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Determining the investors’ strategy during the COVID-19 crisis based on the S&P 500 stock index[1]

Juraj Pekár
University of Economics in Bratislava, Bratislava, Slovakia
https://orcid.org/0000-0002-3614-2962

Ivan Brezina
University of Economics in Bratislava, Bratislava, Slovakia
https://orcid.org/0000-0002-6227-3616

Marian Reiff
University of Economics in Bratislava, Bratislava, Slovakia
https://orcid.org/0000-0002-4064-704X

Abstract

Background: The most significant changes caused by the COVID-19 crisis were the sharp increase in working from home and the growing importance of e-commerce, which affected the development of some industries. This change also affects the investors' investment operations, which are based on analysis to ensure an unquestionable certainty of the invested financial amount and a satisfactory return. It is, therefore, interesting to analyze the possible return of the chosen investment strategy based on the optimization model of portfolio selection based on the CVaR risk measure.

Purpose: The paper aims to present the possible use of the analysis of returns of effective portfolios constructed based on the optimization model of portfolio selection based on the CVaR risk measure during the crisis (COVID-19) and the pre-crisis period.

Study design/methodology/approach: Paper presents the impact of the COVID-19 crisis on investor decision-making through the CVaR risk measure, which was implemented on the historical data of the components of the Standard and Poor's 500 stock index (S&P 500) in the crisis period as well as in the pre-crisis period.

Findings/conclusions: The presented approach based on the CVaR risk rate measure and the relevant portfolio selection model provides the investor with an effective tool for allocating funds to the financial market in particular segments in both monitored periods.

Limitations/future research: Time series data are divided into two periods based on visible factors such as the number of COVID-19 cases. In future research, we aim to divide monitored periods based on unobservable factors influencing investors' decisions, such as bull or bear mood on the market.

Keywords
optimization model, return, portfolio selection CVaR, COVID-19 crisis, S&P 500

[1] Extended version of the paper presented at Strategic Management and Decision Support Systems in Strategic Management SM 2022 scientific conference

Introduction

The global economy had already been affected by the climate crisis before the crisis caused by the COVID-19 virus. The COVID-19 virus caused a global crisis (Sukharev, 2020), (Figus, 2021), which directly affected the economies of individual countries and the stock markets (precious metals, commodities, and cryptocurrencies also experienced a significant drop), and the resulting losses were very significant for all investors sometimes with catastrophic consequences. The closure of individual economies had an impact on entire industrial sectors and thus also on the financial sector. There are signs that a return to the normal functioning of financial markets is out of the question in the foreseeable future. It is possible that the world has entered an age of accelerating significant crises.

After the global crisis caused by the COVID-19 virus subsided, the invasion of Ukraine changed global geopolitics, which also caused a dramatic increase in energy and food prices, significantly impacting the global economy. This price increase had a significant knock-on effect across national and transnationally sectors.

In general, it can be assumed that even though particular crises may end at some point in time, it is likely that other crises will emerge, whether in the form of disease, conflict, or natural disasters. All these facts cannot be assumed, and if so, then only with a certain probability.

Therefore, in times of accelerating crises, any company's decision-making and management are complex and based on uncertain information and knowledge, accumulated experience, and, to a large extent, intuition. Therefore, it is necessary to transform existing decision-making models and proven management practices into models and practices that can at least partially capture new realities, contributing to managing current and future crises and perhaps even mitigating their impacts (Zinecker, Doubravský, Balcerzak, Pietrzak, & Dohnal, 2021). Above all, decision-making models that can respond to current crises must be applied. The aspect of volatility and uncertainty must be incorporated into these models.

It is evident that every crisis is not only temporary, but in the end, it is always an excellent investment opportunity. Therefore, every investor should decide which assets to invest in the next one. An investor cannot predict the future, but they should know how it might develop. The development in 2020 turned out to be unpredictable and proved the truth of the claims that it is impossible to forecast the development of markets with greater accuracy.

The effects of the COVID-19 crisis caused a significant drop in the value of investments, which can be observed in the stock markets by a temporary drop in share prices. A good prerequisite for successfully overcoming the crisis is the effective distribution of the investor's assets and the creation of a portfolio that reduces the risk of losses in unexpected and unpredictable situations. One of the approaches to creating an efficient stock portfolio is using an optimization model based on the Conditional Value at Risk (CVaR) risk measure. At the same time, decision-making assumptions can include a current phenomenon, the assumption of a crisis's emergence, e.g., the crisis caused by the COVID-19 virus.

The contribution aims to present the possible use of the analysis of returns of efficient portfolios constructed based on the optimization model of portfolio selection based on the CVaR risk measure. The analysis was carried out on the historical data of the Standard and Poor's 500 stock index (S&P 500) components during the crisis and pre-crisis period. The S&P 500 stock index, one of the world's best-known stock indexes, is composed of the stocks of the 500 most prominent and most widely traded US companies in the United States. Analyses of the impact of the COVID-19 pandemic on the investment strategy were carried out based on historical prices (weekly data) of selected shares included in the S&P 500 stock index (491 shares). Because the authors wanted to analyse investment strategies based on a portfolio selection model using data before the COVID-19 crisis and data affected by the COVID-19 crisis, two cases were analysed:

1. Input data for Period 1 from 1. Jan 2018 to 31. Dec 2019 - before COVID-19.
2. Input data for Period 2 from 1. Jan 2020 to 31. Dec 2021 – occurrence of COVID-19.

1. Investing under uncertainty

Decision-making is an integral part of every investor's work. Investors use accumulated experience, necessary information, knowledge about the given problem, and intuition. When dealing with various investment situations, it is assumed that the investor knows the possible variants of the decision and their consequences. Variants of the decision and their consequences depend on the state of the investment environment.

In contrast, in conditions of risk, which is part of every investment, the investor knows the probability of occurrence of individual states of the investment environment. In conditions of uncertainty, the investor only knows the types of states of the investment environment without knowing the probability of their occurrence (Kaplan & Barish, 1967). An economic crisis can be predicted with some probability, but the occurrence of other types of crises (e.g., a crisis caused by COVID-19) is highly uncertain.

