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The possibilities and consequences of investment decisions by stepwise optimization

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ABSTRACT

The paper deals with the application of stochastic optimization principles for investment decision making. The authors present the investment management system based on an adequate portfolio model. For optimal portfolio construction and stock selection, the method of stochastically informative expertise and ranging is used. Investment portfolios in equity and currency markets are formed considering investor risk tolerance and risk preference level, as well as an individual utility function. Investment portfolios are constructed according to three criteria: return, risk, and reliability. The markets of Germany, the USA, and China, as well as foreign exchange markets, are analysed. The results reveal the efficient investment possibilities in the mentioned markets, allowing to reach investment return substantially exceeding market index return. Along with that, an innovative stochastic clustering methodology for investment assets is proposed. The obtained results are of great value for individual as well as institutional investors and are a suitable means to form efficient investment strategies in financial markets.

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Decision-making; investment portfolio; return; risk; uncertainty; utility; stochastic process

JEL CLASSIFICATION CODES
G11; G15

1. Introduction

Stock prices are affected by a wide array of factors (e.g. Huy et al., 2020; Kaluge, 2019; Kumaraswam et al., 2019; Masood et al., 2020). In its turn, change in stock prices affects numerous stakeholders, such as, e.g. the listed companies themselves (Hilkevics & Hilkevica, 2017), investing banks (Adeniran et al., 2020), the macroeconomic variables (Mazzanti et al., 2020; Shang & Zheng, 2021).

In this wide and complex area of investment research, the authors set boundaries of their focus by setting an objective of this paper. Thus, the objective is to reach the moderately risky and high return-generating investment portfolio using stepwise return maximization criteria, operational risk management instruments and fully applying the intelligence gathered in historical data.

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The stated objective also tackles the tasks, which embrace:

- Presentation of the investment portfolio, which can achieve high standards of return on investment, while ensuring full security against the possible effects of risks, revealing the possibilities of its practical application;
- Presentation of stochastically informative expertise and ranking scheme as a key tool for achieving the objectives of the portfolio;
- Introduction of the principles of market intelligence and stochastic optimization as key sources of information provision and quantification tools in formulating and selecting investment strategies;
- Comments on the experimental investment results obtained through the prepared portfolio based on three parameters: return, risk, and reliability, and formed strategies.

Making the investment decision in the text presented can be directly understood as testing the past and future market intelligence.

The structure of the paper is as follows. The first part is literature analysis, where research on portfolio theory, investment decision-making and stochastic optimization is presented. Section 3 presents the main methodological steps and certain organizational moments of the performed research. Section 4 describes in detail the stepwise solution and presentation of the experimental results. Operation and management of the investment system are presented in Section 5. Section 6 pays attention to the investor's objectives and capabilities, including the innovative idea of stock clustering. Section 7 provides practical implications. The paper ends with conclusions.

2. Literature review

Investment portfolio research has mainly started with the appearance of classical portfolio theory proposed by H. Markowitz in 1952. The optimal portfolio selection problem was formulated as a mathematical optimization problem: the portfolio return is maximized under fixed variance. According to H. Markowitz's portfolio theory, investors apply only two characteristics: expected return and risk (dispersion, or standard deviation). Thus, when under uncertainty, a multidimensional investment selection problem must select a portfolio out of various asset classes, which has been simplified to two dimensions. Because of that, such a portfolio optimization method is often called a mean-variance method. The portfolio is optimal if, under a certain fixed average return, the risk is minimized, or under a certain fixed risk the expected return is maximized (Fahmy, 2020; Markowitz, 1959).

However, the initially created mean-variance portfolio has been further developed into three following directions: 1) simplifying the required data and decreasing its amount; 2) inclusion of alternative risk measures; 3) inclusion of additional criteria or constraints. After analysing portfolio optimization literature, it can be seen that scientists often conclude that the portfolio selection problem should include additional parameters besides return and risk (Meghwani & Thakur, 2017; Sanchez-Roger et al., 2020; Siddique et al., 2020; Steuer et al., 2008). Examples of such criteria are liquidity (Al Janabi et al., 2019; Jana et al., 2009; Li & Zhang, 2021), skewness

(Kerstens et al., 2008; Konno & Yamamoto, 2005; Pahade & Jha, 2021; Saborido et al., 2016), conditional value at risk (CVaR) (Aboulaich et al., 2010; Najafi & Mushakhian, 2015; Strub et al., 2019). Other scientists also broadly analysed various aspects of stock market and investment (Ogiugo et al., 2020, Dvorsky et al., 2020; Masood et al., 2020; Giacomella, 2021; Becheikh, 2021; Zumente & Bistrova, 2021; Slávik et al., 2021; Kasperovica & Lace, 2021; Nassar & Tvaronavičienė 2021; Mura & Hajduová, 2021), thus, these topics get proper attention.

One more possible additional criterion in the portfolio selection problem is reliability proposed by A.V. Rutkauskas (2000), who developed the adequate portfolio model. The proposed technique allows investors to use the return, risk, and reliability parameters that naturally coincide with the investment decision management logic. Under the adequate portfolio, not efficient frontier is being formed, as in Markowitz's case, but already efficient surface. Thus the adequate portfolio can be treated as a certain amplification of the Markowitz portfolio. An efficient surface is formed as a three-dimensional network of portfolio return survival functions and isoguarantees. Also, an optimal portfolio is selected by using a three-dimensional utility function of a particular investor. Adequate portfolio theory has been further developed, revealing its various application possibilities (Arribas et al., 2019; García et al., 2020; Rutkauskas, 2006; Rutkauskas et al., 2009; 2017; Rutkauskas & Stasytytė, 2011; 2020).

The mentioned works describe the presented theory in details, thus in the current paper there is no need to repeat all the related elements. This adequate portfolio theory is applied to investment decision-making in current research.

Most real-world decision problems involve uncertainty. The same is with investment portfolio selection. Thus, it is already an extensive perception that portfolio optimization should be a stochastic process (Ekblom & Bloomvall, 2019; Post et al., 2018). Separate works have been written on stochastic portfolio theory (Buła, 2020; Cuchiero, 2019; Fernholz, 2002; Pal, 2019). The adequate portfolio methodology used in this paper fully considers the stochasticity of investment return, as it uses the whole probability distribution of forecasted return, not only its mean value.

Expert systems are also often applied in portfolio construction. Usually, we can see fuzzy expert systems applied to portfolio decision-making and uncertainty management in investment problems. For example, Fasanghari and Montazer (2010) proposed a fuzzy expert system for selecting superior stocks to encounter the uncertainty of stock portfolio recommendation and model the recommendation rules which experts at Tehran Stock Exchange (TSE). Yunusoglu and Selim (2013) also developed a fuzzy rule-based expert system to support portfolio managers in their middle-term investment decisions. Bogachov et al. (2020) draw attention to the significance of artificial intelligence components and fuzzy regulators in the decision-making process. Thus, we will apply a certain type of expert system in our research, namely a scheme of stochastically informative expertise and ranging.

3. Research methodology

The overall objective of the performed research is the attempt to contribute to the possibilities to train the sustainability of the investment powers development in terms

of investment intelligence, as well as in terms of efficiency. The selected objective entirely coincides with the investment rules. The invested monetary power in the selected period should create the return vector attaining the highest amount of value-added with regard to its stochasticity and investors' risk resistance. This is a rather complex problem that requires a quantitative assessment of the investor's risk acceptance. Thus, selecting the portfolio stocks should concentrate our attention on their riskiness and capability to generate higher value-added.

Often discussing the global goals and long-term perspectives, we forget the value of the stepwise attempts while implementing these goals. Nor do we pay attention to the fact that the most efficient creative work and development results originate in relatively short but very favourable time intervals. Probably it is natural that the majority of the research directly concentrates on the so-called continuous space. Here the problems of the causes and effects recognition and assessment, as well as possibilities of relationships disclosure and consequence measuring, are revealed adequately. In such a way, usually, the assumptions of efficient management are being formed.

The provisions and instruments to reach the main goal assume selecting the most suitable share or a set of shares in a portfolio. In turn, the selection and management of the solution demand continuous monitoring. It is checked whether the risk of decreasing the generated return in a portfolio (the formed set of stocks) accumulates and a threat to the investor's interests – to have a return of no less than a certain level – arises.

