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Optimization of the Investment Portfolio in the Environment of Table Processor MS Excel

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ABSTRACT

This topic's study is due to modern challenges to ensure sustainable development in a volatile market environment. It is especially so for those who want to invest money to generate additional income, taking into account financial risks. For this, it is necessary to increase the level of use of information computer technologies to minimize financial risks. The work's practical significance is based on the analysis of mathematical models used in the formation of investment portfolios. For the first time, a comparative study of investment portfolios containing various types of assets in the Ukrainian economy (particularly cryptocurrency) was carried out, and their residual risks were analyzed. Optimal investment portfolios for direct and inverse problems have been formed. For the optimal use of savings and consideration of factors affecting the adoption of final investment decisions, the necessity of applying modern mathematical models and the capabilities of information computer technologies has been substantiated. Applied solutions are associated with processing a large amount of information, including in tabular form. Also, a significant part of these tasks is associated with optimization, and therefore the use of information technology is essential. One of these programs is a universal MS Excel, which can handle the tabular data and optimize both linear and nonlinear problems with the «Solver» and analyzed by the «Sensitivity» tool. Table processor MS Excel allowed processing tabular data using mathematical and statistical functions for working with matrices. For ease of use of the table processor features, a program was created in the VBA environment to install and select the parameters of the optimization models. The investment portfolio's optimal structures were calculated from the considered assets, which provide the maximum possible profitability at a given risk level (direct problem) or the lowest potential risk at given profitability (inverse problem). As a result, the investment portfolio's direct and inverse optimization problems were solved using the quasi-Sharpe model. All this allows the spreadsheet processor to be widely used both by professionals.

Keywords: investment portfolio; financial risks; financial arrangement (mehanizm), sustainability.

JEL classification: G32, C65, D24, F21, M21, O12, O42

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1. Introduction.

Accelerated processes to ensure the goals of sustainable development and enhance Ukraine's integration into the world economic space can be implemented to achieve systemic effects through sustainable financing mechanisms. The emergent properties of financial agreements and arrangements in investment markets are characterized by introducing new types of currencies, including cryptocurrency, new opportunities for individuals to make effective use of their financial resources to increase them. Increasing opportunities lead to an increase in the financial risks of losses that accompany individuals' investment activity. The relevance of this topic is due to the modern challenges faced by individuals in present conditions. They are ready to invest in generating additional income, taking into account financial risks. It leads to the need to increase the level of use of information technology to minimize financial risks.

It is necessary to apply modern mathematical models and capabilities of information computer technologies to optimize savings and consider factors affecting the adoption of final investment decisions. The solution of applied problems is associated with processing a large amount of information, including tabular form. Also, a significant part of these tasks is related to optimization; therefore, information technologies are essential. One of such universal programs is MS Excel. It allows you to process tabular data and optimize both linear and nonlinear problems with a «Solver» and analyze it with the help of the «Sensitivity» tool. Besides, this table processor can be programmed using VBA.

2. Literature review.

The investment theory uses many models that are actively used within their functional purpose. As a rule, researchers focus on the formation of investment portfolios of institutions of various types. Such scientists as D. Zinchenko, H. Markovitz, V. Mischenko, S. Naumenkova, V. Sharp, M. Yurchuk considered using household financial resources as an investment potential. However, the insufficient substantiation of investment directions that individuals choose when making decisions leaves this issue topical, especially in a market economy's changing environment.

Kong, F., & Zhao L. (2020) [1] presented approaches to the formation and development of an optimization model of investment portfolios that depend on the psychology of entrepreneurship and financial risks; such studies were conducted on the example of investments of college students. Modeling of investment portfolios is carried out using various software based on different techniques, ranging from gamification. Scientific works of Arango, M., Rios, J., Montiel, C., & Luna, E. (2020) [2] formate an artificial neural network to construct models with a high level of approximation. The authors Oliinyk, V., & Kozmenko, O. (2019) [3] built an optimization model of investment portfolio management based on two sources (own and borrowed financial resources). In the presented model, the optimum management function taking into account the received income is offered. Luz Yolanda Toro Suarez. (2015) [4] presented a model of investment portfolio management in the context of expanding supplementary pensions. Scientists Vo, NNY, He, X., Liu, S., & Xu, G. (2019) [5] presented a socially-oriented approach to investment portfolio management, which features the use of a multidimensional bidirectional neural network. Still, it, in our opinion, requires in-depth study and adaptation of the neural network for in-depth detail of sustainable financing mechanisms, which in normal conditions becomes problematic for practical application in small business. In their article, scientists Dubinskas, P., & Urbšienė, L. (2017) [6] compared the effectiveness of different approaches to optimization processes. They proposed a model for optimizing the investment portfolio based on estimates of the genetic algorithm's suitability. The authors used MatLab software, which requires the highest level of user competence. Much effort on scientific work is given to Financial agreements and arrangements in investment markets. The international movement of capital is the driving force of world production, and the rights of beneficial ownership are the guarantor of financial mechanisms in international business. Valuation

of the chain of beneficial ownership is presented in the article by Voynarenko M. et al. (2020) [7], which draws attention to its formation's peculiarities.

The research aims to consider the MS Excel spreadsheet processor's capabilities to form an optimal investment portfolio for an individual, using the interrelation of the capabilities of mathematical models and information computer technologies.

3. Results and discussion.

An investment portfolio is a set of financial and real investment objects with different profitability, maturity, and liquidity levels managed as a single asset. The purpose of portfolio formation is to improve investment results and provide a set of assets of such investment quality, which is possible only if combined (Table 1). An individual has a goal when forming an investment portfolio: achieving a certain level of profitability, additional income, minimization of investment risks, liquidity of the invested funds at the level acceptable for the investor. None of the investment values has the above properties in the aggregate, which leads to the alternativeness of the aforementioned goals of forming the investment portfolio. Thus, security is usually achieved at the expense of high profitability and growth of investments. In world practice, government debt obligations are safe (without risky ones). Still, their income rarely exceeds the average market level, and, as a rule, there is no significant increase in investments.