In general, every crisis impacts the global and national economies and causes upheavals in the financial market. For example, in the 2008 crisis, oil lost more than 70% of its value (oil price fell from more than $147 per barrel to around $36 per barrel). The crisis also caused shocks in the financial market, which is confirmed by the fact that in the same period, the stock market was 20% below its historical highs already for 12 months before the collapse. The current crisis started a few days after the historically highest levels of stock markets.

During the crisis caused by the COVID-19 virus, the price of oil fell twice as fast as it did during the crisis in 2008. The COVID-19 virus caused a global crisis that affected individual countries' economies and the stock markets (Kotlebova, Arendas, & Chovancova, 2020). This crisis caused a significant drop in the value of investments in the stock markets. It was possible to observe a temporary drop in share prices (Pekár, Berezina, & Reiff, 2022).

Economic theory expects repeated economic crises that lead to depression and, consequently, recession. In the 20th century, approximately twenty economic crises and many other crises associated with geopolitical events such as wars, and terrorist attacks, were identified. The economic crisis itself is part of a natural economic cycle. It can be characterized by a sharp and immediate deterioration of most economic indicators (e.g., short-term interest rate, individual companies' insolvency, financial institutions' collapse, and asset prices). In the past, economic crises were mostly a rare phenomenon. Nowadays, the frequency of their outbreaks is higher. A study by Davis (2014) analyzed 28 worst political or economic crises in the last hundred years, which result primarily from the increasing liberalization of globally connected financial markets, resulting in crisis transmission from one country to another. (Kirman, 2010).

It can be assumed with certainty that the COVID-19 crisis is not the last global crisis that will affect the global economy and, therefore, the world financial and stock markets. According to Deutsche Bank, at least four possible crisis scenarios will probably threaten the world economy in the next decade. It can be a major flu pandemic, a global war, the global consequences of a volcano eruption, or a solar flare (Reid, Templeman, & Allen, 2020). Deutsche Bank considers a power outage caused by a solar flare or a world military conflict the most likely scenario. Of course, this would affect not only traditional financial and stock markets. The aforementioned Deutsche Bank analysis does not claim that any of the mentioned scenarios will actually occur. It is based only on available statistical data and the impact of the crisis on the capital markets.

The crisis caused by the COVID-19 pandemic significantly accelerated global changes and trends, essentially forcing consumers to change their behavior (Youssef, Redzepagic, & Zeqiri, 2022), which also led to a change in companies' production processes. There was a sharp change in dependence on new technologies, e-commerce, social networks, etc. It is possible to assume that after the end of the COVID-19 crisis, investment funds will continue to be directed to sectors preferred during the crisis, such as technology and related digitization, healthcare, environmental protection, and mitigating the effects of climate change (Małkowska, Urbaniec, & Kosała, 2021).

In addition to global changes, the crisis caused by COVID-19 also changed the mindset of many people who, after many years of economic growth, did not think about securing their own financial reserves. In the past period, many realized that they could lose not only their income but also their savings could depreciate, and therefore began to lose the possibility of investing their financial resources.

The most significant changes caused by the COVID-19 crisis were the sharp increase in working from home and the growing importance of e-commerce, which affected the development of some industries:

1. Information technology - the importance of software and hardware companies grew.
3. Communication services - telecommunications companies can be described as relatively stable businesses, but in times of recession, they usually appear to be a good investment choice.
4. Entertainment industry - some entertainment companies have grown

because staying at home has made people play more video games or subscribe to streaming services (like Netflix or Disney+).

5. Food industry - due to the unpredictability of further developments, food industry companies, especially food delivery companies, have also grown.

An appropriately chosen investment strategy is an essential factor in every investment in the financial markets. In contrast, investments should be diversified into assets such as shares, bonds, funds, or gold. In addition to financial knowledge, skills, and the ability to make the most of available funds, an investor's effective decision-making on the stock market also requires an overview and understanding of mutual relationships (Chandra, 2008). The investor's decision-making about financial investments is determined by the optimal use of the invested resources. The goal is to create an "optimal" portfolio with the highest possible returns. The profitability of the created portfolio can be calculated as a weighted average of the returns of the individual financial assets that make up the portfolio. At the same time, the weights are formed by the shares of individual types of financial assets (Pekár et al., 2022).

It is evident that historically all crises affected the stock markets, and losses during the crisis amounted to several tens of percent. However, any dip in the stock markets was only temporary, and in the long run, the crisis factor was negligible because historically, markets always rise. That is why investing during a crisis is also very important, even if it has its peculiarities. Investing during a crisis is primarily affected by uncertainty, is riskier, and the timeline and extent of economic recovery are highly uncertain. Because nothing is certain during a crisis (companies may cease operations, and the value of their shares may fall), it is essential to diversify the portfolio (Paunov, 2012).

Different financial portfolios can be created by combining different financial assets. Financial assets generally represent cash accounts in a bank or the value of accounts of securities, bonds, and other intangible assets of an individual or institution. Every investor can invest in any financial asset, but they should respect the fundamental intertwined factors: the yield, risk, and liquidity of the given asset. The decision on the method of distribution of financial assets fundamentally impacts the overall performance of the created portfolio.

When deciding on the created portfolio, the investor must emphasize a certain level of risk because, from the point of view of the future, the cash flows of individual assets are uncertain. The investor is only interested in the expected returns and risk, with the help of which the investor can express the perceived attractiveness of the created portfolio. In general, the investor tries to build a type of portfolio of securities that bring high profit while simultaneously differing to minimize possible loss from risk. The problem is that these two goals are often at odds, so investors must consider the trade-off they are willing to accept.

2. Risk measures

In order to achieve the highest return, the investor must accept a certain level of risk. Risk represents the possibility that the actual return differs from the expected return. Thus, risk essentially represents the uncertainty of future income. Certain risks, but not all, can be reduced by diversifying investment funds. An investor can decide to place his investment funds instead of in one security in many securities and thus create a diversified portfolio. Thus, the basis of diversification is the allocation of investments in different variations of assets in order to minimize the risk associated with the expected returns of individual securities.

