. The DJIA is an index composed of the stocks of the thirty most extensive publicly traded stocks of US companies in the United States. Only 26 stocks were used for analysis because of weekly data availability. Based on the historical prices with the weekly periodicity of the selected stocks, the effect of the Covid-19 pandemic on the investment strategy was carried out. Because the authors wanted to analyze investment strategies based on a portfolio selection model using pre-Covid-19 and Covid-19 data, two input data periods were analyzed:

1. Input data for the first period from 1.1.2018 to 31.12.2019 - before Covid-19.
2. Input data for the second period from 1.1.2020 to 31.12.2021 - occurrence of Covid-19.

Table 1: Average weekly return on DJIA shares for the first and second period

Mean	AAPL	BA	CAT	CSCO	CVX	DIS	GE	GS	HD	IBM
First period	0.59%	0.17%	0.05%	0.28%	0.05%	0.31%	-0.28%	0.00%	0.21%	-0.06%
Second period	0.96%	0.19%	0.46%	0.40%	0.24%	0.17%	0.21%	0.68%	0.78%	0.23%
Difference	0.37%	0.02%	0.41%	0.12%	0.19%	-0.14%	0.49%	0.68%	0.57%	0.29%
	INTC	JNJ	JPM	KO	MCD	MMM	MRK	MSFT	NKE	PFE
First period	0.40%	0.11%	0.33%	0.26%	0.20%	-0.18%	0.54%	0.63%	0.50%	0.17%
Second period	0.03%	0.26%	0.32%	0.22%	0.39%	0.12%	0.01%	0.82%	0.62%	0.59%
Difference	-0.37%	0.15%	-0.01%	-0.04%	0.19%	0.30%	-0.53%	0.19%	0.12%	0.42%
	PG	TRV	UNH	VZ	WMT	XOM				
First period	0.39%	0.11%	0.33%	0.26%	0.25%	-0.09%				
Second period	0.36%	0.30%	0.70%	-0.03%	0.26%	0.15%				
Difference	-0.03%	0.19%	0.37%	-0.29%	0.01%	0.24%				

Source: Own calculations

Table 1 shows the calculated average weekly returns of DJIA shares for the first period (2018-2019) and the second period (2020-2021). From data in Table 1, it is clear that in the first period, before covid time, the average returns reached lower values than in the second period 2 (it is valid for 18 shares), e.g., AAPL shares achieved an average return of 0.59% in the first period and 0.96% in the second period. A similar conclusion is also valid for 18 stocks with non-negative values in the row labeled difference. The difference in the average returns of Goldman Sachs (GS) reached the highest value, as the average yield in the first period was 0.00%, and in the second period, the yield was 0.68%. Merck & Co. (MRK) acquired the lowest value in indicator difference. Its average return in the first period was 0.54%, but in the second period, only 0.01%. Covid-19's impact on the financial markets was relatively significant in the second period from the information mentioned above. The average return on most DJIA stocks was higher in the second period than the first period.

As already mentioned, CVaR (also mean excess loss) is a risk indicator used to quantify the extent of potentially significant losses. The metric is calculated as the average α % of the worst-case scenarios over a given time horizon. It is clear from Table 2 that the highest risk (lowest value) of CVaR during the first period was calculated for General Electric Company (GE), which corresponds to -11.54%. The lowest CVaR risk was calculated for Boeing (BA) in the second period, which represents -16.29%. Also, the most considerable difference between the calculated CVaR values in the first period and the second period was calculated for Boeing (BA) at -8.02%, which means that the investment risk for this company increased. Conversely, the highest positive value of 1.27% in the row difference in Table 2 for Walmart (WMT) means that in the second period, compared to the first period, the investment risk decreased the most of all the companies considered.