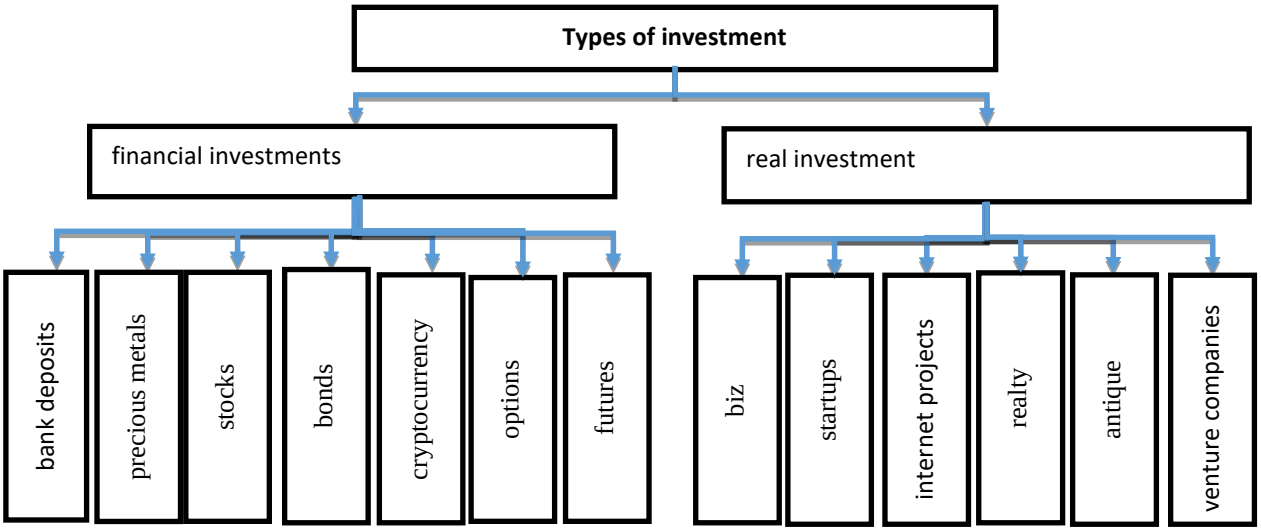
Table 1. Investment portfolio for various investors [8, p. 60]

Investor type	The primary purpose of the investor	The degree of risk	Type of security	Type of portfolio	Term of investment
Conservative	Guaranteed income Minimal risk Protection against inflation	Low	Government securities, shares and bonds of large stable issuers, bank deposits, metals	Highly reliable but low profitable	Up to 5 years old
Moderately aggressive	Growth of capital in the long term	Average	Government bonds, large share of securities	Diversified	Up to 5 years old
Aggressive	The possibility of fast capital growth	High	The high share of high-yield securities of small issuers, venture companies, futures, options	Risky but highly profitable	From 10 years old

Securities of other issuers, real investment projects can bring more investors to the investor (both current and future). Still, there is an increased risk in terms of returning funds and generating income. Investment objects that provide an increase in investments are, as a rule, the least liquid – realty has minimal liquidity (Fig. 1).

Bank deposits are the most reliable type of investment. The main advantage of investing in a bank is zero volatility. That is, the investor knows exactly how much money he can receive after a certain period. Precious metals are the investment for 5-10 years. Gold is a crucial component of the portfolio, as it allows for leveling the profitability of assets during periods of recession. For the period of a crisis in the economy, gold is gaining popularity from investors, who view it as a more reliable alternative to unstable currencies and companies' stock fluctuations. In most cases, gold in the period of instability in the global economy keeps investors' free cash and multiplies them.

Figure 1. Classification of investments [9]



Bonds are a financial instrument designed for investors, are not subject to risks. Domestic government bonds (DGBs) – government securities placed exclusively on the domestic market. GBS confirms the obligations of Ukraine to reimburse those who presented these bonds with their face value, with income paid following the terms of the bonds placement. Government bonds are issued by the Ministry of Finance of Ukraine and are the most reliable Ukraine securities.

Redemption of government bonds in full (100 % of the amount) is guaranteed by the state. But the minimum size of this operation is 40,000 USD / 1,000,000 UAH. Besides this, the person must go through verification procedures. So, government bonds cannot be a publicly available type of investment [10].

Bitcoin is the first and most famous of many other virtual currencies. Its main advantage is the impossibility of forgery. It is carefully protected from hacking and copying using various cryptographic (cryptographic) protection methods. Today, bitcoin is viewed as a speculative asset rather than a currency, limiting its widespread adoption. Bitcoin, like other cryptocurrencies, is very volatile. Its volatility far exceeds the volatility of securities [9]. It is necessary first of all to conduct a comparative description of economic and mathematical models to determine the optimal composition of the investment portfolio (Table 2).

The ideal formulation of the portfolio optimization problem is to get maximum profitability with minimal risk. But such a task does not have a unique solution; therefore, it is appropriate to introduce critical constraints.

The first option is to set a particular maximum permissible risk value σ_{req}. Then the optimization problem is reduced to choosing a portfolio structure in which the risk of the portfolio does not exceed a given value, and the portfolio yield is maximum (the immediate problem). The second option is defined by a particular minimum allowable value of m_{req}. In this case, the optimization task is reduced to choosing such a portfolio structure whose profit is higher or equal to the specified value. The risk is minimal (the inverse problem). The most common are two models for defining portfolio characteristics: the Markowitz model and the Sharpe model. Both models are created and successfully operate in Western stock market conditions, in which stability and predictability prevail. Ukrainian stock market belongs to countries with stock markets that are in the formative phase. In these countries, the use of the Markowitz and Sharp models leads to errors due to the peculiarities of these markets' development, which are characterized by instability and impulsivity of profitability [11]. Effectively implement the model of «Quasi-Sharpe» with an unstable stock market. Unlike the Sharpe model, the average yield of a single portfolio, rather than government liabilities, is taken at a

non-risky rate. At the present stage of development of the stock market of Ukraine, when optimizing the securities portfolio, you can use the Quasi-Sharp model.