Further, we will disclose and structure the objectives, knowledge, information, sources, actions and interaction needed to solve the stated problem and visualize the results of the solution. We will do this by applying the scheme and a set of steps.

Figure 1 presents a structuring of the stochastic expert system.

In steps 2 and 3 of the proposed expert system, the portfolio logic and technique is used. In this case, it is an adequate portfolio already mentioned earlier in this paper. The model assesses the investment possibilities according to three parameters: return, risk and reliability. Reliability is an element used to analyse uncertain and risky situations. We can often hear that risk and reliability management problems are similar. But, these are different problems of stochastic phenomena cognition. We can always determine the stochastic phenomena' riskiness (let us treat it as a discrete stochastic value X1 for convenience), which is measured in its standard deviation (1).

$$STDEV = \left(\frac{1}{n} \sum_{i-1}^{n} (x_i - \bar{x})^2 \right)^{0,5} \tag{1}$$

Along with that, we can determine the structure of the reliability function (2).

$$R(x_1), R(x_2), \ldots, R(x_n) \tag{2}$$

here $x_1, x_2, \ldots, x_n$ – are the possible values of the random number, $\bar{x}$ is their arithmetic mean, $R(X_i) = p\{X_i > {}_{xi}\}$, $i=\overline{1,n}$ – reliability functions.

The reliability function structure reveals another, probably more constructive perception of the random number that can be seen while measuring risk by standard

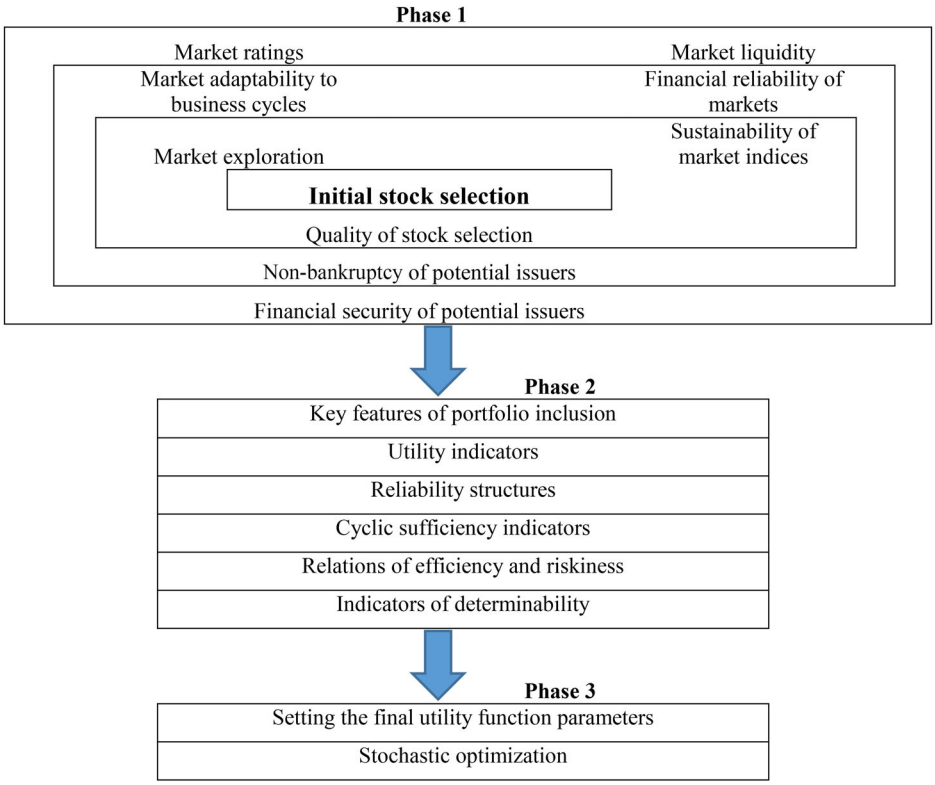


Figure 1. Structuring the expert system for assets, issuers and market selection. Source: Compiled by authors.

deviation because the probability $P\{X_i > x\}$ is a natural measure of the possibility's reliability Xi. However, it is worth noticing that using any of these features also the random number itself can be revealed as a probability distribution.

Every probability distribution can be expressed by three usually applied forms: density function, accumulated density function and reliability function. In a discrete case, formally, every form can be expressed as follows:

- density function – $P(X_i) = p(X = X_i)$, $i = \overline{1, n}$;
- accumulated density function – $F(X_i) = P(X \leq X_i) = \sum_{X_j \leq X_i} p(X = X_i)$;
- reliability function – $R(X_i) = p(X > X_i) = 1 - F(X_i)$.

These forms of the probability distribution are used while optimizing the portfolio.

In order to reveal the contents and possibilities of the adequate portfolio, it should be treated as an amplification to the modern or Markowitz portfolio (Markowitz, 1952). We can simply explain the Markowitz portfolio as follows. Let us have n investment assets $A_1, A_2, \ldots, A_n$ that is the possession of a subject (investor) and generate him revenues expressed in random numbers: $a_1(\alpha_1, \sigma_1), a_2(\alpha_2, \sigma_2), \ldots, a_n(\alpha_n, \sigma_n)$. Here α_i and σ_i are the mean and standard deviation of the random number, respectively. The investor can decide how to allocate the capital intended for investment among the separate assets. It means that he should select the proportions

$w_1, w_2, w_3, \ldots, w_n, \sum_{i=1}^{n} w_i = 1$, according to which all the capital should be distributed among the assets. In other words, w_i are parts of the monetary unit. In order to determine the best diversification possibilities of investment capital, it is worth analysing all the possibilities of the possessed capital allocation among assets (3).

$$\begin{aligned} &w_1^1 a_1 + w_2^1 a_2 + \ldots + w_n^1 a_n = S^1 \\ &w_1^2 a_1 + w_2^2 a_2 + \ldots + w_n^2 a_n = S^2 \\ &\ldots \\ &w_1^m a_1 + w_2^m a_2 + \ldots + w_n^m a_n = S^m \end{aligned} \tag{3}$$

In order to find the best diversification case of investment capital, we need to revise all the possibilities of structural allocation. i.e. to demand that structural vectors $\{w_i^j\}, i = 1, 2, \ldots, n; j = 1, 2, \ldots, m$ would reflect all the capital allocation possibilities among the selected investment assets. Practically, the assessment of the capital possibilities is performed using the following calculations (4).

$$\begin{cases} w_1^1 a_1 + w_2^1 a_2 + \ldots + w_n^1 a_n = S^1 \\ w_1^2 a_1 + w_2^2 a_2 + \ldots + w_n^2 a_n = S^2 \\ \ldots \\ w_1^m a_1 + w_2^m a_2 + \ldots + w_n^m a_n = S^m \end{cases} \tag{4}$$

Here $\left(\sum_{i=1}^{n} w_i^j = 1\right)$ for every $j = 1, 2, \ldots, m$; S^j, $j = 1, 2, \ldots, m$ are variously diversified portfolio values obtained as functions of the assets and distribution coefficients. These are random numbers with their parameters – mean, standard deviation, variance, quartiles, deciles and other quintiles. They, in turn, directly depend on the probability distributions of assets' possibilities and their interrelationships.

For optimal decision-making in the adequate portfolio, the utility function is being used. This is a three-parametrical utility function. The analytical expression of the function is as follows (5).

$$U = \exp\left(\frac{e}{r}\right) \times g \tag{5}$$

Here U is the utility level of a possibility; e – profitability (return); r – risk; g – guarantee (reliability).

Based on the adequate portfolio formation logic, the guarantee of every return possibility is analysed, and it is described as a probability that investment return will not be lower than a certain level. Such a decision-making approach allows us to fully reveal the investor's utility function's interrelation of return guarantee and risk.

Following the structuring, basement and presenting of historical selection data using visualization tools is described. The scheme will be described in textual form due to the large volume of data to be delivered.

Our named stock links to businesses, issuers, investment process managers, and direct stockholders must also track contact information. Experimental calculations often focused on a 30-stock set. For this number of shares, all available detailed valuations have been prepared. Therefore, it can be considered a Standard for conducting

time-consuming calculations with your own goals formulated during the interview. The total number of shares to be considered may vary.