The cornerstone of portfolio management (modern portfolio theory) is the portfolio theory created by Markowitz (1952). Markowitz was the first to contribute to the theory of financial markets with the theory of decision-making on portfolio selection under conditions of uncertainty. This theory showed how the multidimensional problem of investing in a large number of assets, each with different characteristics, can be solved under conditions of uncertainty. He reduced this problem to a relationship between only two elements: the expected return and the variance of portfolio returns. An investor should diversify his portfolio and, at the same time, maximize the expected return. Markowitz pointed to a solution to the problem of practical calculation of an optimal portfolio using a quadratic programming problem. In his theory, he was criticized for using the concept of risk using the variance of investments and the covariance between investments, given that the variance measures the dispersion of an asset's returns around the expected return and considers returns below and above the expected return to be equal (Markowitz, 1952).

In a later study Markowitz (1959) recognized these limitations and proposed a new measure of lower partial risk that measures risk below expected return. He called it semi-dispersion (semi-variance). In the subsequent periods, investors' interest revolved around measures of lower partial risk, among which we include the already mentioned lower semi-variance (lower semi-standard deviation), lower semi-absolute deviation, and Value at Risk (VaR) and Conditional value at risk (CVaR). The advantage of lower partial risk measures is that they are appropriate when the distribution of returns is asymmetric (Krokhmal, Palmquist, & Uryasev, 2002). Currently, many authors are engaged in the search for suitable measures of risk (Roman & Mitra, 2009), (Liu & Chen, 2018).

Drawdown risk rate

Investors tend to compare the risk's current value with the past's best value. In (Cheklov, Uryasev, & Zabarankin, 2003), the drawdown function is defined as the difference between the maximum return of the portfolio until time T and the value of the portfolio at time T. Examples of drawdown risk measures are Absolute Drawdown (AD), Maximum Drawdown (MDD), Average Drawdown (AVDD), Drawdown at Risk (DAR) and Conditional Drawdown at Risk (CDaR). Despite their computational simplicity, drawdown measures do not describe the actual market situation and should be used in combination with other measures.

Quantile risk measure

Quantile risk measures include Value at Risk (VaR) or Conditional Value at Risk (CVaR). The risk rate VaR determines what the minimum level of loss with a given probability, confidence level is. On the other hand, the CVaR risk rate expresses the average value of the loss below a specified level of confidence. These measures will be analyzed in more detail below.

The first regulatory VaR measurements were initiated in 1980 when the Securities and Exchange Commission tied firms' capital requirements to losses that would occur with 95 percent certainty over a 30-day interval in various security classes. Historical returns were used to calculate these potential losses in order to create sufficient capital to cover the potential losses. Garbade and Kenneth (1986) introduced the VaR risk measure based on covariances in bond yields of different maturities.

The breakthrough associated with the expansion and subsequent development of VaR is attributed to J.P. Morgan, which developed the market standard for measuring risk using VaR, the so-called Risk Metrics system. Currently, VaR is used not only by large but also by smaller financial companies and investors.

VaR is actually a risk assessment method that uses classical statistical methods. It can be included among the measures of lower partial risk. VaR essentially measures the largest expected loss in a certain period at a given confidence interval (Yamai & Yoshiba, 2005). It is therefore defined as a one-sided confidence interval of possible value losses that arose as a result of changes in the prices of commodities, securities, interest rates, and exchange rates. At the same time, every investor asks himself how much value he can lose with a certain probability in a certain period. VaR is an accepted tool for answering this question (Wang, Huang, Wu, & Zhang, 2019).

VaR has become a standard tool for risk management in the financial sphere, mainly due to its conceptual and computational simplicity. Conceptual problems of VaR are also presented in the literature (Artzner, Delbaen, Eber, & Heath, 1999), (Basak & Shapiro, 2001), (Guo, Chan, Wong, & Zhu, 2019) and (Arreola Hernandez & Al Janabi, 2020). For example, in (Artzner et al., 1999), the following shortcomings are mentioned:

2. VaR measures only the percentile of profits and losses, so it does not take into account losses above the VaR level ("tail risk")
3. VaR is not a coherent measure of risk because it is not subadditive.

It is precisely to mitigate the problems that VaR brings that the alternative risk measure CVaR was proposed. CVaR is already a coherent measure of risk. Another advantage in solving portfolio selection tasks is the possible transformation into a mathematical programming task. CVaR is defined as the expected loss exceeding the VaR value. Based on this definition, CVaR only considers loss values that are higher than the VaR value. The CVaR value is defined:

$$CVaR_{\alpha}(X) = E\big(L(X)\,\big|\,L(X) \geq VaR_{\alpha}\big) \quad (1)$$

alternatively

$$CVaR_{\alpha}(X) = E\left(-X \,|\, -X \geq VaR_{\alpha}\right) \quad (2)$$

where X denotes the random variable representing the return, $L(X) = -X$ denotes the loss function of the random variable X and VaR_α is the value at risk at the significance level α.

In the case of defining the CVaR value using the return function represented by the random variable X, we can express the CVaR based on equation (2):

$$CVaR_\alpha(X) = -E(X \mid X \le -VaR_\alpha) \quad (3)$$

Let $f(x), x \in X$ be the probability density function of a continuous random variable X. Then CVaR can be expressed:

$$CVaR_\alpha(X) = -\frac{1}{\alpha}\int_{-\infty}^{-VaR_\alpha} xf(x)dx \quad (4)$$

Assuming the existence of a discrete random variable X, represented by the vector $r = (r_1, r_2, \dots r_T)$, where T is the number of components, the above risk measure can be defined:

$$CVaR_\alpha(X) = VaR_\alpha - \frac{1}{\alpha}E\left[\left|\mathbf{r} + VaR_\alpha\right|_-\right]$$
$$CVaR_\alpha(X) = VaR_\alpha + \frac{1}{\alpha}\sum_{t=1}^{T} p_t \max(-(r_t + VaR_\alpha), 0) \quad (5)$$

VaR and CVaR values can also be interpreted graphically. Figure 1 shows at the significance level α and assuming a normal distribution.