Table 2. Comparative characteristic of economic and mathematical models

Model	Exploitation	Disadvantages
Markowitz	in stable markets with growing returns, when a portfolio is formed from securities owned by different industries	estimate of income as average arithmetic returns over the past years
Sharpe	to consider a large number of securities covering most of the stock market	The need to forecast stock market returns and risk-free rates of return. The model does not take into account the risk of fluctuations in risk-free returns. Also, with a significant change in the ratio between risk-free returns and stock market returns, the model gives inaccuracies.
Quasi-Sharpe	– to consider a small number of securities belonging to one or more industries; – with this model, the optimal structure of the already created investment portfolio is maintained.	ignoring global trends affecting portfolio returns

4. Methodology of the study.

The methodological base of the research is the Markowitz, Quasi-Sharpe models, methods of analysis and synthesis. Table 3 presents the assumptions that underlie the economic and mathematical models of H. Markowitz, V. Sharp. According to the Markowitz model, the return on the securities portfolio is the weighted average yield of the securities that make up it, which is determined by the formula [12]:

$$m_p = \sum_{i=1}^{n} W_i m_i,$$

where W_i – the share of the total investment in the *i*-th security; m_i – expected yield of *i*-th securities, %; m_p – expected return on portfolio, %; *n* – the number of securities.

The mathematical expectation of profit on the *i*-th security:

$$m_i = \sum_{j=1}^{n} R_i P_{ij},$$

where R_i – possible profit; P_{ij} – the probability of profit.

The Sharp model contrasts with the Markowitz model, which considers the relationship of securities returns. The Sharp model considers the relationship between the yield of securities and the yield of the whole market due to the covariance between the securities' returns necessary to optimize the Markowitz portfolio. For this, a single-factor model was used to determine the long-term security yield on the factor – the weighted average of the capitalization of security assets – market profitability.

Table 3. The assumptions underlying the economic and mathematical models

The Markowitz model	The Sharpe model
– the expected value of the return is taken as the yield of the securities; – the average risk of return is taken as the risk of securities; – it is considered that the data of previous periods, which are used in the calculations of profitability and risk, fully reflect the future values of profitability; – a linear correlation coefficient expresses the degree and nature of the relationship between securities.	– as the yield of a security, the expectation of yield is used; – there is some risk-free rate of return R_f, that is, the yield is determined by the security, the risk of which is always minimal compared to other securities; – the interrelation of deviations of the yield of security from the risk-free rate and the deviation of the profitability of the market as a whole; – a linear regression function describes the risk-free rate; – the risk of security is the degree of dependence of the yield of security changes on the profitability of the whole market changes; – it is believed that historical data used in calculating returns and risks fully reflect future returns; – for a risk-free rate of return, take the yield of government bonds, for example, a DGBs; – as a whole, the yield on the securities market in the period uses expert estimates of market returns from similar companies from the media.

According to the Sharpe model, the return on the securities portfolio is the weighted average yield of the securities that make it up, taking into account their risk β [13] is calculated by the formula:

$$R_p = R_f + \sum_{i=1}^{N} \alpha_i W_i + \left(R_m - R_f\right) \sum_{i=1}^{N} \beta_i W_i,$$

where R_f – risk-free yield, R_m – expected market profitability in general.

The function determines the risk of a portfolio of securities:

$$\sigma_p = \sqrt{\sum_{i=1}^{n} \sum_{j=1}^{n} (W_i W_j \sigma_i \sigma_j \rho_{ij})},$$

where σ_p – portfolio risk; σ_i, σ_j – the risk of these securities (standard deviation); W_i та W_j – total investment attributable to *i*-th and j-th of securities; ρ_{ij} – coefficient of linear correlation; n – number of securities portfolio [12, 14].

For the Sharpe model, the risk of a securities' portfolio can be found using an estimate of the mean square deviation of a function and is determined by the formula:

$$\sigma_p = \sqrt{(\sum_{i=1}^{N} \beta_i W_i)^2 \sigma_m^2 + \sum_{i=1}^{N} \sigma_{\varepsilon i}^2 W_i^2},$$

where σ_m – the standard deviation of the profitability of the market as a whole, that is, the riskiness of the market, β_i – *β*-risk of the *i*-th securities, $\sigma_{\varepsilon i}$ – standard deviation of the *i*-th security.

So, the two most common models for defining portfolio characteristics are the Markowitz model and the Sharpe model. Both models are created and successfully work in Western stock markets with stability and relative probability [11]. The optimization task for the Markowitz model is given in Table 4.

With an unstable stock market, the Quasi-Sharpe model is effectively implemented. Unlike the Sharpe model, the average yield of a single portfolio is taken as a risk-free rate, not government bonds. The use of Markowitz and Sharp models in developing countries leads to errors associated with the instability of the quotations of securities and the stock market as a whole [11]. In particular,

a new model of calculating the characteristics of the investment portfolio was developed, which can be used in the conditions of the modern stock market of Ukraine. The model was called Quasi-Sharp because it was based on the Sharpe model [14].