Table 2: CVaR values of DJIA shares for the first and second period

Mean	AAPL	BA	CAT	CSCO	CVX	DIS	GE	GS	HD	IBM
First period	-7.70%	-8.27%	-8.89%	-7.37%	-6.73%	-5.22%	-11.54%	-7.26%	-6.40%	-7.55%
Second period	-9.12%	-16.29%	-7.91%	-8.03%	-9.57%	-9.19%	-13.49%	-8.18%	-7.79%	-8.70%
Difference	-1.42%	-8.02%	0.98%	-0.66%	-2.84%	-3.97%	-1.95%	-0.92%	-1.39%	-1.15%
	INTC	JNJ	JPM	KO	MCD	MMM	MRK	MSFT	NKE	PFE

First period	-8.28%	-5.92%	-6.20%	-5.02%	-5.93%	-9.03%	-5.87%	-5.52%	-5.80%	-6.93%
Second period	-12.02%	-5.90%	-8.25%	-8.32%	-8.07%	-7.44%	-7.32%	-7.39%	-8.35%	-7.38%
Difference	-3.74%	0.02%	-2.05%	-3.30%	-2.14%	1.59%	-1.45%	-1.87%	-2.55%	-0.45%
	PG	TRV	UNH	VZ	WMT	XOM				
First period	-4.74%	-5.68%	-8.19%	-5.60%	-6.36%	-6.63%				
Second period	-5.05%	-8.81%	-8.32%	-4.82%	-5.09%	-11.06%				
Difference	-0.31%	-3.13%	-0.13%	0.78%	1.27%	-4.43%				

Source: Own calculations

6. RECOMMENDATION FOR INVESTING BASED ON A PORTFOLIO SELECTION MODEL

The mathematical programming problem depicted by the notation (1) is used to compile a portfolio based on considered historical data. Historical data are weekly returns in the first and second periods for 26 DJIA companies ($n = 26$). By solving the optimization problem, we obtain efficient portfolios at the set of different values of expected weekly returns listed in Tables 3 and 4 in the column labeled E_P (determined required minimum expected portfolio return). The stated values are obtained as the smallest and largest values of the expected returns of the portfolio, while the other values are determined by dividing the interval into equal parts.

Table 3: Distribution of investments in effective portfolios for the first period. Unlisted shares have weights equal to 0, no investment is made in them in any of the analyzed periods.

	CVaR	E_P	AAPL	CAT	DIS	INTC	KO	MCD	MMM	MRK	MSFT	NKE	PFE	PG	TRV	VZ	WMT
EP1	3.416%	0.412%	0.0%	0.0%	4.9%	0.0%	5.5%	5.6%	0.0%	20.3%	0.0%	39.0%	0.0%	1.3%	0.3%	0.0%	23.1%
EP2	3.430%	0.438%	0.0%	0.0%	7.0%	0.0%	0.0%	4.1%	0.0%	22.1%	0.0%	44.4%	0.0%	5.7%	0.0%	0.0%	16.7%
EP3	3.470%	0.465%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	26.7%	1.1%	48.1%	0.0%	7.0%	0.0%	0.0%	17.1%
EP4	3.543%	0.492%	0.0%	0.0%	0.0%	2.5%	0.0%	0.0%	0.0%	32.1%	5.6%	48.1%	0.0%	0.0%	0.0%	0.0%	11.7%
EP5	3.620%	0.519%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	38.1%	11.2%	44.6%	0.0%	0.0%	0.0%	0.0%	5.6%
EP6	3.767%	0.546%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	35.9%	21.9%	42.2%	0.0%	0.0%	0.0%	0.0%	0.0%
EP7	4.342%	0.572%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	12.8%	51.5%	35.6%	0.0%	0.0%	0.0%	0.0%	0.0%
EP8	5.055%	0.599%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.4%	76.8%	19.9%	0.0%	0.0%	0.0%	0.0%	0.0%
EP9	5.841%	0.626%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Own calculations

Table 3 (the first period) and 4 (the second period) show the computed solutions. The value of the objective function that represents the minimum CVaR value is listed in the column labeled CVaR. The shares invested in individual stocks are listed in the following columns, with different expected return values.