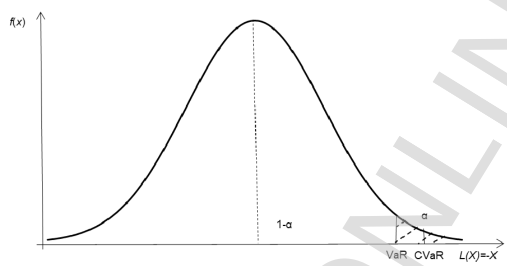

Figure 1 VaR and CVaR in case of normal distribution
Source: the authors' own calculation

In the general distribution of returns, CVaR has more suitable properties than VaR. Numerical experiments indicate that CVaR minimization usually also leads to near-optimal solutions in terms of VaR since VaR never exceeds CVaR. Therefore, portfolios with a low CVaR value must also have a low VaR value. Moreover, when the distribution of losses and returns is normal, these two measures of risk are equivalent (Rockafellar & Uryasev, 2002), i.e., and provide the same optimal portfolio. However, for other types of distributions, the optimal CVaR and VaR risk portfolios may be completely different. In addition, VaR minimization can extend the tail in excess of VaR because VaR does not control for losses in excess of VaR. (Gaivoronski & Pflug, 2005) confirmed that in some cases, VaR and CVaR optimization could lead to quite different portfolios.

Rockafellar and Uryasev (2002) demonstrated that linear programming tools could be used to optimize the Conditional Value-at-Risk (CVaR). A simple description of the CVaR minimization approach and CVaR constrained optimization problems can be found in (Uryasev, 2000). Several case studies have shown that risk optimization using the CVaR risk measure can be implemented for large portfolios and a large number of scenarios with relatively small computational resources (Uryasev, 2000), (Rockafellar & Uryasev, 2002), (Pekár, Brezina, & Brezina, 2018)and (Sun, Aw, Li, Teo, & Sun, 2020).

3. 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. When searching for an optimal portfolio, we chose CVaR as the risk measure. In this part, a model is constructed that deals with the optimization of the composition of the portfolio, i.e., how to diversify the assets in the portfolio so that the risk is minimal for a given return.

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 and r_{jt} is the t-th component (t = 1, 2, ..., T) of the discrete random variable X_j represented by the returns vector $\mathbf{r}_j$ for j = 1,2, ..., n. Let us 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 $\sum_{j=1}^{n} w_j E(\mathbf{r}_j)$. Assume that the expected value of the random variable X_j can be expressed as the geometric mean calculated from these data. The CVaR function for a discrete random variable at the significance level α has the form:

$$CVaR_\alpha(\mathbf{w}) = VaR_\alpha - \frac{1}{\alpha}E\left[\left(\mathbf{r}^T\mathbf{w} + VaR_\alpha\right)_-\right]$$
$$CVaR_\alpha(\mathbf{w}) = VaR_\alpha + \frac{1}{\alpha}\sum_{t=1}^{T} p_t \max(-VaR_\alpha - \sum_{j=1}^{n} r_{jt}w_j, 0) \quad (6)$$

where $\left(\mathbf{r}^T\mathbf{w} + VaR_\alpha\right)_-$ the expression is the negative part of the sum $\mathbf{r}^T\mathbf{w} + VaR_\alpha$, and thus the given relationship can be written as follows:

$$\left(\sum_{j=1}^{n} r_{jt} w_j + VaR_\alpha\right)_- = -\max(-VaR_\alpha - \sum_{j=1}^{n} r_{jt} w_j, 0) \quad (7)$$

Since we are using the VaR value in the definition of CVaR, which is unknown, it must be a variable in the model, and we must include it in the objective function. An objective function can then be written for the portfolio selection problem based on the CVaR risk measure:

$$\min\left\{VaR_\alpha - \frac{1}{\alpha} E\left[\left(\mathbf{r}^{\mathrm{T}}\mathbf{w} + VaR_\alpha\right)_-\right]\right\} \quad (8)$$

alternatively

$$\min\left\{VaR_\alpha + \frac{1}{\alpha}\sum_{t=1}^{T} p_t \max(-VaR_\alpha - \sum_{j=1}^{n} r_{jt} w_j, 0)\right\} \quad (9)$$

The optimization aims to minimize the risk in the area of CVaR and the portfolio's expected return. Therefore, the minimization task for CVaR has the form:

$$\min\left\{VaR_\alpha + \frac{1}{\alpha}\sum_{t=1}^{T} p_t \max(-VaR_\alpha - \sum_{j=1}^{n} r_{jt} w_j, 0)\right\}$$

$$\sum_{j=1}^{n} E_j w_j \geq E_P \quad (10)$$

$$\sum_{j=1}^{n} w_j = 1$$

$$w_1, w_2, ... w_n \geq 0$$

where E_P is the required minimum portfolio return.

The first structural constraint ensures the admissible portfolio achieves a minimum return at the E_P level. The second structural limitation corresponds to the assumption of investing all available funds, i.e., the sum of the weights equals 1.

To transform the objective function into a linear form, a non-linear relation $\max(-VaR_\alpha - \sum_{j=1}^{n} r_{jt} w_j, 0)$ must be replaced. For this transformation, the variables z_t can be used, where $z_t \geq 0$ (t = 1, 2, ..., T), and will take the value of the difference between VaR and the return of the portfolio in state t, if the return is lower than or equal to VaR, otherwise will be equal zero. Then the final linear programming problem with the new variable $z_j \geq \max(-VaR_\alpha - \sum_{j=1}^{n} r_{jt} w_j, 0)$ can be expressed as:

$$\min\left\{VaR_\alpha + \frac{1}{\alpha}\sum_{t=1}^{T} p_t z_t\right\}$$

$$z_t + \sum_{j=1}^{n} r_{jt} w_j + VaR_\alpha \geq 0, t = 1, 2, ... T$$

$$\sum_{j=1}^{n} E_j w_j \geq E_P$$

$$\sum_{j=1}^{n} w_j = 1$$

$$w_1, w_2, ... w_n \geq 0, z_1, z_2, ... z_T \geq 0 \quad (11)$$

When determining the effective portfolios in the following text, we used model (11). At the same time, in the fourth section of the paper, the investment weights in individual shares were calculated for different values of E_P (required minimum return). By solving this task, we will determine the optimal weights of assets in the portfolio at the specified minimum value of the expected return while minimizing the CVaR risk function. The interested reader can find more about CVaR in Hamdi, Karimi, Mehrdoust, & Belhaouari, (2022), Bodnar, Lindholm, Niklasson, & Thorsen, (2022), Arici, Campi, Care, Dalai, & Ramponi, (2021), Wang & Zhu, (2021) and Kang, Li, & Li, (2020).