Table 4. Optimization tasks for calculating portfolio characteristics using the Markowitz model [11]

The direct problem	The inverse problem
$\begin{cases} \sum_{i=1}^{n} W_i m_i \to max; \\ \sqrt{\sum_{i=1}^{n}\sum_{j=1}^{n}(W_i W_j \sigma_i \sigma_j \rho_{ij})} \le \sigma_{req}; \\ W_i \ge 0; \\ \sum W_i = 1. \end{cases}$	$\begin{cases} \sum_{i=1}^{n} W_i m_i \ge m_{req}; \\ \sqrt{\sum_{i=1}^{n}\sum_{j=1}^{n}(W_i W_j \sigma_i \sigma_j \rho_{ij})} \to min; \\ W_i \ge 0; \\ \sum W_i = 1. \end{cases}$

Basic assumptions of the Quasi-Sharp model: the mathematical expectation of profitability is taken to characterize the yield of security; a single portfolio of securities should be understood portfolio consisting of all securities, taken in equal proportions; a linear function describes the relationship between the yield of a security and the yield of a single portfolio; the risk of security should be understood as the degree of dependence of changes in the yield of security on changes in the profitability of a single portfolio; it is considered that the data of previous periods used in the calculation of profitability and risk reflect in full the future value of profitability.

According to the Quasi-Sharp model, security yield is associated with a single portfolio yield by the linear regression function of the form:

$$R_i = \bar{R}_i + \beta_i \cdot (R_{sp} - \bar{R}_{sp}),$$

where R_i – profitability of the security, R_{sp} – profitability of a single portfolio, β_i – regression coefficient, $\bar{R}_i$ – average profitability of the security for previous periods, $\bar{R}_{sp}$ – the average return on unit portfolio for past periods.

The coefficient β characterizes the degree of dependence of the yield of a security on a single portfolio yield. The higher β the more depends on the yield of security on changes in a single portfolio's profitability, that is, changes in the yield of other securities included in a single portfolio. Coefficient β (β-risk) – its interpretation is different from the interpretation of the indicator in the Sharpe model. The overall risk of investing in given security consists of β-risk and residual risk $\sigma_{\varepsilon i}$, that is, the risk of decreasing profitability and the discrepancy between the regression line [14]. For the quasi-Sharpe model, the profitability of securities portfolio is the weighted average amount of the yield of securities as of its components:

$$R_p = \sum_{i=1}^{N}(\bar{R}_i \cdot W_i) + (R_{sp} - \bar{R}_{sp}) \cdot \sum_{i=1}^{N}(\beta_i \cdot W_i),$$

where R_{sp} – profitability of a single portfolio.

The formula calculates the risk of a portfolio of securities:

$$\sigma_p = \sqrt{\sum_{i=1}^{N}(\beta_i \cdot W_i)^2 \cdot {\sigma_{sp}}^2 + \sum_{i=1}^{N}({\sigma_{\varepsilon i}}^2 \cdot {W_i}^2)},$$

where σ_{sp} – single portfolio risk ratio.

The immediate problem in the quasi-Sharp model calculate the characteristics of the portfolio is:

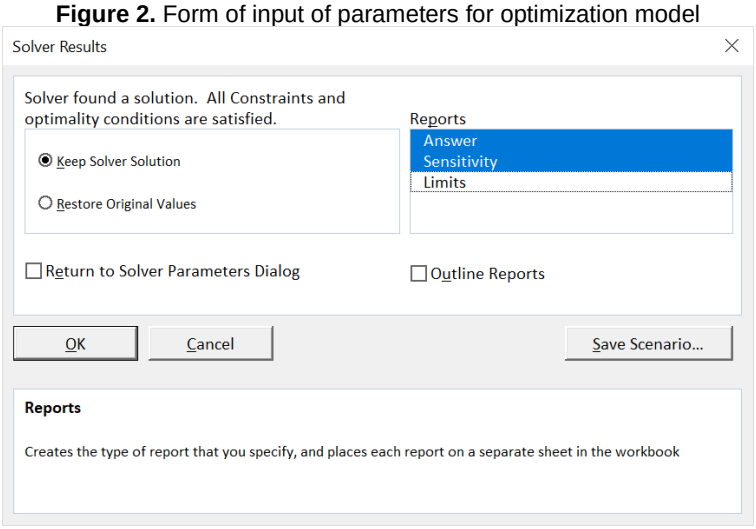
$$\begin{cases} \sum_{i=1}^{N}(\bar{R}_i \cdot W_i) + (R_{sp} - \bar{R}_{sp}) \cdot \sum_{i=1}^{N}(\beta_i \cdot W_i) \to max; \\ \sqrt{\sum_{i=1}^{N}(\beta_i \cdot W_i)^2 \cdot {\sigma_{sp}}^2 + \sum_{i=1}^{N}({\sigma_{\varepsilon i}}^2 \cdot {W_i}^2)} \le \sigma_{req}; \\ W_i \ge 0; \\ \sum W_i = 1. \end{cases}$$

The inverse problem is written in the same way:

$$\begin{cases} \sum_{i=1}^{N}(\bar{R}_i \cdot W_i) + (R_{sp} - \bar{R}_{sp}) \cdot \sum_{i=1}^{N}(\beta_i \cdot W_i) \ge R_{req}; \\ \sqrt{\sum_{i=1}^{N}(\beta_i \cdot W_i)^2 \cdot {\sigma_{sp}}^2 + \sum_{i=1}^{N}({\sigma_{\varepsilon i}}^2 \cdot {W_i}^2)} \to min; \\ W_i \ge 0; \\ \sum W_i = 1. \end{cases}$$

Solving data from applied optimization problems requires processing large data sets and then using appropriate mathematical models. These calculations are pretty cumbersome, so for this, they use specialized software. The simplest and most optimal solution was to use the MS Excel spreadsheet processor, which made it possible to process tabular data using mathematical and statistical functions for working with matrices. Also, in this environment is the ability to use the tool «Solver», which allows for solving linear and nonlinear mathematical programming tasks. The VBA environment program was created to establish and select the optimization models' parameters for the convenience of using the capabilities of the table processor. The form of this program is presented in Fig. 2 by the results of which the «Solver» parameters window is called (Fig. 3).

