Automated Forming of Insurance Premium for Different Risk Attitude Investment Portfolio Using Robo-Advisor

Vitaliy Kobets [1], Valeria Yatsenko [2] and Ihor Popovych [1]

[1] *Kherson State University, 27, Universitetska st., Kherson, 73003, Ukraine*
[2] *Taras Shevchenko National University of Kyiv, 90-A, Vasulkivska st., Kyiv, 03022, Ukraine*

Abstract

The volume of private investment is growing steadily nowadays. In this case, it is crucial to analyze investors' behaviour, decision-making factors and the specifics of their investment portfolio formation and especially their cognitive constraints, which prevent them from effectively defining investment goals and profitable achieving them. This research shows that investors, even experienced and financially literate, often make significant mistakes when creating their own investment portfolios. Thus, the use of automated tools for determining the insurance premium and the optimal investment portfolio, which is a robo-adviser, becomes relevant. The paper presents the model for estimating personal insurance premium for different risk attitude investment portfolios using robo-advisor. Three types of investors are analyzed: conservative, aggressive, and moderately aggressive. The model helps determine the individual size of the insurance premium for each investor profile, taking into account his or her risk attitude.

Keywords

Robo-Advisor, risk attitude, insurance premium, investment portfolio.

1. Introduction

Modern Portfolio Theory (MPT) of H. Markowitz is based on two main factors: risk and expected returns. In this case, an investor chooses a portfolio with the highest returns and the slightest danger. The goal of an investor is to get more income with less risk [1]. An investor acts in two possible situations to create a portfolio: complete uncertainty (an investor can not determine possibilities of scenarios) and risk conditions (possibilities can be determined). Nowadays, to clarify this model, we can add one additional factor – risk tolerance or risk aversion, which is influenced by various factors and described by the Arrow-Pratt coefficient. It is valid only if an investor behaves rationally: can calculate different scenarios, identify their utility, maximize benefits, always choose the optimal variant among current.

However, even experienced investors, often make conflicting and sometimes erroneous decisions about their finances – such as an undiversified portfolio or risk concentration. C. Frydman and C.F. Camerer explain it by low financial literacy and popularity of managed funds [2]. However, we tend to see the main problem of investors' mistakes in cognitive limitations.

According to D. Kahneman's research, the decisions made by economic agents usually differed from those that were made based on the "homo economicus" model [3]. J.Y. Campbell insists that "households do not save and invest according to normative models" [4]. Consequently, they "typically have underdiversified stock holdings and low retirement savings rates" [2]. De Bondt says that people forget basic principles and laws of investment theory during investing and rely on intuition and other factors but not on quantitative measures [5].

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EMAIL: vkobets@kse.org.ua (A. 1); ValeriaYatsenko5@gmail.com (A. 2); ihorpopovych999@gmail.com (A. 3)
ORCID: 0000-0002-4386-4103 (A. 1); 0000-0002-2925-7470 (A. 2); 0000-0002-1663-111X (A. 3)

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It is true not only for private investors but for experienced thriving financial educated managers as well: "even top corporate managers, who are typically highly educated, make decisions that are affected by overconfidence and personal history" [2]. What is more, "even Markowitz, creator of MPT, did not use MPT in his own choice of portfolio" and simply created a 50/50 mix of stocks and bonds [6].

We tend to explain it through the following reasons and behavioral patterns:

- Prospect theory – different attitudes to the same situation depending on the expected result: $risk_{to\ prevent\ losses} > possibility_{to\ gain\ benefits}$;
- Errors in estimating the probability - overestimation of the likelihood of occurrence of positive events/events that will not happen, underestimation of the likelihood of adverse events/events that are most likely to occur;
- Allais paradox – a rational individual, prefers absolute stability to maximum utility;
- Tunnel vision –concentration on the experience means;
- Overconfidence and illusion of control – the ability to overestimate personal knowledge, risks, control, the performance of assets people own;
- Disposition effect – desire to avoid regret and seek a pride;
- Herd instinct or masses' effect – behave like others do, even if it is irrational and illogical.