4. Preference of financial assets for the creation of a portfolio and the analysis of COVID-19 impact on the investment strategy

Different financial portfolios can be created by combining different financial assets. Financial assets generally represent cash accounts in a bank or the value of accounts of securities, bonds, and other intangible assets of an individual or institution. Every investor can invest in any financial asset, but he should respect the fundamental intertwined factors: the yield, risk, and liquidity of the given asset. The decision on the method of distribution of financial assets fundamentally impacts the overall performance of the created portfolio.

The investor's decision-making about financial investments goes through the process of searching, finding, and realizing the optimal use of invested resources. At the same time, the investment operations should be based on analysis to ensure particular security of the invested financial amount and a corresponding satisfactory return. Its goal is, therefore, to create a suitable portfolio. The profitability of the created portfolio can be calculated as a weighted average of the returns of the individual financial assets that make up the portfolio. In contrast, the weights comprise the shares of individual types of financial assets.

Therefore, in order not have to follow many different types of stocks, the investor can focus on existing stock indexes. Stock indices generally represent an essential indicator of the development of the world economy, as they provide information on the development of a specific part of the stock market or the entire market. They are also used to measure the average profitability of a specific market (benchmark). A stock index is a dimensionless stock market indicator that concentrates the movement of individual stock prices into one aggregate number and therefore has an indicative value about the tendency of the entire market. Most stock exchanges have their own index.

Standard and Poor's 500 stock index (S&P 500) components were analysed to compare the impact of the COVID-19 disease. The S&P 500 stock index, one of the world's best-known stock indexes, is composed of the stocks of the 500 most prominent and most widely traded US companies in the United States. Based on the historical prices of stocks included in the S&P 500 index, analyses of the impact of the COVID-19 pandemic on the investment strategy were conducted exactly on weekly data from 491 stocks with available data for the analysed periods. Because the authors aim to analyse investment strategies based on a portfolio selection model using pre- COVID-19 and during-COVID-19 data, two cases were analysed:

1. Input data for Period 1 from 1. Jan 2018 to 31. Dec 2019 - before COVID-19.
2. Input data for Period 2 from 1. Jan 2020 to 31. Dec 2021 – occurrence of COVID-19.

The time series data are divided into periods based on the COVID-19 pandemic information illustrated in Figure 2 with the number of daily new cases in US (Finch & Hernández Finch, 2020). In order to describe the analysed periods, Tables 1A and 1B summarize the calculated average weekly returns of the S&P 500 stocks that are preferred in the investment strategy in Period 1 (2018-2019) and the stocks that are preferred in the investment strategy in Period 2 (2020-2021). The stock symbols used in the tables are the following: AES Corporation (AES), Amcor plc (AMCR), Advanced Micro Devices (AMD), Broadcom Inc. (AVGO), Chipotle Mexican Grill, Inc. (CMG), Copart (CPRT), DexCom, Inc. (DXCM), Enphase Energy (ENPH), Essex Property Trust (ESS), Entergy Corporation (ETR), Garmin International Ltd. (GRMN), HCA Healthcare (HCA), Hartford Financial Services Group, Inc. (HIG), Hershey Company (HSY), Dr Pepper (KDP), Eli Lilly & Co (LLY), Lamb Weston Holdings, Inc. (LW), Mettler-Toledo International Inc. (MTD), Newmont (NEM), Nike, Inc. (NKE), O’Reilly Auto Parts (ORLY), Healthpeak Properties, Inc. (PEAK), PulteGroup, Inc. (PHM), Pinnacle West Capital (PNW), Pool Corporation (POOL), Public Storage (PSA), Qualcomm (QCOM), Qorvo (QRVO), Everest Re (RE), Ralph Lauren Corporation (RL), Tesla, Inc. (TSLA), Tyler Technologies, Inc. (TYL).

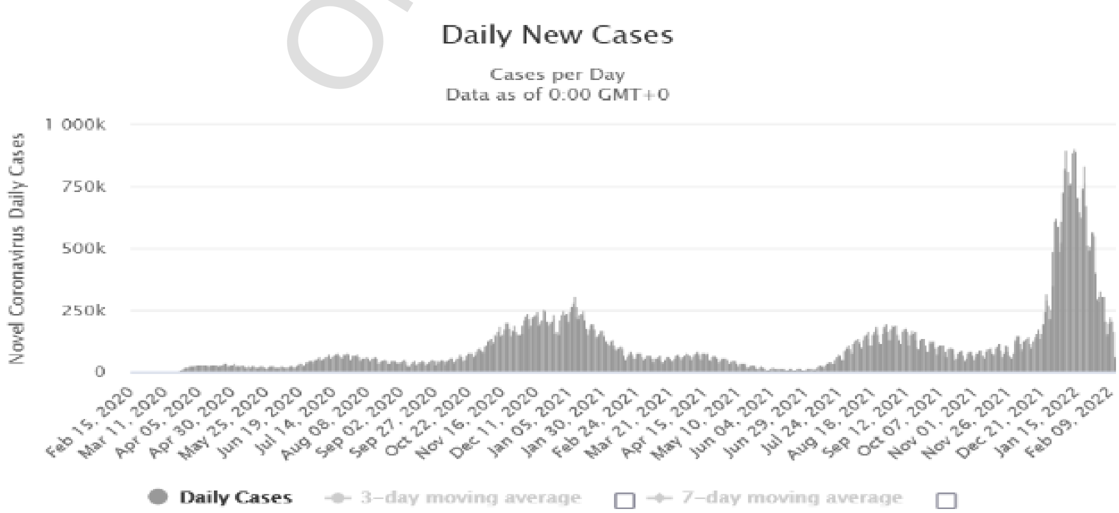

Figure 2 Number of new cases reported in the USA
Source: https://www.worldometers.info/coronavirus/country/us/ Retrieved February 15, 2022

Table 1A Period 1 average weekly return and period 2 average weekly return of S&P 500 index stocks preferred in investment strategy during Period 1 Units of data are in %.