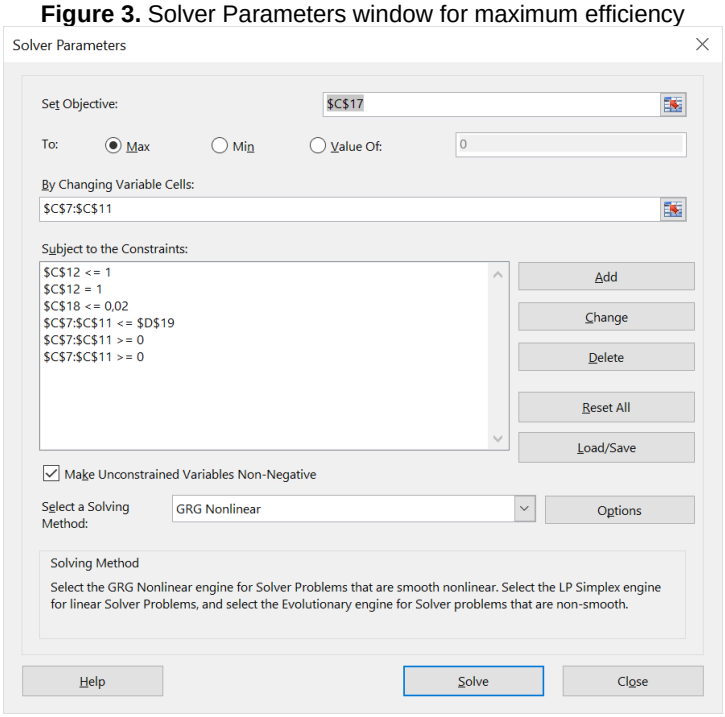
Figure 2. Form of input of parameters for optimization model



5. Results of the study.

We analyzed the indicators of the most common types of investments available to an individual in Ukraine to form the portfolio components. GBS was considered as one of the options. The majority of residents are «uninteresting», since the minimum contribution is 1 million UAH or 40 thousand Euro. Also, the person must pass the verification procedure. Therefore, the most common were chosen, and those gaining popularity among the population, namely: USD, Euro, UAH, Gold and Bitcoin. The National Bank of Ukraine and U.S. Finance Reference data were used as input data on deposit rates, precious metals, and Bitcoin in a table for the period 01.2014–11.2018 [15–17]. Data on deposit rates were given monthly. For UAH deposits were set, the impact of the consumer price index on profitability was taken into account according to the State Statistics Service of Ukraine [10]. For Gold and Bitcoin were given the monthly increase in value was calculated in %.

Figure 3. Solver Parameters window for maximum efficiency



Changes in the value of Gold and Bitcoin (total global market), the riskiest of the selected assets, in UAH and USD are shown in the chart for the period 2014–2018 (Fig. 4).

The formulas given in [14] were also used in the practical implementation of the Quasi-Sharpe model to optimize the investment portfolio. The algorithm for using formulas will be discussed in more detail.

The first step after data processing was to calculate the β-coefficient in several stages for each of the securities by the formula:

$$\beta_i = \frac{\sum_{t=1}^{T}\left[\left(R_i^{\,t} - \bar{R}_i\right)\cdot\left(R_{sp}^{\,t} - \bar{R}_{sp}\right)\right]}{\sum_{t=1}^{T}\left(R_{sp}^{\,t} - \bar{R}_{sp}\right)^2};$$

the profitability of a single portfolio in the period *t* is taken as the average value of the securities profitability, its components, for the same period:

$$R_{sp}^{\,t} = \frac{\sum_{i=1}^{N} R_i^{\,t}}{N},$$

where $R_{sp}^{\,t}$ – profitability of a single portfolio during the period *t*, $R_i^{\,t}$ – Profitability of *i*-th securities for the period *t.*

The formulas calculate the average yield of a security and the average yield of a unit portfolio for previous periods:

$$\bar{R}_i = \frac{\sum_{t=1}^{T} R_i^{\,t}}{T}, \qquad \bar{R}_{sp} = \frac{\sum_{t=1}^{T} R_{sp}^{\,t}}{T}$$

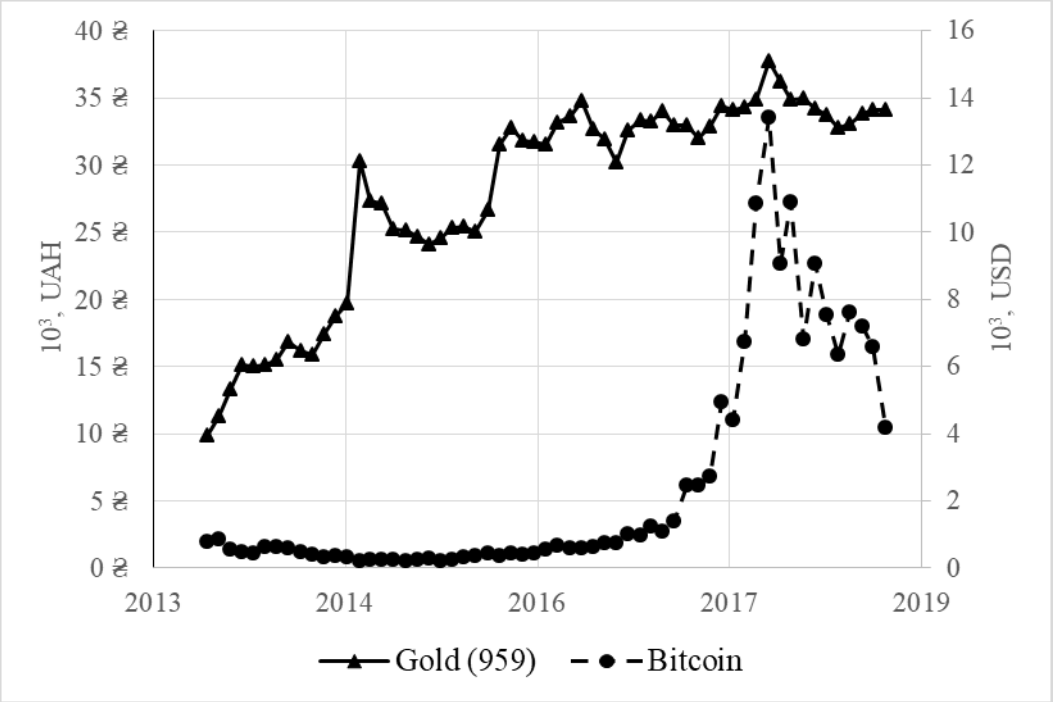
where T – considered the amount of period.