So, below we will present the thirty stock-based solutions, i.e. we will start with 30 stocks of 100 days and 100 weeks of historical data presentation and by scrolling further, we will present the historical data transformations required by the sequential search for a solution with the following numbering:

1. *The initial selection of historical data*

As mentioned above, here are 30 stocks with 100 daily and weekly historical prevaluations and know-how selected from the portfolio to help you meet your objectives.

2. *Several shares were selected for the most appropriate portfolio objectives through stochastic informative expertise and ranking systems.*
3. *Factology of stepwise growth.*

In the introduction, we will also mention that we will pursue our objectives through a stepwise approach to investing. And the technique of stock performance and investor utility decisions mentioned in the previous paragraph directly requires us to have stepwise stock price volatility indicators and fully-fledged statistics for decision making. Thus, before specifying a solution, it is necessary to consider the content of the paragraph title, all the more that certain step-growth statistics determine the location of the solution.

4. *Embedding risk hedging tools in the portfolio's strategic objectives.*

This can be said to be the pivotal moment in which 30 more shares were selected using more general economic and managerial criteria. Now, we have to remember that in reality, equities function in three-dimensional space – opportunity, reliability and risk. What's more, the interests of investors and stock options are constantly being matched in the market in the same language, which allows the stochastic optimization methodology to allow the investor to see the stock that promises him the best value.

5. *Forecasting and solutions*

Investment success is a dual phenomenon where chance proves its existence perfectly. When deciding where to allocate our solution, it is essential to employ adequate and adaptive forecasting methods and even more careful attention to the investing entity's resistance to risk power.

6. *Stepwise solving trajectories and their confidence zones.*
7. *Geometric images of these areas are informative tools for monitoring the development of investment results and gaining management experience.*

4. A detailed description of the goals and capabilities of each stepwise solution and the presentation of the experimental results

This section will analyse the investment decision-making in German, USA Chinese and currency markets in 100 days and 100 weeks. Decision-making has been performed according to the following sequence:

1. Inadequate daily return for all stocks was transformed to the 'stop-loss' limitation, taking into account the price of such limitation;
2. Further, using the transformed historical data and ranging algorithms intended to determine the stock adequacy for the investment portfolio, we select the most suitable group of stocks for the investment;
3. During the investment decision-making process, we select the highest return-giving shares out of 30 for further decision-making, and then on each step (a day or a week) we usually select particular shares to invest in. Thus, we forecast not the obtained return with the final step but the share indicating the highest return.

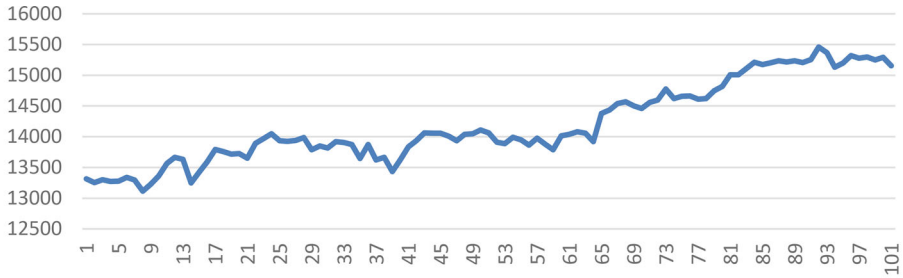
Considering the nature, sources, and ways of gathering and processing of the used information, it is worth noticing that in many cases, the key sources of the principal indicators are directly the international organizations that watch and record the data. In essence, these were the indicators of the stock price change in the world markets. They are unambiguously perceived as stochastic values or processes. The following prerequisite was checked: whether a set of historical stock price data can be treated as a stochastic vector that conforms to the triangle probability distribution or the canons of other probability distributions. The presented views of confidence intervals were formed using their accepted construction technique.

The stock ranging was implemented using the publicly available ranging system in MS Excel. The features of stock utility for the investment portfolio efficiency were also identified as the vector change's classical characteristics. However, special attention has been given to the qualities of random numbers generated by the annual growths of the stock-generated return, as well as for the possibilities to form the portfolio adaptivity to the positive investment decisions under changing conditions. It was necessary to take into account the purpose of orienting towards the highest return-generating stock on every step.

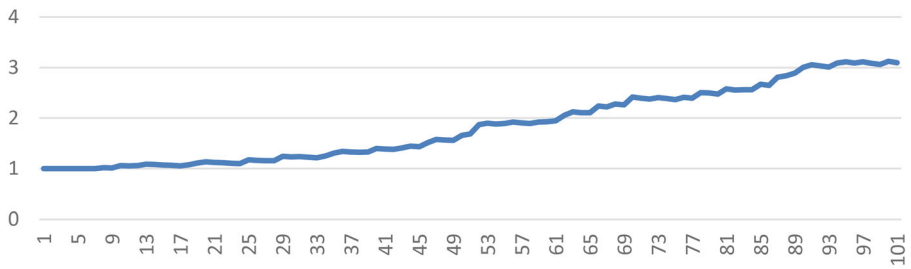
Particular attention has also been given to the possibilities of the 'stop-loss' system to equate the investment return increase with the costs required to implement it. It was performed by simulating the transformation process of the generated portfolio return with the help of the developed model, as well as assessing the possibilities of the 'stop-loss' capability ensuring.

In this article, without arguing the need for an opportunity for fundamental research, we will attempt to discover, through the principles of digital visualization, so-called proximity patterns and use them to find successful investment solutions.

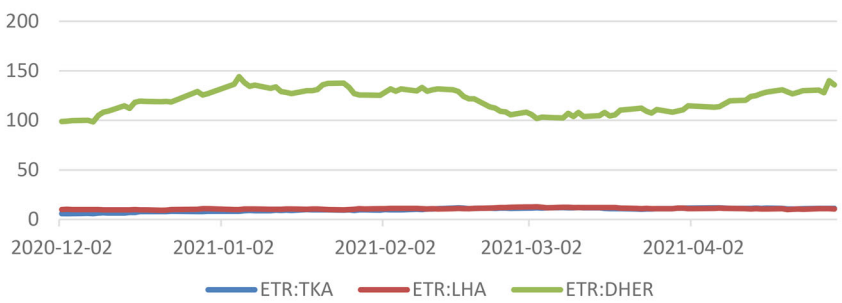
Thus, we will use the software at our disposal to provide the results of efficient investment solutions, using stochastic informative expertise and ranking capabilities, digital visualization techniques of alleged regularities, statistical forecasting capabilities and relevant statistics. Using the most recent data from the capital and currency



Section 2.1. German GDAXI index



Section 2.2. Optimal growth of portfolio returns over the selected 100-days period.

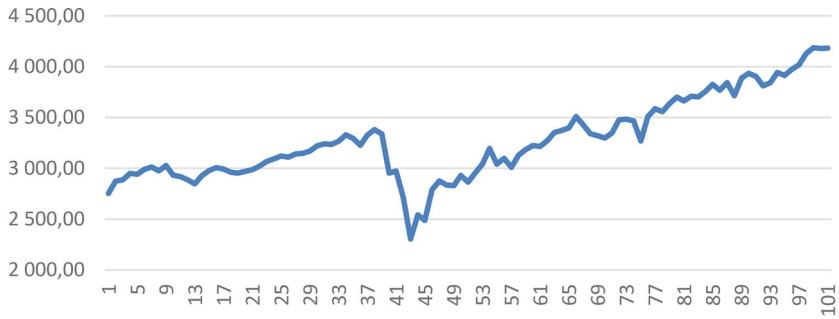


Section 2.3. The price dynamics of three stocks generating the highest return

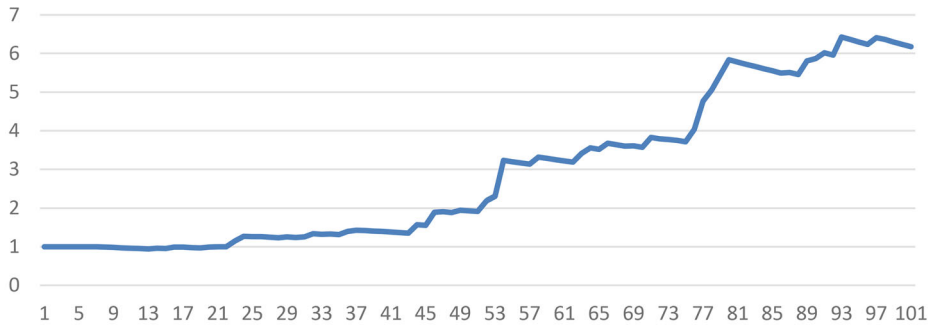
Figure 2. The German financial market.
Section 2.1. German GDAXI index.
Section 2.2. Optimal growth of portfolio returns over the selected 100-days period.
Section 2.3. The price dynamics of three stocks generating the highest return.
Source: compiled by authors based on Yahoo Finance data.

markets, we will appeal to mitigate or completely avoid the effects of local financial crises while using historical data from the USA financial market 2008–2012 to illustrate solutions that may have made sense at the time. The results of the decisions, together with historical data, are presented in Figures 2–6: Figure 2 – German financial market, Figure 3 – USA financial market, Figure 4 – financial crisis period (USA market); Figure 5 – Chinese financial market, Figure 6 – currency market.