Mean	AES	AMCR	AMD	AVGO	CMG	CPRT	DXCM	ENPH	ESS	ETR	GRMN	HCA
Period 1	0.66	0.01	1.30	0.22	0.95	0.71	1.36	2.27	0.27	0.46	0.53	0.53
Period 2	0.23	0.22	1.06	0.80	0.68	0.46	0.82	1.77	0.22	0.01	0.37	0.55
Difference	-0.43	0.21	-0.24	0.58	-0.26	-0.25	-0.54	-0.49	-0.04	-0.46	-0.17	0.01

Mean	HIG	HSY	KDP	LLY	LW	MTD	NEM	NKE	ORLY	PEAK	PHM	PNW
Period 1	0.13	0.30	0.64	0.45	0.40	0.21	0.18	0.46	0.50	0.40	0.14	0.14
Period 2	0.19	0.31	0.29	0.75	-0.33	0.73	0.39	0.50	0.47	0.13	0.37	-0.14
Difference	0.05	0.01	-0.35	0.30	-0.73	0.52	0.21	0.04	-0.03	-0.27	0.23	-0.28

Mean	POOL	PSA	QCOM	QRVO	RE	RL	TSLA	TYL
Period 1	0.49	0.11	0.35	0.52	0.25	0.15	0.26	0.46
Period 2	0.95	0.60	0.74	0.33	0.05	0.01	2.37	0.53
Difference	0.46	0.49	0.39	-0.19	-0.20	-0.14	2.11	0.06

Source: the authors' own calculations

Table 1B Period 1 average weekly return and period 2 average weekly return of S&P 500 index stocks preferred in investment strategy during Period 2 Units of data are in %.

Mean	ABBV	CLX	CTRA	DLR	ETSY	FTNT	HRL	IDXX	KEYS	KR	MSCI
Period 1	-0.04	0.10	-0.47	0.11	0.76	0.86	0.24	0.43	0.82	0.10	0.66
Period 2	0.51	0.17	0.18	0.45	1.53	1.13	0.12	0.88	0.69	0.48	0.83
Difference	0.54	0.07	0.65	0.33	0.77	0.27	-0.12	0.44	-0.12	0.38	0.17

	NFLX	NVDA	ORCL	REGN	SEDG	TSLA	WST
Period 1	0.42	0.08	0.11	-0.03	0.88	0.26	0.40
Period 2	0.59	1.55	0.50	0.52	0.99	2.37	1.10
Difference	0,18	1.47	0.39	0.55	0.11	2.11	0.70

Source: the authors' own calculations

The highest value was achieved by the difference (2.11%) in the average earnings of Tesla, Inc. (TSLA) because the average return in Period 1 was 0.26%, and in Period 2, the return was 2.37%. The lowest value was achieved by difference (-0.73%) and was acquired by the company Lamb Weston Holdings, Inc. (LW), whose average return in Period 1 was 0.4%, but in Period 2 only -0.33%. From the above, it follows that the average weekly return of S&P 500 shares for period 1 and period 2, which are preferred in the investment strategy in period 2, COVID-19 had a substantial impact on the financial markets because the average return of most of the selected S&P 500 shares was significantly higher than in the first period.

As mentioned earlier, CVaR (also Average Excess Loss) is a risk indicator used to quantify the extent of potentially large losses. The metric is calculated as the average α% of the worst-case scenarios over a certain time horizon.

From Table 2a and 2b, it is clear that the highest risk (the lowest value) CVaR of the S&P 500 stocks that occur in the investment strategy in Period 1 (2018-2019) and the stocks that occur in the investment strategy in Period 2 (2020-2021), was calculated for Dr Pepper (KDP), which corresponds to a value of -63.76%. In the second period (Period 2), the lowest CVaR risk rate of the S&P 500 stocks that appear in the investment strategy in Period 1 (2018-2019) and the stocks that appear in the investment strategy in Period 2 (2020-2021) was calculated for the company PulteGroup, Inc. (PHM), which represents a value of -34.77%. Also, the most notable difference between the calculated values of CVaR in Period 1 and Period 2 was calculated for the company Dr Pepper (KDP). The value of 52.06% means that the investment risk has decreased for this company. Conversely, the highest negative value of -26.63% in the "difference" row in Table 2a for company PulteGroup, Inc. (PHM) means that in Period 2, compared to Period 1, the investment risk increased the most among all companies considered.

Table 2A Period 1 CVaR values and period 2 CVaR values of S&P 500 index stocks preferred in investment strategy during Period 1 Units of data are in %.

CVaR	AES	AMCR	AMD	AVGO	CMG	CPRT	DXCM	ENPH	ESS	ETR
Period 1	-6.43	-6.30	-15.71	-11.97	-5.42	-13.65	-8.51	-16.36	-4.99	-3.52
Period 2	-16.75	-24.76	-9.25	-18.36	-10.70	-4.91	-17.34	-21.82	-12.98	-12.32
Difference	-10.32	-18.47	6.46	-6.39	-5.29	8.74	-8.82	-5.46	-8.00	-8.80

CVaR	GRMN	HCA	HIG	HSY	KDP	LLY	LW	MTD	NEM	NKE	ORLY
Period 1	-3.29	-8.81	-5.71	-5.63	-63.76	-6.24	-6.81	-7.89	-8.10	-5.72	-3.54
Period 2	-8.31	-29.78	-22.50	-8.63	-11.70	-8.37	-19.55	-6.29	-8.31	-11.99	-13.12
Difference	-5.02	-20.97	-16.79	-3.00	52.06	-2.13	-12.74	1.60	-0.20	-6.26	-9.58

CVaR	PEAK	PHM	PNW	POOL	PSA	QCOM	QRVO	RE	RL	TSLA	TYL
Period 1	-5.46	-8.14	-4.59	-4.80	-4.93	-12.28	-5.31	-5.29	-7.67	-12.31	-5.66
Period 2	-21.24	-34.77	-15.97	-9.71	-10.64	-5.43	-10.58	-11.37	-15.92	-11.29	-9.21
Difference	-15.78	-26.63	-11.37	-4.91	-5.71	6.84	-5.27	-6.08	-8.25	1.02	-3.55

Source: the authors' own calculations

Table 2B Period 1 CVaR values and period 2 CVaR values of S&P 500 index stocks preferred in investment strategy during Period 2 Units of data are in %.