Yield calculations were done step by step because of the large amount of data for each of securities for each period using the formulas.

Residual risks were found for each object of financial investment for each period, respectively (Table 5) and the total residual risks for each security based on the data [15-17] by the formula:

$$\sigma_{\varepsilon i} = \frac{\sum_{i=1}^{T}\left(R_i^{\,t} - \bar{R}_i - \beta_i\cdot\left(R_{sp}^{\,t} - \bar{R}_{sp}\right)\right)^2}{T}.$$

Figure 4. The cost of gold and bitcoin for the period 2014–2018



The calculation of the first of the inequalities – restrictions (3) was carried out in stages for each financial investment object (Table 6). These data are also used to look for a single portfolio risk, which is calculated by the formula:

$$\sigma_{sp} = \sqrt{\frac{\sum_{t=1}^{T}(R_{sp}{}^{t} - \bar{R}_{sp})^2}{T}}.$$

Table 5. Results of calculating residual risk and β-coefficients for each object of financial investment for each period

	β-coefficients	**Average yield**	**Residual risk**
UAH	0,102	-0,0009879	0,000636
USD	-0,013	0,00535066	0,000003
EUR	-0,012	0,0044493	0,000003
Gold (959)	0,276	0,02475638	0,008681
Bitcoin	4,647	0,05803829	0,039813

Table 6. Data used to find the risk of a single portfolio

	R×W	$\beta_i \cdot W_i$	$\sigma_{\varepsilon i} \cdot W_i$	$\sigma_{\varepsilon i}{}^2 \cdot W_i{}^2$
UAH	0,00E+00	0,00E+00	0,00E+00	0,00E+00
USD	1,87E-03	-4,45E-03	1,98E-05	1,15E-12
EUR	9,67E-04	-2,670E-03	7,15E-06	4,48E-13
Gold (959)	8,66E-03	9,65E-02	9,32E-03	9,23E-06
Bitcoin	4,79E-03	3,83E-01	1,47E-01	1,082E-05

All of the above indicators (apart from the risk of a single portfolio) are independent of optimization. They are constant in the range of selected financial investment objects and periods of consideration. Thus, individual portfolios' residual risk is equal to the USD and the Euro 0 %, UAH – 1 %, Gold – 18 %, Bitcoin – 81 %.

All subsequent calculations were carried out using the «Solver» tool. The program calculated the investment portfolio's optimal structures under consideration, having processed the data from the assets that provide the highest possible return at a given risk level (the immediate problem) or the lowest possible risk at a given return (the inverse problem). The results are shown in Fig. 5 and Fig. 6, respectively (author's calculations).

5.1 Maximum efficiency portfolio.

Five variants of the optimal portfolio were calculated for each model, taking into account the established limits for the share of each asset, it assumes that their amount is 100 %: n/l (no limited), 60 % (the share of the asset cannot exceed 60 %), 50 % (similarly with the previous one), 40 %, 30 %. The optimal investment portfolio was calculated for the portfolio from 30 % to 60 % in 5 % increments (Table 7).

The optimal structures of the considered investment portfolio of assets that provide the highest possible return at a given risk level (the immediate problem) or the lowest possible risk at a given return (the inverse problem) were determined based on the presented data using the software. The results are shown in Fig. 5, which depicts a comparative diagram with the results of calculations of the model to form an optimal portfolio of maximum efficiency depending on constraints.

Table 7. The structure of optimal investment portfolios (maximum income) depending on the share of asset limitations and the risk of 2 %, in %

	UAH	USD	Euro	Gold (959)	Bitcoin	Portfolio yield
n/l	0	0	0	94	6	3,23
60 %	0	32	0	60	8	2,66
55 %	0	37	0	55	8	2,56
50 %	0	42	0	50	8	2,48
45 %	0	45	2	45	8	2,36
40 %	0	40	12	40	8	2,26
35 %	0	35	22	35	8	2,15
30 %	2	30	30	30	8	2,03

Based on Fig. 5, it can be concluded that regardless of the limitation of the asset's share, Gold will be closest to the maximum percentage share. Due to greater volatility of Gold against USD and Euro and, as a result, greater profitability and lower risk concerning the UAH and Bitcoin.

The share of the UAH is zero in the portfolios of n/l, 60 %, 50 %, 40 % and the most minor (2 %) in the 30 % portfolio, which is associated with inflation in Ukraine in the years taken for research, and, as a result, it is not advisable to use the hryvnia to form an optimal portfolio of maximum efficiency. Given figure 5 and the results of calculations, we can conclude that the historical volatility of Bitcoin exceeds the volatility of gold, so gold is a more reliable investment.