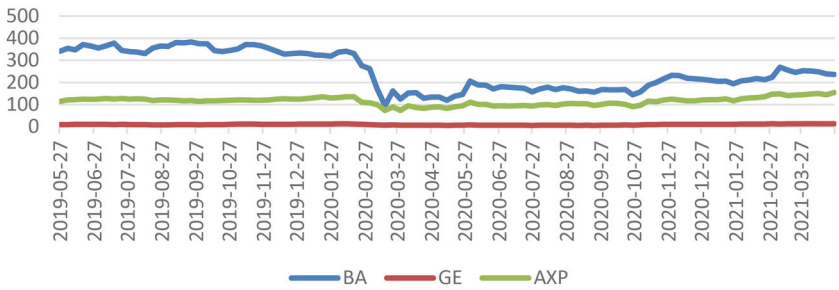
Here also a brief description of the figures is presented. Figures 2–5 give the following information about the characteristics of the country/entity under consideration:



Section 3.1. USA S&P 500 index



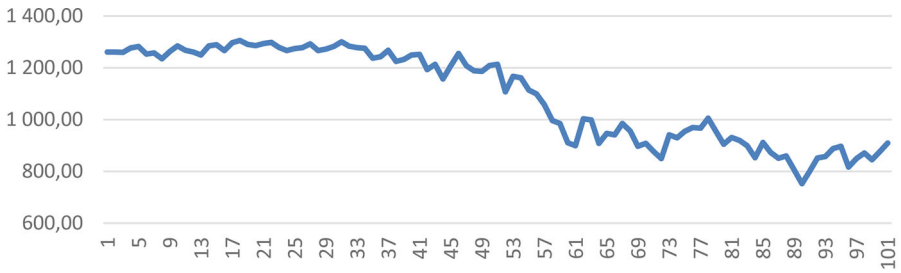
Section 3.2. Optimal growth of portfolio return over the selected 100-weeks period



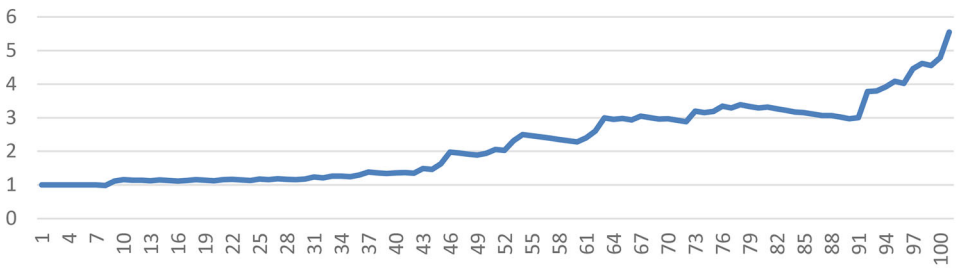
Section 3.3. The price dynamics of three stocks generating the highest return

Figure 3. USA financial market.
Section 3.1. USA S&P 500 index.
Section 3.2. Optimal growth of portfolio return over the selected 100-weeks period.
Section 3.3. The price dynamics of three stocks generating the highest return.
Source: compiled by authors based on Yahoo Finance data.

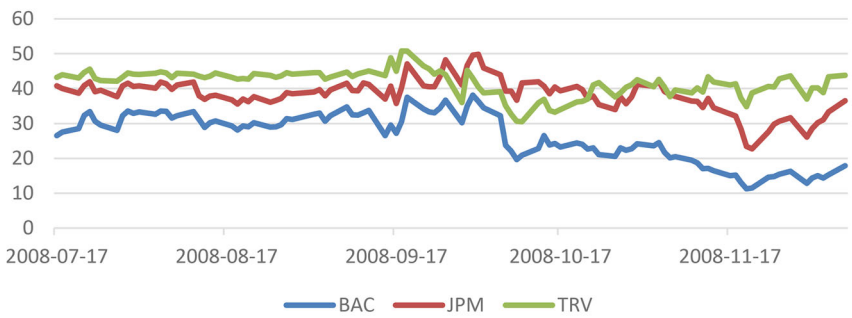
1. The variation of the index of the market under experiment during the period under review.
2. Possibility of the maximum trajectory of the three stocks (one stock on a particular step) returns to be generated within the 100 days or weeks.
3. Three stocks generating the highest return in a portfolio.
4. 30 stocks initially selected for a portfolio (only in USA market during the crisis period).
5. Calendar and other information.



Section 4.1. Dynamic of the average return generated in the USA financial market during the financial crisis (S&P 500 index)



Section 4.2. Optimal growth of portfolio return over the selected 100-days period

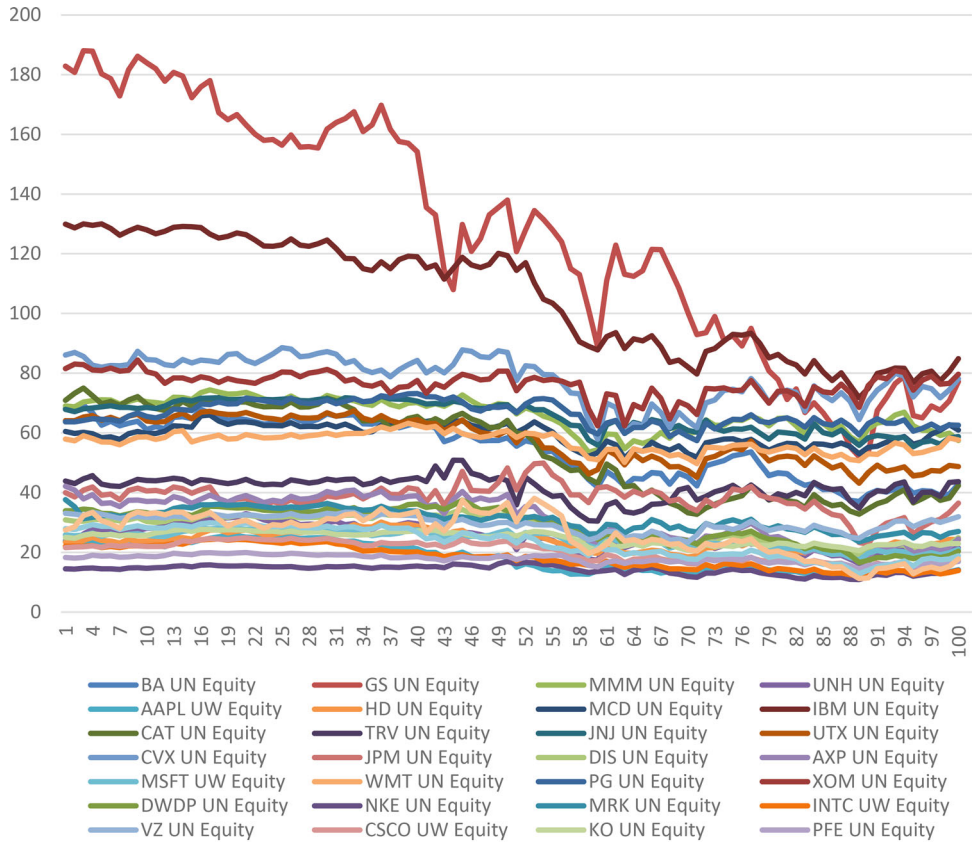


Section 4.3. The price dynamics of three stocks generating the highest return

Figure 4. The financial market of the USA financial crisis period.
Section 4.1. Dynamic of the average return generated in the USA financial market during the financial crisis (S&P 500 index).
Section 4.2. Optimal growth of portfolio return over the selected 100-days period.
Section 4.3. The price dynamics of three stocks generating the highest return.
Section 4.4. The price dynamics of 30 stocks initially selected.
Source: compiled by authors based on Yahoo Finance data.