CVaR	ABBV	CLX	CTRA	DLR	ETSY	FTNT	HRL	IDXX	KEYS	KR	MSCI
Period 1	-8.17	-6.35	-9.81	-6.32	-12.33	-7.93	-5.13	-7.64	-6.87	-10.97	-7.26
Period 2	-9.25	-9.97	-11.48	-9.16	-16.14	-5.91	-4.88	-9.51	-7.01	-7.41	-8.59
Difference	-1.08	-3.62	-1.66	-2.84	-3.81	2.01	0.26	-1.87	-0.14	3.56	-1.33

CVaR	NFLX	NVDA	ORCL	REGN	SEDG	TSLA	WST
Period 1	-9.00	-13.56	-9.60	-10.49	-16.60	-12.31	-6.82
Period 2	-8.99	-11.74	-6.28	-8.04	-19.39	-11.29	-6.08
Difference	0.02	1.81	3.32	2.45	-2.78	1.02	0.74

Source: the authors' own calculations

4. Investment recommendation based on the portfolio selection model

We use a mathematical programming model (11) to construct a portfolio based on the historical data (historical weekly returns in Period 1 and Period 2) for 491 S&P 500 stocks. By solving the model, we obtain efficient portfolios at different values of the expected weekly returns listed in tables 3 and 4 in the column marked E_P (set required minimum expected return of the portfolio). The stated E_P values are obtained as the smallest and largest values of the portfolio's expected returns, while the other values are determined by dividing the interval into equal parts.

Table 3 for period 1 and table 4 for period 2 show the calculated solutions. The value of the objective function representing the minimum value of CVaR is given in the column labelled CVaR. In other columns, the shares invested in individual stocks are listed for different expected return values.

Table 3 Distribution of investment in effective S&P 500 portfolios for Period 1. Unlisted stocks have weights equal to 0, thus they are not invested in any analyzed period. Units of data are in %.

	CVaR	Ep	AES	AMCR	AMD	AVGO	CMG	CPRT	DXCM	ENPH	ESS	ETR	GRMN	HCA	HIG	HSY	KDP
EP1	1.54	0.28	0.0	2.5	0.0	4.7	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	8.6
EP2	1.76	0.57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	3.5	16.7	0.0	7.3	1.6	2.7	17.0
EP3	2.57	0.85	0.0	0.0	0.0	0.0	7.1	0.0	0.8	12.1	0.0	29.1	2.4	2.2	0.0	0.0	18.8
EP4	3.91	1.14	5.9	0.0	0.2	0.0	17.5	0.0	0.0	19.9	0.0	0.0	4.6	0.0	0.0	0.0	19.7
EP5	5.53	1.43	13.1	0.0	4.0	0.0	16.8	0.0	4.3	28.4	0.0	0.0	0.0	0.0	0.0	0.0	13.8
EP6	7.35	1.71	7.0	0.0	4.4	0.0	0.0	3.3	18.7	38.9	0.0	0.0	0.0	13.6	0.0	0.0	0.0
EP7	9.31	2.00	0.0	0.0	11.1	0.0	0.0	5.4	28.6	44.5	0.0	0.0	0.0	4.9	0.0	0.0	0.0
EP8	11.42	2.29	0.0	0.0	11.0	0.0	1.0	0.0	32.1	55.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EP9	14.45	2.57	0.0	0.0	11.3	0.0	0.0	0.0	10.9	77.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EP10	18.36	2.86	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	0.0

	CVaR	Ep	LLY	LW	MTD	NEM	NKE	ORLY	PEAK	PHM	PNW	POOL	PSA	QCOM	QRVO	RE	RL	TSLA	TYL
EP1	1.54	0.28	0.0	0.0	1.2	7.0	3.6	0.0	0.0	5.1	22.9	0.0	23.9	0.0	0.0	13.0	6.3	0.0	0.8
EP2	1.76	0.57	0.0	0.0	0.0	11.1	1.5	3.0	0.0	14.4	2.4	2.0	0.5	0.0	0.0	10.4	0.0	0.0	0.0
EP3	2.57	0.85	1.6	0.0	0.0	0.0	3.7	0.0	8.0	5.8	0.0	0.0	0.0	8.5	0.0	0.0	0.0	0.0	0.0
EP4	3.91	1.14	0.0	5.2	0.0	0.0	21.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.0	0.0	0.0	0.0
EP5	5.53	1.43	0.0	0.0	0.0	0.0	7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	0.0	0.0	3.8	0.0
EP6	7.35	1.71	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	0.0	0.0	6.6	0.0
EP7	9.31	2.00	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	0.0	5.5	0.0
EP8	11.42	2.29	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	0.0	0.1	0.0
EP9	14.45	2.57	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	0.0	0.0	0.0
EP10	18.36	2.86	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	0.0	0.0	0.0

Source: the authors' own calculations

Table 4 Distribution of investment in effective S&P 500 portfolios for Period 2. Unlisted stocks have weights equal to 0, thus they are not invested in any analyzed period. Units of data are in %.

	CVaR	Ep	ABBV	CLX	CTRA	DLR	ETSY	FTNT	HRL	IDXX	KEYS	KR	MSCI	NFLX
EP1	2.53	0.42	6.7	37.6	5.8	0.6	0.0	0.0	16.7	1.2	5.6	0.0	10.1	0.0
EP2	3.43	0.71	0.0	23.4	0.0	0.0	0.0	0.0	0.0	0.0	6.0	10.7	1.9	19.5
EP3	4.92	0.99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.3	0.0	22.6
EP4	6.53	1.27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	21.7
EP5	8.28	1.55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
EP6	10.23	1.83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EP7	12.22	2.12	0.0	0.0	0.0	0.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EP8	14.30	2.40	0.0	0.0	0.0	0.0	20.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0
EP9	16.51	2.68	0.0	0.0	0.0	0.0	25.4	2.9	0.0	0.0	0.0	0.0	0.0	0.0
EP10	19.50	2.96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	CVaR	Ep	NVDA	ORCL	REGN	SEDG	TSLA	WST
EP1	2.53	0.42	0.0	0.0	15.8	0.0	0.0	0.0
EP2	3.43	0.71	9.9	0.0	15.6	7.3	0.0	5.8
EP3	4.92	0.99	25.5	0.0	18.4	5.3	0.3	9.6
EP4	6.53	1.27	21.5	0.0	24.4	0.0	12.0	17.9
EP5	8.28	1.55	54.6	0.0	19.9	0.0	9.6	15.0
EP6	10.23	1.83	42.1	0.0	21.6	0.0	29.7	6.6
EP7	12.22	2.12	21.8	0.1	22.7	0.0	49.6	0.0
EP8	14.30	2.40	0.0	3.6	11.2	0.0	63.1	0.0
EP9	16.51	2.68	0.0	0.0	0.0	0.0	71.7	0.0
EP10	19.50	2.96	0.0	0.0	0.0	0.0	100.0	0.0

Source: the authors' own calculations

We can read from Table 3 that the recommendation based on the portfolio selection model using input data for Period 1 (years 2018-2019 before COVID-19) is to invest in the shares: AES, AMCR, AMD, AVGO, CMG, CPRT, DXCM, ENPH , ESS, ETR, GRMN, HCA, HIG, HSY, KDP, LLY, LW, MTD, NEM, NKE, ORLY, PEAK, PHM, PNW, POOL, PSA, QCOM, QRVO, RE, RL, TSLA, TYL.