In general, historical volatility is calculated by the formula:

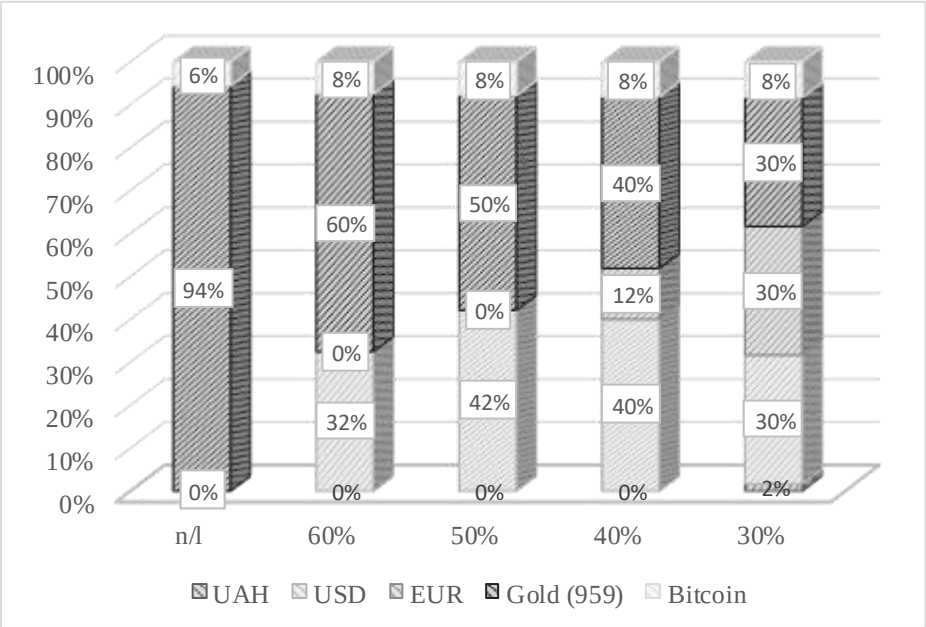
$$\sigma = \frac{\sigma_{SD}}{\sqrt{P}},$$

where P – the period in years, σ_{SD} – standard deviation of value for the period.

The formula calculates volatility for the period T: $\sigma_{\mathrm{T}} = \sigma\sqrt{\mathrm{T}}$.

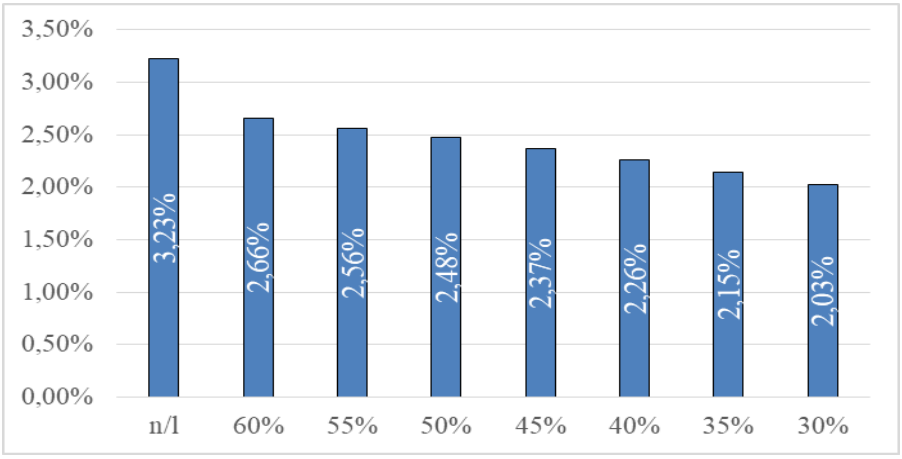
The results of calculating the volatility for each of the assets are presented in Table. 8. As can be seen, Bitcoin is the most volatile (risky) of the selected assets. Thus, the share of Bitcoin in the investment portfolio does not exceed 8 %. Note that the USD and the Euro have zero risks and, as a result, the minimum yield.

Figure 5. *The results of the task are maximally effective: optimal investment portfolio for the mainstream*



Dependence of portfolio profitability on the type of restrictions presented in Fig. 6 indicates that volume limits reduce profitability.

Figure 6. *The results of the task of maximum efficiency: the accumulation of the portfolio's return to the share of the asset is 2 %*



It means that an individual should determine how vital its diversification of investments and profitability is, which will vary accordingly from 2 to 3,2 %. So, a compromise solution remains for the individual.

In our opinion, for reliability, it is not worth investing more than 50 % in each asset, since the basis of the contribution will be in gold (Fig. 6), whose profitability fluctuations are pretty significant (Table 8), which in the short term may have negative consequences.

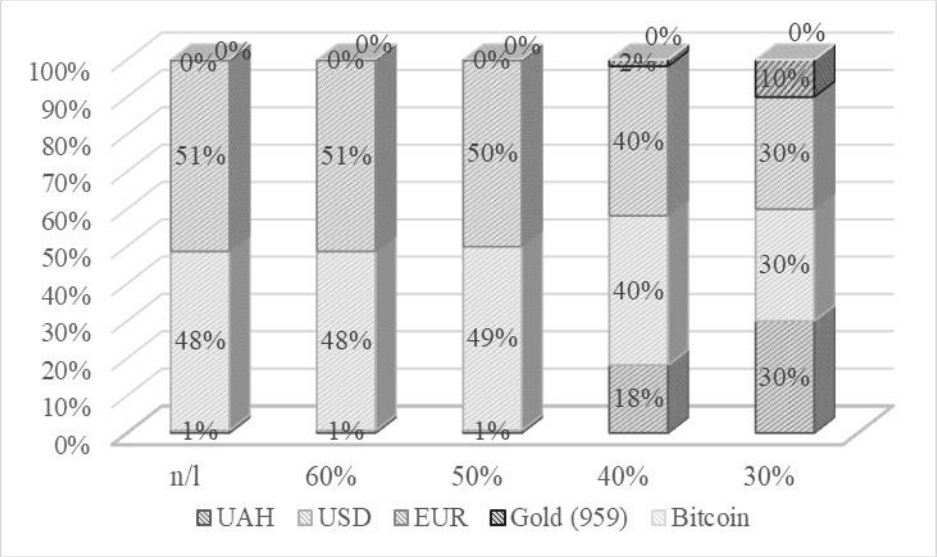
Table 8. Volatility calculation table for each asset