Below we present all the markets mentioned:
Calendar information of the German market:

- 100 days periods (2 December 2020–29 April 2021).
- The theoretical growth per the whole period is 3.09 times, while the growth of the index is 1.14 times.



Section 4.4. The price dynamics of 30 stocks initially selected

Figure 4. Continued

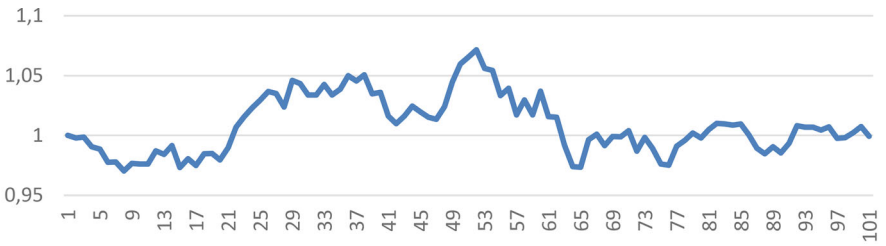
- The 1-sigma confidence interval of the return ranges from 2.39 to 3.79.
- The stocks analysed are TKA, LHA and DHER.
- Transaction costs constitute 0.3 percent.

Calendar information of the USA financial market:

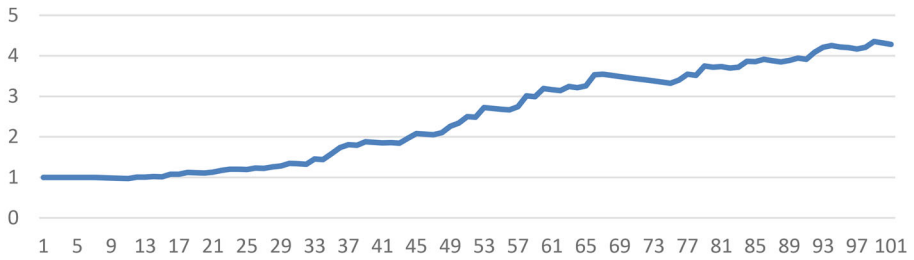
- 100 weeks periods (30 May 2019–29 April 2021).
- The theoretical growth per the whole period is 6.17 times, while the growth of the index is 1.52 times.
- The 1-sigma confidence interval of the return ranges from 4.24 to 8.11.
- The stocks analysed are BA, GE and AXP.
- Transaction costs constitute 0.5 percent.

Calendar information of the USA financial market in the period of crisis:

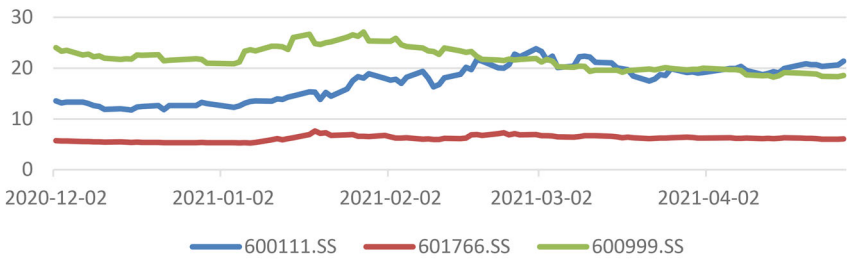
- 100 days periods (17 July 2008–10 December 2008).



Section 5.1. Shanghai Composite Index



Section 5.2. Optimal growth of portfolio returns over the selected 100-days period



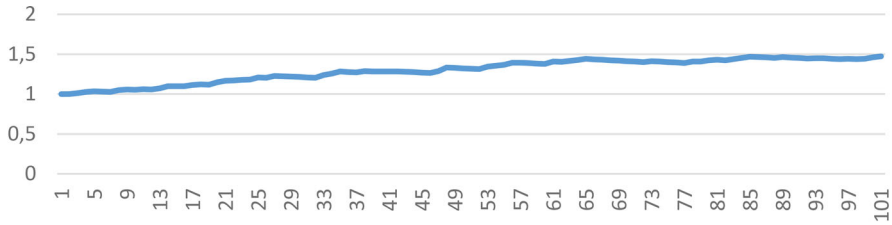
Section 5.3. The price dynamics of three stocks generating the highest return

Figure 5. The Chinese financial market.
Section 5.1. Shanghai Composite Index.
Section 5.2. Optimal growth of portfolio returns over the selected 100-days period.
Section 5.3. The price dynamics of three stocks generating the highest return.
Source: compiled by authors based on Yahoo Finance data.

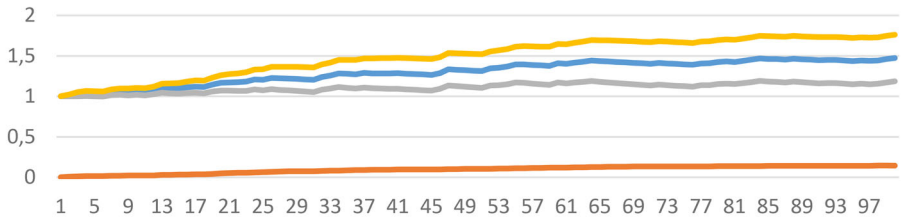
- The theoretical growth per the whole period is 5.54 times, while the growth of the index is 0.72 times (decrease).
- The 1-sigma confidence interval of the return ranges from 4.45 to 6.63.
- The stocks analysed are BAC, JPM and TRV.
- Transaction costs constitute 1 percent.

Calendar information of the Chinese market:

- 100 days periods (2 December 2020–29 April 2021).
- The theoretical annual growth per the whole period is 4.28 times, while the growth of the index is 0.99 times (decrease).
- The 1-sigma confidence interval of the return ranges from 3.13 to 5.43.



Section 6.1. Optimal growth of portfolio returns over the selected 100-week period



Section 6.2. Return growth confidence zone and risk dynamics of the portfolio

Figure 6. Foreign Exchange market.
Section 6.1. Optimal growth of portfolio returns over the selected 100-week period.
Section 6.2. Return growth confidence zone and risk dynamics of the portfolio.
Source: Compiled by authors.

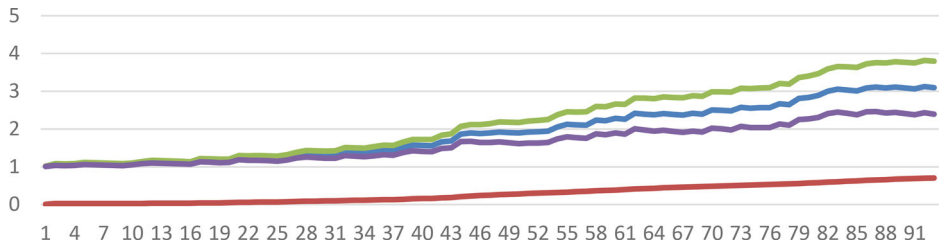


Figure 7. Return growth confidence zone and risk dynamics of the portfolio: German financial market. Source: Compiled by authors.