In the conditions of growing volumes of information, insufficient information culture and financial literacy of economic agents, the problem of cognitive limitations will only intensify. Moreover, as E. Bikas et al. say, investing in financial markets is becoming more popular with the express aim of individual investors [7]. It requires the use of automated financial and investment decision-making tools.

This paper aims to estimate personal insurance premium for different risk attitude investment portfolios using robo-advisor to guarantee investor desirable income.

We organize the remainder of our paper as follows: in section 2, we consider related works. In section 3, we present models of robo-advisor for different goals of the investor. Section 4 is devoted to methods for identifying investor's risk attitude. In section 5, we revealed the automated estimation of insurance premium for different risk attitude investment portfolio. Finally, the last section concludes.

2. Related works

2.1. Cognitive constraints and investing

When investing, cognitive limitations become more specific and more threatening, leading to lower returns or significant losses (Fig. 1). In particular, when pro-cessing numerical data, such as prices, investors tend to focus on round numbers, the left-most digit of a number or prefer integer, halves and quarters prices [8]; another case, investors, prefer low-cost shares [9]. From another perspective, investors can pay disproportionate attention to irrelevant information, which will most influence their final decision while skipping an important one [10].

One of the most popular patterns is the disposition effect that incentivises to sell good assets (winners) quickly, while bad assets (losers) are being kept [2]. The second constrain overconfidence described as the following potential consequences of it: poor decisions, purchase the wrong stocks (selling a good-performing stock instead to buy a poor one), unreasonable risk taking, and ultimately portfolio losses, overtrading with higher costs, rely on masses or leading market players, wrong interpretation of information and news (concentration on past events rather than important ones) [2; 7; 11]. Overconfidence can result in higher risk level in the context of risks due to two reasons: purchasing risky as-sets and under diversify portfolio [11].

Furthermore, mental accounting limits investors' ability to assess portfolio risks while some new investments are added, focusing only on risks of individual assets rather than the interaction between them [11].

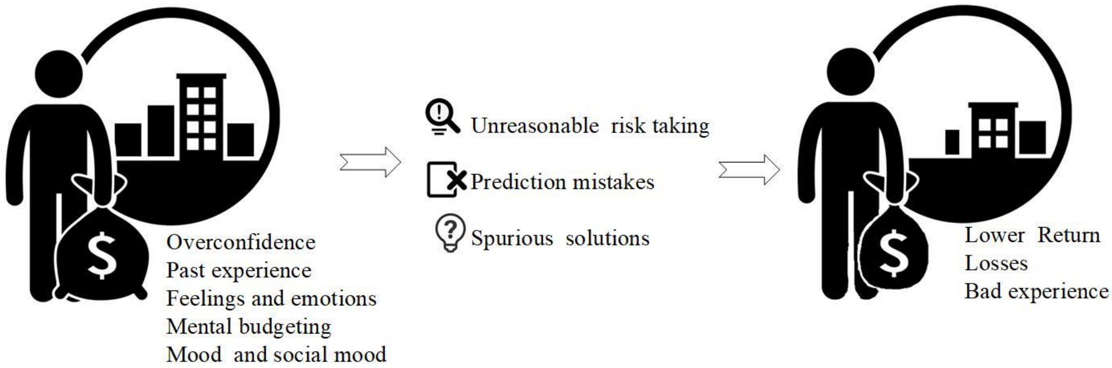

Figure 1: Consequents of an investor's cognitive limitations

Many studies prove that the economic cycle or financial market dynamic plays a significant role in the investor's behaviour. When the market grows, investors seem to be more optimistic and pay more attention to their portfolio [12], seeking risk assets and vice versa.

Interestingly, Wei-Yu Kuo, Tse-Chun Lin, Jing Zhao found that "individual investors that are cognitively more constrained suffer from greater losses in their investments" that can be reduced by experience helping to improve cognitive capability [8]. However, the experience can not influence errors [4-5] or can vice-versa deface further investor's behavior or even reduce net returns [13]. In general, investors become riskier after successful practices because they do not fully consider profit as their own money and instead reinvest them into riskier business, called the "house-money" effect. The opposite effect is the "snakebite" effect, when investors will try to avoid risks after obtaining losses. Similarly, when an investor wants to "keep going" already done investments, it is called the "sunk-cost" effect [11].