	UAH	USD	Euro	Gold (959)	Bitcoin
Average yield, %	-0,10	0,54	0,44	2,48	5,80
Historical volatility	-0,003	0,019	0,015	0,086	0,201
Volatility for five years	-0,008	0,041	0,034	0,192	0,450

5.2 Minimal risk portfolio.

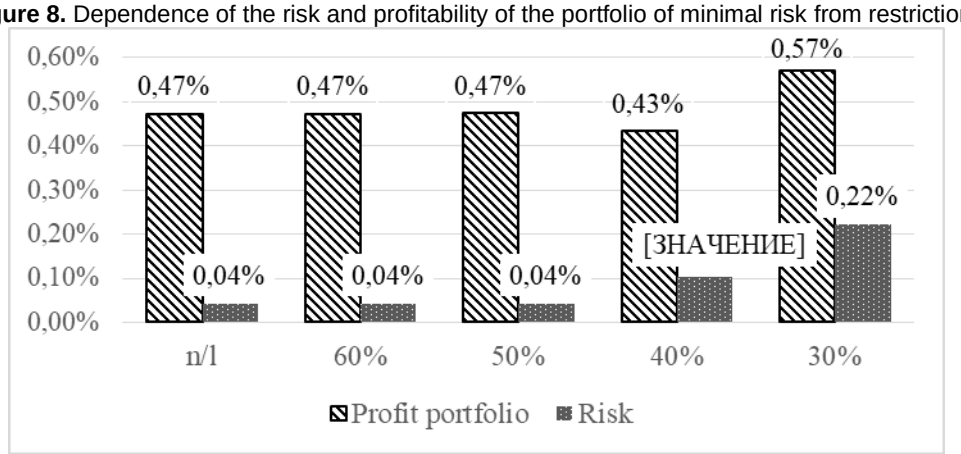
Low yield values characterize the task of finding the optimal solution based on minimal risk. Fig. 6 shows a comparative chart with the calculations of the optimal minimum risk portfolio formation model. Thus, based on Fig. 4–6, Table 8 shows that Bitcoin, given its volatility, is risky from the selected assets. Therefore, it is ignored when forming the optimal portfolio of minimal risk (Fig. 7 – author's calculations).

Figure 7. Optimal investment portfolios for various constraints (minimal risk)



Given the nearness to zero risks of the USD and the Euro, these assets form the basis of such an investment portfolio: the maximum shares in the 30 % and 40 % portfolios, in the 50 % and 60 % portfolios of the n/l share are 50 % ± 2 %. Gold is a risky asset that, if possible, is ignored or taken to the minimum required share.

Figure 8. Dependence of the risk and profitability of the portfolio of minimal risk from restrictions



UAH, given the instability of the Ukrainian economy, is the riskiest asset from bank deposits but less risky than Gold and Bitcoin. Therefore, the introduction of the UAH in the minimum risk portfolio is minimized compared to other currencies, but its share is greater than the Gold share. If risk and return dependence on restrictions are analyzed, the risk value is close to the minimum while limiting the share of single security to 50 %. This solution is optimal. A further decrease in the share provokes a sharp increase in risk with a slight increase in portfolio yield (Fig. 8– author's calculations).

It should be noted that the «minimum risk» strategy is accompanied by low rates of return (up to 0,5 % per month), which is five times lower than the corresponding rates with the «maximum profit» strategy. If necessary, you can choose the middle (compromise) option. Given the significantly lower

profitability for the minimum risk problem, we consider it appropriate to select the maximum efficiency model with 50 % top share limitations in the portfolio.

6. Conclusions and Prospects for Further Studies.

With capabilities of information computer technologies, an investment portfolio has been proposed that contains various types of assets to diversify and likely increase the total return on the investment portfolio. Analyzed different mathematical models used in investment analysis in the formation of portfolios and decided to use the Quasi-Sharp model as the most appropriate for the economy of Ukraine.

So, the direct and inverse optimization problems of the investment portfolio were solved using the Quasi-Sharpe model. In portfolios with the chosen strategy of maximum efficiency, Gold has a large share, considering its profitability; Bitcoin, despite the return, has a high residual risk, which explains a small proportion of the asset. In the portfolios of minimal risk, foreign currency has a significant share: Euro and USD, the residual risk of which approaches zero.

The share of the UAH is minimal in both portfolios, associated with inflation in the country. According to the tasks, the possible components of the investment portfolio were analyzed, which are most relevant for an individual in the Ukrainian stock market, including domestic government bonds, cryptocurrency, bank deposits, precious metals, and the five most common investments were identified: Bitcoin, USD, EUR, UAH and Gold.

Optimal investment portfolios were formed following the strategy (maximum profit, minimum risk). In the case of maximum profit, the most optimal is Gold – 50 %, USD – 42 % and Bitcoin – 8 %. A low share of cryptocurrency is associated with a high residual risk of this security. Using strategy of «minimal risk» is in EUR – 50 %, USD – 49 % and UAH – 1 %.

MS Excel is consciously chosen for this scientific research. The undeniable advantage of this product is the ease of importing and processing data. So, MS Excel can satisfy the needs of students for processing plane data to use the standard functions of a tabular processor and demanding teachers and scholars to conduct research. The editor has at its disposal tools for analyzing and optimizing data for this. Besides, you can use the macro programming language VBA. For the presentation of data, it is convenient to use diagrams. We should also mention the ability to use MS Excel add-ins, which greatly extend the spreadsheet capabilities.

Such use of universal MS Excel programs allows you to maximize the applied nature of information skills in each individual's practice.

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