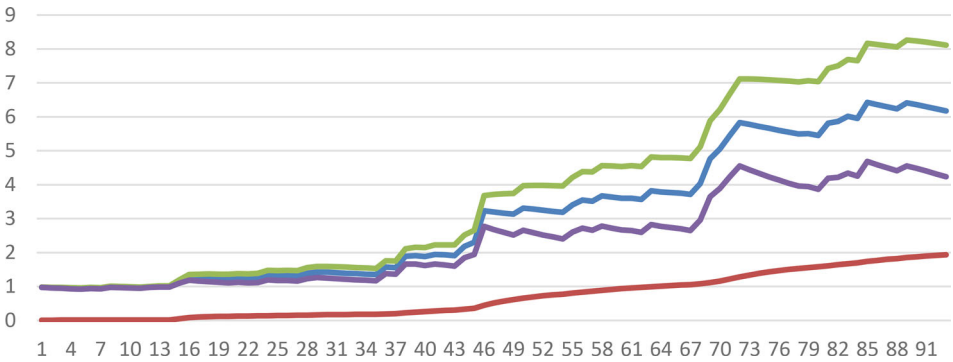


Figure 8. Return growth confidence zone and risk dynamics of the portfolio: USA financial market. Source: Compiled by authors.

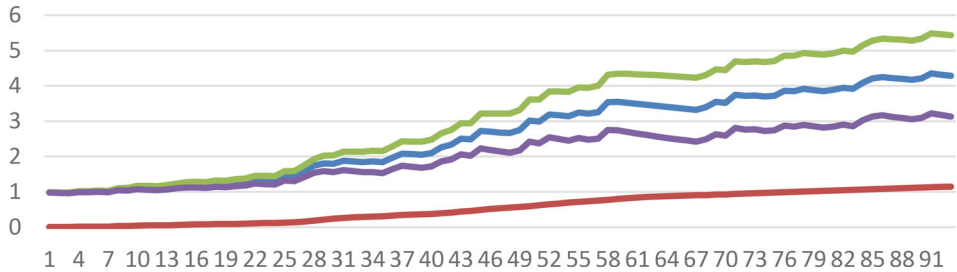


Figure 9. Return growth confidence zone and risk dynamics of the portfolio: Chinese financial market. Source: Compiled by authors.

- The stocks analysed are 600111.SS, 601766.SS and 600999.SS.
- Transaction costs constitute 0.3 percent.

Calendar information for the foreign exchange market:

- 100 weeks periods (21 December 2017–6 January 2019).
- Theoretical potential annual growth of the invested unit is 2.89 times.
- Transaction costs constitute 0.3 percent.

Having formulated sufficiently ambitious objectives in the introduction to achieve consistently high trajectories of return on investment, by transferring a significant component of the risk management function to operational investment management tools, we present a set of subjectively in the first paragraph organizing-digitalized presentation. This has allowed us to see and understand a portfolio's ability as an organizational system to generate a return on investment under quite a variety of conditions.

We want to discuss provisions, objectives, statistical and information provision and the proposed problem delivery and resolution formats, which are purposeful or even necessary to address the escalating problems in complex situations.

5. On the specific features of the operation and management of the investment system under consideration

5.1. Stochastic manner

In the last part of the article, it was noticed that thinking, analysis, and decisions are made using in a stochastic manner in this work. Thus, the historical data we choose, the expert judgment and the solutions we make must be seen as stochastic magnitudes, stochastic processes and stochastic fields. This is not an exclusive requirement for understanding the job. The knowledge and methods of probability theory and mathematical statistics, which comprehensively cover various aspects and moments of thinking and quantification, allow for efficient use of stochastic thinking manners. In the following, we would just like to highlight those moments or situations that, without exploring the possibilities of probability theory and mathematical statistics, would cause additional problems. In this context, solving management decision-making

problems, which can be described as a discussion with the future, is likely not to turn any process into a vision of the future without a quantitative view of that process's physical capabilities and the probability of their reliability.

5.2. Stochastic utility function, stochastically informative expertise and ranking and stochastic optimization

We have already mentioned that when designing investment solutions, i.e. speaking or just negotiating with a prospect results in a level of credibility that is almost equivalent to the scale of the results sought. Thus, already in this two-dimensional plane, we can think of the most beneficial global development strategies using stochastic utility functions. Naturally, then, one must also have an understanding of stochastic utility or simply stochastic utility functions.

Finding the objectively stochastically optimal solution is quite complicated both in terms of adequate assessments of the real situation, constraints on output and dynamics and in terms of the compatibility of indicators reflecting objectives. There is also the problem of choosing the appropriate methods for solving these difficult situations. This complex system of complex problems was solved in this thesis by using the intelligence accumulated in the financial data historical data arrays and formed regularities of the return on investment and the simulation possibilities of the stochastic neural network.

5.3. Testing opportunities for historical transformation and perspectives

Backtesting of historical facts, dependencies and data is carried out in the specification of the investment decision. We will briefly present how information accumulated in historical data and structured wisdom is used to conduct a quantitative conversation with future objectives and opportunities. First, the following information for the subjective understanding of markets, issuers and shares is collected:

1. Accumulating information about the business represented by the portfolio shares, its viability and efficiency;
2. Information on issuers, managers and markets in which shares are held and which are in trading progress;
3. Expertise, ranking and selection of the portfolio for the first step of the portfolio is carried out.

Next, a quantitative view of the evolution of objective financial market processes is being formed using the following information:

1. The formation of the value of shares and their interdependence with the business characteristics represented by the shares, as well as their dependence on significant financial and economic events;
2. What type of portfolio should become the address of the specific stock presence;
3. How are the inheritance regularities of stock value changes formed.

The latter property of value change regularity was used in this article as follows. Using the last k of the n available historical data for each share, each share's first forecast value was predicted. Unfortunately, the following scheme was used to test this prediction under the so-called historical data testing scheme. Selecting the first values of historical data k compares (tests) with the historical significance of $k+1$. This is the first step in back-testing to show how our forecasting system aligns with market behaviour. Next, moving the historical data for each stock, forecasting and forecasting one unit, we take the second step of back-testing. And so on until we get to the last n-th historical indicator. As we traverse the full array of historical data, we have seen how our stock choices' environment and interactions have changed over time. At the same time, we have become aware of our investment system's capabilities.

Further realizing that the n-k steps were only pseudo-steps, we begin the real step. And now, the next investment step, using the last k-lines of historical stock data and all the information gathered in back-testing, is becoming the first real investment step.

Note. Seeing the informativeness and usefulness of back-testing, we can reapply those opportunities in preparation for the second investment step.

5.4. Assessment of equity portfolio as preparation of investor opportunities

Before specifying the answer to the question above, it is useful to take a deeper look at the capabilities of a portfolio as an analytical framework to explore the real-world complex, multidimensional, multisectoral, multicriteria systems, generate unique perspectives, helps to become a pragmatic consultant for the optimal alignment of personal powers and objectives.

Portfolio ideology and the principles, methods and means of realizing an adequate (stochastic nature of the returns generated) investment portfolio have been the main tools for understanding, analysing and deciding this research. The primary objective has been to disclose maximum return generation opportunities within fairly general conditions and limitations. The results of the problems examined for this purpose are listed in Section 4.

When attempting to comment on results obtained in named markets or in a set of other markets where similar calculations have been made, returns are often referred to as 'unlawfully' high, appealing to return trajectory indices or the like. Here, in our opinion, one should look more closely at reality. There is probably no doubt that the units invested are divided into groups (i.e. clustering) in all markets, where the levels of return are very different. Therefore, the results of receivable returns should perhaps be compared with those that generate prestigious returns. In turn, those offering should be aware of it.

So, once again, looking at the results generated by the investment portfolio in Section 4 and not being frustrated that these are quite typical results for a wide variety of markets, one has to accept that only adaptive stochastic expertise and ranking systems are sufficient to obtain them. True, it must be remembered that no investor was mentioned here as the owner of the investment. Perhaps the desired results are

not satisfactory for him, or the path to even such results is too risky. Therefore, we will further test portfolio options into a space that necessarily considers both investor's aspirations and market capabilities to deliver the results with acceptable risk for the investor and investor's risk resistance.

6. The characteristics, objectives and results of the actual investment steps in relation to the investor's objectives and capabilities

Before analysing the ways and methods of achieving the entities' objectives, we must remind that in each case, the key function of determining the solution will be the utility function of the navigating entity, which necessarily takes into account the extent of returns and their risks. At the same time, we would like to point out that in sports terms, investment to one (understandably the best) share is a relay rase that is carried out by all the shares running together and passing the 'wand' of the investment resource to the best moving share.