Finally, investment decisions can be driven by a variety of others factors [14]. The simplest one is mood when people in a good mood overestimate the probability of positive events and are ready to take higher risks than people in a bad mood [11]. Another case is when we investigate the mood of groups or even society described as market sentiment [11]. Similarly, investors react to the news: they overestimate negative news and become too pessimistic, while good news makes them more optimistic, but too little [2].

Among other factors, we can mention weather and quantity of sunny days [15], results of sports events [16, 17], closeness to the investor's home, which is called "home bias", and national identity of a company [2], what is more, related to investors' with not diversified portfolio [5] and those who aim at pension retirement and mostly prefer local companies [18] (table 1).

Table 1

Various factors influence the investment process

Type	Factors	Meaning
Economic	Economic cycle	Market risk premium is higher in economic recession
Economic	Individuals' reaction	Consumption growth and inflation news
Economic	Availability of information	Available information can reduce risk aversion
Physiological	"Ambiguity aversion"	Consumers are pessimistic and act as the worst scenario happened
Physiological	Heuristic theory	The most recent observations significantly influence on an individual's decisions

Physiological	Investors' beliefs	Return experiences, confidence and investment beliefs; patience and intelligence
Physiological	Timing	The close risk is, the higher risk aversion will be
Physiological	Past experience	Coming to important events increases patience
Demographic	Age	Risk aversion and patience increase with age
Demographic	Genetic	Some people are initially more risky than others
Demographic	Behavioral biases	Testosterone or stress influence risk aversion
Social	Family exceptions	Family influence the final investment decision
Social	Consumer's environment	Income uncertainty or possible liquidity increase risk aversion

Based on [2; 19; 20; 21]

However, it is essential for the long-run investment process to include a mechanism to counteract cognitive limitations and irrationality, especially about risk assessment and acceptance, which outlines the need for automated robotic consultants.

2.2. Risk and its role in investing

Investment risk arises due to the depreciation of the investment portfolio, which includes different financial instruments. The main task of the investor is to achieve the maximum level of expected return on investment at a certain level of risk and reduce the possible risk at the expected return [22]. Not achieving this task is an investment risk indeed, which means both indirect (underpayment of returns compared to the expected level) and direct losses (lost revenue) and can measured in real or relative terms. Considering both of these factors is essential, since relying on one of them can lead to ineffective investment decisions. For instance, based on risk factor the list of acceptable investments include assets in the following decreasing order: bonds, real estate and stocks [23], notwithstanding in terms of risk-return ratio real estate is considered more effective compared with stocks [24]. That is why, Markowitz proposed a theoretical concept of the "optimal" investment portfolio. The essence of the concept is that the financial instruments of the investment portfolio should be diversified by different terms, types and modifications issued by corporations of different industries and geographical locations [25-27].

Risk is a crucial indicator in an economic system, both at micro and macro levels. Furthermore, risk is a heterogenic category including risk appetite and risk aversion (describe wiliness to take risk or its lack), risk capacity (readiness to take specific amount of risk), and risk tolerance (the risk limit).

In investing theory, risk aversion influences the composition, and therefore, the profitability of the investment portfolio. Many scientists investigated this topic from various point of views. Y. Kitanov investigated systemic and non-systemic investment risks, called them fundamental (related to overall economic situation and all types of investments) and specific risks (targeting some assets) [28]. H. Walter and I. Maike found that risk seekers prefer to hold bonds, stocks, and company assets, other than life insurance, while savings account or home savings do not correlate with risk level [19]. I. Dittmann found that market mature can significantly influence on an investor's decision [29] leading to different results among countries. Other important factor is time horizon which determines "the investor's cash flow needs, and hence capacity to absorb short term volatility risk" [30], and consequently influence on risk aversion. It impacts on investor's decision meaning greater ability and capacity to take short-term volatility in terms of long-term investing [30].