Table 4: Distribution of investments in effective portfolios for the second period. Unlisted shares have weights equal to 0, no investment is made in them in any of the analyzed periods.

	CVaR	E_P	AAPL	CAT	DIS	INTC	KO	MCD	MMM	MRK	MSFT	NKE	PFE	PG	TRV	VZ	WMT
EP1	4.442%	0.213%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.7%	0.0%	10.6%	0.0%	0.0%	0.0%	0.0%	35.6%	50.2%
EP2	4.697%	0.306%	0.0%	3.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	18.5%	0.0%	0.0%	0.0%	0.0%	22.5%	56.0%
EP3	5.043%	0.400%	0.0%	7.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	24.8%	0.0%	0.0%	0.0%	0.0%	5.9%	61.7%
EP4	5.436%	0.493%	0.0%	9.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	37.9%	0.0%	0.0%	0.0%	0.0%	0.0%	52.8%
EP5	5.881%	0.587%	0.0%	10.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	54.2%	0.0%	0.0%	0.0%	0.0%	0.0%	35.5%
EP6	6.447%	0.680%	2.8%	10.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	65.7%	0.0%	2.9%	0.0%	0.0%	0.0%	18.3%
EP7	7.236%	0.774%	19.6%	11.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	61.4%	0.0%	2.3%	0.0%	0.0%	0.0%	5.1%
EP8	8.228%	0.867%	42.7%	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	52.8%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%
EP9	9.739%	0.961%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Own calculations

From Table 3, it is clear that the recommendation that is based on the portfolio selection model using the input data for the first period (years 2018-2019 before Covid-19) is to invest in stocks: DIS, INTC, KO, MCD, MRK, MSFT, NKE, PG, TRV, WMT, which will form the investment portfolio.

When applying the model for input data for the second period (years 2020-2021, Covid-19 crisis), the investment portfolio consists of shares AAPL, CAT, MMM, MSFT, PFE, VZ, WMT listed in Table 4. From a comparison of the results in Table 3 and Table 4 obtained from applying the model approach (1), it is clear that in both periods, the recommended investments are the same only for MSFT and WMT stocks, which occur in both investment portfolios.

Table 5 shows the percentage differences in the investment amount for each solution. Positive values represent an increase in the amount of investment in the relevant share in the second period compared to the first period, and negative values a decrease.

It is also clear from Table 5 that the highest positive values representing the increase in the share of the relevant stocks in the total investment correspond to the IT companies (AAPL and MSFT). Another typical company with an increased share of investment is Walmart (WMT), which operates a chain of discount department stores, a segment in which there has been an increased demand for products and services during the Covid-19 pandemic.

Table 5: Difference in the distribution of investments in efficient portfolios (from the least risky) for the first period and for the second period. Unlisted shares have weights equal to 0, no investment is made in them in any of the analyzed periods.

	AAPL	CAT	DIS	INTC	KO	MCD	MMM	MRK	MSFT	NKE	PFE	PG	TRV	VZ	WMT
EP1	0.0%	0.0%	-4.9%	0.0%	-5.5%	-5.6%	3.7%	-20.3%	10.6%	-39.0%	0.0%	-1.3%	-0.3%	35.6%	27.1%
EP2	0.0%	3.1%	-7.0%	0.0%	0.0%	-4.1%	0.0%	-22.1%	18.5%	-44.4%	0.0%	-5.7%	0.0%	22.5%	39.3%
EP3	0.0%	7.7%	0.0%	0.0%	0.0%	0.0%	0.0%	-26.7%	23.6%	-48.1%	0.0%	-7.0%	0.0%	5.9%	44.6%
EP4	0.0%	9.3%	0.0%	-2.5%	0.0%	0.0%	0.0%	-32.1%	32.3%	-48.1%	0.0%	0.0%	0.0%	0.0%	41.2%
EP5	0.0%	10.3%	0.0%	-0.4%	0.0%	0.0%	0.0%	-38.1%	43.0%	-44.6%	0.0%	0.0%	0.0%	0.0%	29.9%
EP6	2.8%	10.3%	0.0%	0.0%	0.0%	0.0%	0.0%	-35.9%	43.8%	-42.2%	2.9%	0.0%	0.0%	0.0%	18.3%
EP7	19.6%	11.7%	0.0%	0.0%	0.0%	0.0%	0.0%	-12.8%	9.8%	-35.6%	2.3%	0.0%	0.0%	0.0%	5.1%
EP8	42.7%	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%	-3.4%	-23.9%	-19.9%	1.7%	0.0%	0.0%	0.0%	0.0%
EP9	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Own calculations