As the first step in this direction, we will choose to testify how a particular portfolio management strategy can influence the receivable return trajectory. In Section 4 we have illustrations of return opportunities where the portfolio strategy was to maximize return without imposing any additional conditions. Let you compare these results with those used in this context in a so-called oppositional investment strategy when the growth potential is simply divided by the riskiness of that stock. We will provide portfolio feasibility assessments for the German, USA and Chinese markets, respectively while noting that the trajectory the portfolio generates is determined here in the search for maximum return growth opportunities at each weekly market step. Also, the stochastic expertise and ranking scheme of the 30 pre-selected stocks were used to select the best performing portfolio for the portfolio. In contrast, the stochastic optimization approach focused on the most beneficial stock.

Thus, in order to have a reasoned debate on the issues identified, we will choose the two investment criteria that we consider to be oppositional. The first one will be the one that can use the highest-yielding shares, the second one will be the one that can generate the highest return for each of its risk units. The results obtained according to the first criterion are included in paragraph 3. Here we present the opportunities of the German, USA and Chinese markets using the second criterion.

The following is an assessment of the three markets' portfolio options – Germany, USA and China, with only three stocks left in the portfolio. We will present a figure for each market showing the standard deviation and return confidence zone for the selected stocks, representing the return utility for the investor (Figures 7–9). Next, Table 1 presents examples of the structure of portfolios in three mentioned markets at the beginning and at the end of the investment period. In that table, 1 means the whole sum is invested into that stock on a particular day/week, while 0 means no investment is made in that stock. Also, certain statistical information about the stock's portfolio can be summarized in Table 2 – the most expected theoretical growth value and confidence intervals of 1-, 2- and 3-sigma.

Now, before opening our calculations to the opposition criterion we set out and starting to compare them with the ones just presented, it should be emphasized that

Table 1. Comparison of portfolio structure in three markets.

Days/weeks	German market			USA market			Chinese market		
Stocks	TKA	LHA	DHER	BA	GE	AXP	600111.SS	601766.SS	600999.SS
1	0	0	1	0	0	1	0	0	1
2	1	0	0	1	0	0	0	0	1
3	1	0	0	0	1	0	1	0	0
4	1	0	0	0	1	0	0	0	1
…	…	…	…	…	…	…	…	…	…
98	1	0	0	1	0	0	1	0	0
99	1	0	0	1	0	0	1	0	0
100	1	0	0	1	0	0	1	0	0

Source: Compiled by authors.

Table 2. Portfolio comparison – the statistical information.

	Data	Theoretical growth	−1 sigma	+1 sigma	−2 sigma	+2 sigma	−3 sigma	+3 sigma
German market	Daily	3.09	2.39	3.79	1.69	4.50	0.99	5.20
USA market	Weekly	6.17	4.24	8.11	2.30	10.05	0.37	11.98
Chinese market	Daily	4.28	3.13	5.43	1.98	6.57	0.83	7.72

Source: Compiled by authors.

those calculations we've just given have virtually failed to inform us of any imbalances in our investment decisions that could have happened for some reason.

To begin the discussion about the consistency of the results obtained and the flawlessness of the decision system, one has to recognize that the second of the opposition criteria focus on entirely different, low-return equities than the first, which is a natural decision of the subject or personality to opportunity fellow traveller. In all of the markets considered, criterion two significantly declines the level of the most probable trajectory of return opportunities, which for the market as a whole begins to approach the officially declared market index. However, it is true that the different markets' response to risk acceptance and risk avoidance also begins to unfold. However, we believe that these significant differences in expected (waiting) return require additional attention to understand clustering principles in financial markets.

Clustering stock market data is essential to analyse co-movements between stocks to make better investment decisions (Lahmiri, 2016). Clustering principles in financial markets have already been studied in some previous scientific papers. For example, Kocheturov et al. (2014) studied the dynamics of the cluster structures in the USA and Sweden financial markets, including crisis periods. Entire markets of commodity futures, currencies and equities can be joined into clusters (Lahmiri et al., 2017). However, the authors have not found attempts to form equities clusters according to the stock risk and return characteristics and investor risk/return preferences.

For a more constructive understanding of the problems in this direction or to see that clustering principles can reveal rational equity combinations regarding their productivity and risk compatibility and complementarity and their compatibility with the various types of investor risk avoidance. For this purpose, we will at least briefly look at what stock clusters our stochastic expertise and ranking scheme could generate.

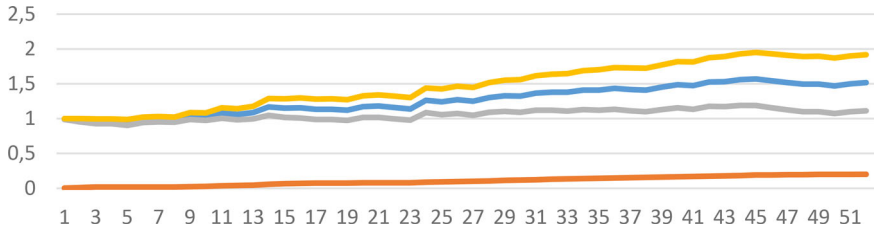


Figure 10. Confidence zone and risk trajectory for excellent IFV (rr.rp & rr) cluster return opportunities. Source: Compiled by authors.

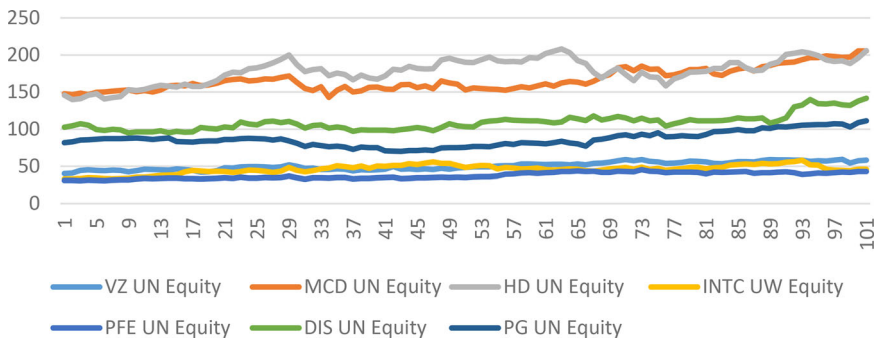


Figure 11. Excellent IFV (rr.rp & rr) cluster shares. Source: compiled by authors based on Yahoo Finance data.

Thus, we will begin this phase by clustering the financial market's return potential or simply the stock as a whole to distinguish clusters adapted to the strategies of individual investors with close risk resistance characteristics that focus on their cluster return on investment, i.e. it is a priority to divide market stocks into clusters where only relative investors based on their return/risks preference (rr/rp.) and risk resistance (rr) would form their portfolios. To this objective, we will use a stochastic expertise and ranking scheme to form a fourth stock cluster on the USA financial market, suitable for already established investor group quartet investors, who would base their portfolios primarily on eligible clusters. There is no doubt that only fully well-matched rr/rp and rr states can guarantee high future value for the investment solution in question.

Naming it very conditionally as an indicator of the investment future value (IFV) and noting the – IFV (rr.rp & rr) formed clusters, respectively: excellent IFV (rr.rp & rr), good IFV (rr.rp & rr), satisfactory IFV (rr.rp & rr), poor IFV (rr.rp & rr) clusters. The article contains only a chart of the excellent IFV cluster return and shares of this cluster to save space (Figures 10 and 11).

Assessing an experiment's success by clustering a selected large stock group into a small number of smaller clusters together pursues two objectives – first, to make market clustering a fundamental tool for improving market efficiency and, second, for clusters to become real 'addresses' of their investors. First of all, it should be noted that at least the first two clusters exhibit relatively equal opportunities to form investment portfolios capable of generating sufficiently high returns. The USA's financial

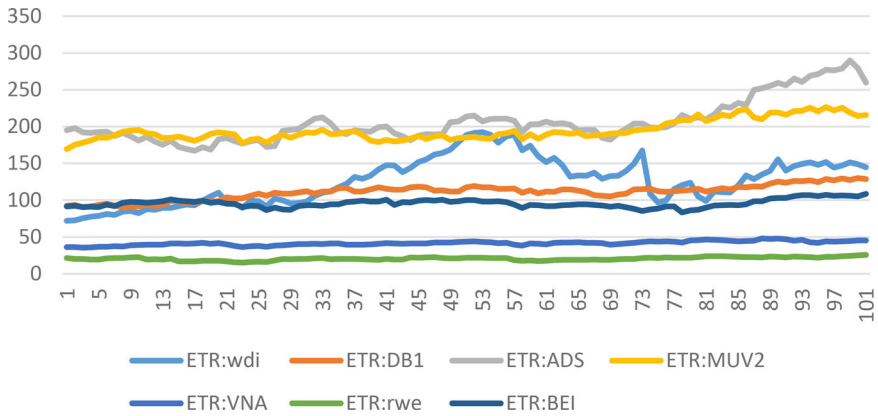


Figure 12. Excellent IFV (rr/rp & rr) cluster shares in the German market. Source: compiled by authors based on Yahoo Finance data.