When applying the model for input data for Period 2 (years 2020-2021, COVID-19 crisis), the investment portfolio consists of shares: ABBV, CLX, CTRA, DLR, ETSY, FTNT, HRL, IDXX, KEYS, KR, MSCI, NFLX, NVDA, ORCL, REGN, SEDG, TSLA, WST (Table 4). Comparing the values in Table 3 and Table 4, results obtained from the model approach (11), it is clear that in both periods, the recommended investments are the same only for the TSLA (Tesla, Inc.) stock, which appears in both investment portfolios.

Conclusion

Investors should have tools available to decide which assets it is possible and crucial to invest in, considering scenarios with the idea of the highest profit with minimal risk, based on the assumption that a global or regional crisis may arise in a specific time horizon for any reasons. Therefore, every investor should be interested in alternative or diverse investment models. Investment companies offer different investment forms, for example, a stock index or a portfolio of shares created by an investment company. The subject of the presented analysis was the proposal of a viable approach and tool for such a decision.

On the Standard and Poor's 500 stock index (S&P 500), the authors compare the impact of the COVID-19 crisis on return and risk indicators, which are fundamental investment indicators, using established methods of calculating returns and risk. A portfolio selection model was proposed to determine a suitable investment strategy, with criteria of return maximization and risk minimization through the CVaR risk measure.

Accomplished analyzes of the impact of the COVID-19 pandemic on the investment strategy was carried out on the historical data of the S&P 500 companies' stock prices. First, average weekly returns for all S&P 500 companies were calculated for Period 1 (pre- COVID-19) and Period 2 (during COVID-19). Tables 1a and 1b show the average weekly returns of selected S&P 500 companies' stocks. At the same time, the investment risk measure was calculated using the CVaR risk for all S&P 500 stocks. Tables 2a and 2b show the CVaR risk indicator for selected S&P 500 stocks, while this table also contains the calculated difference between the CVaR values in Period 1 and Period 2. The lowest value represents the highest risk increase, and the highest positive value represents the most significant reduction in investment risk of all considered index companies S&P 500.

In order to create a portfolio based on information from the historical data of S&P 500 companies, a mathematical programming task (11) was used. The solution provides efficient portfolios at different values of expected weekly returns. The results are shown in Tables 3 and 4, representing the proportion of shares invested in individual companies' stocks.

The article presents an analysis of the impact of the COVID-19 crisis on the stock market, while the main goal is to analyze the impact of the crisis on market changes, which was reflected in demand for individual stocks in various industrial segments. Based on the obtained solutions, a significant impact of the COVID-19 crisis can be noted because the investment strategy in particular periods is diametrically different. It is possible to assume that a different type of global crisis would direct investments to other industry segments. The restructuring of the market manifested itself in investing in such a way that companies that increased the expected returns during this period while maintaining appropriate portfolio diversification came to the forefront of investing.

Similar analyses were published by the authors in a paper (Pekár et al., 2022), in which authors carried out similar analyses for the stock index Dow Jones Industrial Average (DJIA), which is one of the world's most famous stock indices. The DJIA is a stock index of thirty US companies comprising the largest and most widely traded stocks in the United States. The analysis carried out showed that the most significant increase in the share of relevant shares in the total investment corresponds to companies from the field of information technology Apple, Inc. (AAPL) and Microsoft (MSFT)). Another typical company with a significantly increased share of investments is Walmart (WMT), an American multinational retail corporation that operates a chain of hypermarkets, discount department stores, and grocery stores. A segment in which increased demand for products and services was recorded during the COVID-19 pandemic.

The authors reached similar conclusions when analyzing the S&P 500 stock index. Table 3 shows the diversity of the distribution of investments in effective S&P 500 portfolios for Period 1 (32 companies from different industries), which corresponds to the classical recommendations for investors from the point of view of risk diversification. On the contrary, Table 4 shows the distribution of investments in the effective portfolios of the S&P500 for Period 2 in only 18 companies, corresponding to the segments that experienced the most significant growth during the COVID-19 crisis. We can mention above all the IT segment (FTNT, KEYS, NVDA, ORCL), then the pharmaceutical industry (ABBV, IDXX, REGN, WST), online streaming services (NFLX), the energy-saving industry (CTRA, SEDG), and food segment (HRL, KR).

The presented analysis was based on the S&P 500 stock index, while the results are comparable to the authors' previous published results on the DJIA stock index data. Because the S&P 500 stock index contains a more significant number of stocks, the portfolio was made up of stocks of several companies. However, the direction of investments in comparable segments resulted from analyses carried out on both stock indices.

The mentioned analysis procedure does not have to be implemented on the selected stock index. In addition to the listed, e.g., Wilshire, Russell 2000, Nasdaq Composite, FT-SE 100, Morgan Stanley Capital International World, Dow Jones Eurostoxx, RTSI, DAX, ATX, CAC 40, Hang Seng, Nikkei Stock Average, PX 50, SAX, etc., but also on any own set of selected assets.

It can be concluded that the model approach based on the CVaR risk rate and the relevant portfolio selection model provides the investor with an effective tool for deciding on the allocation of available funds in the financial market.

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✉ **Correspondence**

Marian Reiff

Department of Operations Research and Econometrics, Faculty of Economic Informatics, University of Economics, Dolnozemská 1, 852 35 Bratislava, Slovakia

E-mail: marian.reiff@euba.sk