7. CONCLUSION

The Covid-19 crisis has also hit the stock markets hard. It can be assumed that this is not the last global crisis to hit the global economy and, therefore, the global financial and stock markets. For example, according to the renowned Deutsche Bank, at least four possible crisis scenarios are likely to threaten the world economy in the next decade. It can be a major flu pandemic, a global war, the global aftermath of a volcanic eruption, respectively solar flare (Allen, Reid a Templeman, 2020). According to the study, Deutsche Bank considers a power outage caused by a solar flare or a global military conflict the most likely scenario. This would, of course, affect not only the traditional financial and stock markets. However, the above analysis of Deutsche Bank does not claim that any of these scenarios will occur. It is based only on available statistics and the impact of the crisis on the capital markets.

Like all crises, the current Covid-19 crisis has affected stock markets. Its effects have caused a significant drop in the value of investments in the financial markets, while a temporary fall in stock prices can be observed in the stock markets.

Based on the assumption that worldwide, resp., suppose a regional crisis can arise in a specific time horizon. In that case, investors should have the tools to decide which assets will be possible and necessary to invest in the scenarios considered, with the vision of the highest profit with minimal risk. Therefore, every investor should be interested in alternative investing methods and different investment models. However, every crisis is temporary, and therefore, every investor must decide which assets to continue investing in. Therefore, the investor should know how the situation in the financial markets could develop. Therefore, the investor's attention should focus on alternative investing methods, resp., and different investment models. Investment firms offer various investment forms, for example, in an equity index or a portfolio of shares created by the investment firm. The possible approach and tool for such a decision was the subject of the presented analysis.

Portfolio selection models known from the literature can be used to address investment strategy. The authors tried to compare the impact of the Covid-19 crisis on the return and risk indicators, which are the primary indicators of investment, using selected methods of calculating returns and risk on the Dow Jones Industrial Average (DJIA) stock index.

To compare the impact of Covid-19, a price-weighted stock index DJIA was selected and, based on historical stock prices contained in the DJIA stock index, analyzes the impact of the Covid-19 pandemic on the investment strategy before Covid-19 (the first period) and during Covid-19 19 (the second period).

For the analysis, the average weekly returns of DJIA shares for the first period and the second period (Table 1) were calculated, while in the first period, the average returns were lower than in the second period. Investment risk can be calculated using CVaR risk (Table 2). The table also contains the calculated most considerable difference between the

calculated CVaR values in the first and second periods, with the lowest value representing the highest increase in risk and the highest positive value the most considerable reduction in investment risk of all the companies considered.

The mathematical programming model (1) compiled the portfolio based on the considered historical data. The problem's solution provides efficient portfolios at data set of different values of expected weekly returns (Tables 3 and 4). Tables list the amount of shares to be invested in individual stocks.

The percentage differences in the amount of investment for individual solutions are shown in Table 5. Positive values represent an increase in the amount of investment in the relevant stock in the second period compared to the first one and vice versa negative values its decrease. The table shows that during the Covid-19 crisis, industry was restructured, with Pfizer Inc. (PFE) being a representative example.

The paper analyzes the impact of the Covid-19 crisis on the stock market, while the main goal is to analyze the impact on market change, which was reflected in the demand for individual stocks. Based on the obtained solutions, a significant impact of the crisis can be stated, as the investor's strategy in each period is diametrically different. The market restructuring was reflected in the fact that companies that increased sales in this period came to the forefront of investment.

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