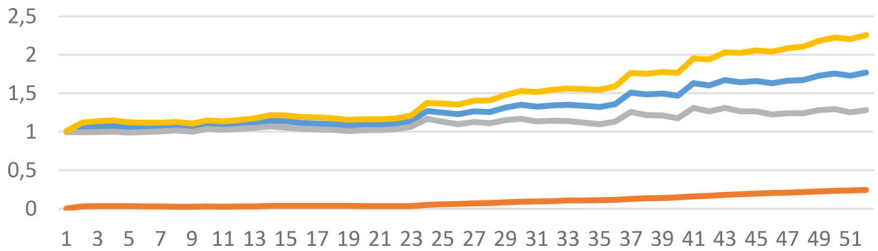


Figure 13. Confidence zone and risk trajectory for excellent IFV (rr/rp & rr) cluster return opportunities. Source: Compiled by authors.

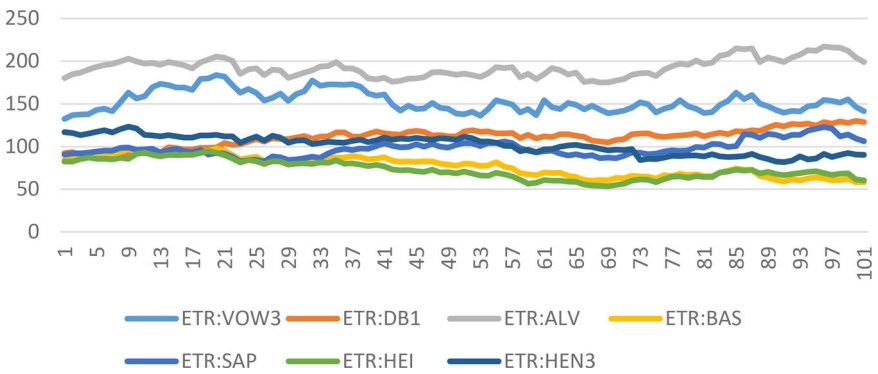


Figure 14. Good shares of IFV (rr/rp & rr) cluster in the German market. Source: compiled by authors based on Yahoo Finance data.

market shares are owned by the D. J index, among which low-yielding stocks are not quoted. Further, it must be accepted that the reasons why all distinguished clusters should be fully occupied do not appear. However, the visible result does not suggest that clustering is a meaningless exercise.

For more comprehensive view disclosure, it would be useful to look at least a couple of similarly formed clusters on the German market. Below are the stock setups

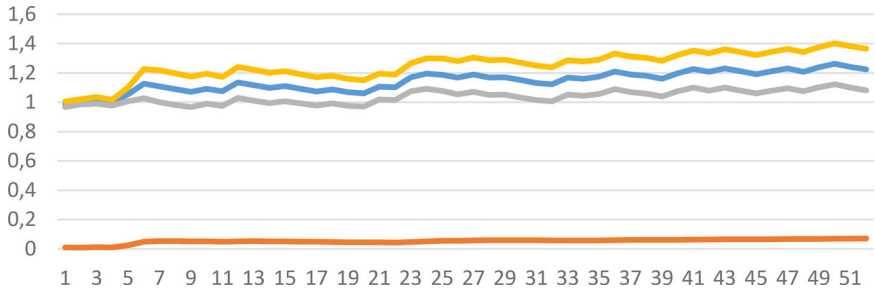


Figure 15. Confidence zone and risk trajectory for good IFV (rr/rp & rr) cluster return opportunities. Source: Compiled by authors.

for the so-called excellent and good IFV (rr/rp & rr) cluster and the trajectories of confidence and risk aversion for the German market (Figures 12–15). Here, quite typically, most markets focus on the efficiency of the very first – most representative cluster on the market. Here, annual return growth is 178 percent, with the risk trajectory rising to 24 percent. The conservative address of those who do not meet the first cluster's requirements is also quite non-repressive in its proposals. The good IFV (rr/rp & rr) cluster addresses a return of 122 percent, but the risk trajectory goes down to 7 percent.

It is like intriguing a priori assessments. All this was done using an adequate portfolio ideology and original decision-making methods developed by the authors themselves.

7. Practical implications

A curious situation about the practical application of the system is already formed when the authors' proposed asset intelligence system (AIS), using only a finite number of historical data steps, allows to see quite favourable results of generating high return opportunities in the following steps, guaranteeing success throughout the analysed period. Such options have been tested through backtesting across a range of markets for different investment instruments and under different market efficiency conditions and over very different historical periods. The effect is quite high and, apparently, allows us to talk about increasing investment efficiency. Thus, it is necessary to consistently check that the construction of the decision system is not based on any assumptions that are unacceptable for market behaviour, both in the provision of investment instruments and other calculations that are not adequate to reality. Of course, it would be most favourable for the authors not to detect fundamental errors or to find those that are correctable.

Thus, when discussing the declared rather unusual investment goal - to use the only stock indicating the highest return on investment in the next step, it can be jokingly said that even the 'investment constitution' does not support such a choice. In addition, it is worth to point out that with the total amount invested in one share, there is a reasonable 'stop loss' order on the real investment platforms with that share. The only stock is not an absolute necessity, but only a basic principle. As already mentioned, a specially designed AIS serves as the insight of the highest

return possibilities. This system is also capable to monitor whether there is a need to change the share, although it would be more appropriate to say whether it is still possible to stick to the share held, because the price of the change in the leading share is usually high. However, the insight of AIS makes it possible to achieve the efficiency in question.

Talking to brokers, it seems that it has been revealed that today's programs regulating the development of market decisions practically do not have a 'stop-loss' complex, which would provide an operational balance between efficiency and risk. The possibility of such harmonization is based on the system we propose. Therefore, the possibilities of using the system currently offered are actively combined with the possibilities of 'trailing stop loss' operating in the trading system. This will enable the trading platform to ascertain the capabilities of our proposed investment system.

8. Conclusions

1. The success of an investment portfolio should be based on the ability of the portfolio to identify the objectives, capabilities and dynamics of the investment market itself, leverage the market as an adaptive complex system to respond to business viability, cyclicality and interactions of AI capabilities in a variety of portfolio management services.
2. The investment portfolio must have stochastics as a means of discovering and shaping the interaction with the future in the manner of seeing, evaluating and deciding, and perhaps, first of all, paying attention to the full-scale understanding of the scope and credibility of opportunity.
3. Disclosure and utilization of portfolio as a market clustering tool to reveal market and investor cluster interaction efficiency are particularly relevant or simply necessary. Investors (individuals and entities) expect a complete set of optimal investment decisions or simply practical tools to formulate optimal investment strategies.
4. Expertise in a combination of a high-return investment strategy with a versatile system of necessarily high-risk, cumbersome restraints informs such a composition's performance. Testing past and future opportunities insufficiently different investment markets and even when they are in various states of their efficiency cycle has demonstrated sustainability to generate sufficiently high levels compared to investment returns caused in other activities.
5. Practical backtesting experiments in stock and currency markets allowed us to reach the following portfolio growth: 3.09 in German stock market, 6.17 in USA stock market, 5.54 in USA stock market during the financial crisis, 4.28 in Chinese stock market, and 2.89 in currency market. These results significantly outperform the stock market indices during the respective time period.
6. Experimental attempts to find efficient investment opportunities in different markets and at the same time try to see the basics and principles of stock clustering in different markets as well, forced us to focus on our stochastically informative portfolio analysis and ranking system.

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