O. Brandouy et al. say that "each trader invests his capital in a portfolio reflecting his risk-aversion" and conclude that "only conservative traders survive in the long run" [20]. According to the experiment, two trade situations present at the market: short-selling is allowed and is forbidden. In the first case, the risk lovers compete for wealth but left the market quickly. In the second one, aggressive and robust conservative investors are overcome by the conservative investor [20].

Moreover, it is a significant indicator for the corporate sector as well. To G. Meunier mind, "the more risk-averse the firm is, the less it produces, and a risk-averse firm produces less as uncertainty increases" [31].

Economic, statistical and analogue methods, expert view are used to assess financial risk. Economic and statistical methods assess financial risk using the following indicators: the average value of the investor's profit as a random variable (risk factor); dispersion; standard deviation of profit; semi-standard deviation; coefficient of variation; profit probability distribution. The density function of the normal distribution allows us to calculate the probability of making a profit. Value at Risk-assessment of risk (VaR) or "investment at risk" is an integral measure of risk that can compare the risk of different investment portfolios and different financial instruments. The value of VaR shows a confidence of x % (with a probability of x %) that the investor's losses will not exceed y UAH over the next n days. In this statement, the value of y is unknown and is VaR, which is a function of two parameters: the time horizon n and the confidence level x [32].

3. Models of robo-advisor for different goals of investor

Before the investment process starts, the risk profile and investment goals of the client are determined. In other words, it is what the person wants to achieve by the means of the investments in the time horizon. The investor should answer a list of questions. Based on it, his/her psychological and investment portrait is formed, and the risk propensity is highlighted. He/she is also asked to determine the particular goals for investments (to buy a new house, to save money for children's education), because "people have different mental accounts for each in-vestment goal, and the investor is willing to take different levels of risk for each goal" [11]. However, it is proposed to choose not only the primary goal but also several additional ones. Clusters of investors can be determined using investors' characteristics [33]. Diversification, meaning the use of various investment instruments for different sectors of the economy, will occur not only for one investment portfolio but also for several investment portfolios will be created based on the selected goals of the person.

For each goal, the investor may have a different attitude to risk:

- Conservative with risk minimization (not inclined to take risks for savings for education, retirement);
- Aggressive with maximizing profitability (inclined to take risks to launch a new startup);
- Moderately aggressive with a desire to achieve minimum risk with maximum return (neutral to risk for savings for a new home).

In addition to the profitability, the investor also has to consider the risk associated with the portfolio of financial instruments. According to the Markowitz model, the risk is expressed as the standard deviation σ_p of each financial instrument. The σ_p value is the level of acceptable portfolio risk for the investor. In addition to considering the standard deviation of financial instruments, it is necessary to analyse the correlation between the profitability of different financial instruments r_{ij}. As a result, we can present the risk of the entire portfolio by the formula (1), where X – matrix of finance instruments' shares, X' - transposed matrix, V^2 – matrix of variations of financial instruments, V_{ij} – matrix of covariations:

$$\sqrt{X^2V^2} + X'V_{ij}X = \sigma_p \tag{1}$$

The mathematical model of the optimal portfolio of financial instruments for an aggressive type of investor with maximum efficiency $M_p = R'X$, in which the portfolio risk does not exceed a given value σ_p, and considered all restrictions on the portfolio, will have the following form (R' - transposed matrix of profitabilities of financial instruments):

$$
\begin{cases}
M_p \to max; \\
\sigma_p = const; \\
\sum_{i=1}^{n} x_i = 1; \\
x_i > 0, \quad i = 1, \dots, n.
\end{cases}
\qquad (2)
$$

The inverse problem of portfolio optimisation relates to the choice of such a portfolio structure, which has higher or equal expected return M_p with minimal risk σ_p. Consequently, we create a portfolio for a conservative type of investor. In this case, the mathematical model of the problem has the form:

$$
\begin{cases}
\sigma_p \to min; \\
M_p = const; \\
\sum_{i=1}^{n} x_i = 1; \\
x_i > 0, \quad i = 1, \dots, n.
\end{cases}
\qquad (3)
$$

When developing a portfolio for a neutral type of investor, risk minimisation and profit maximisation are simultaneously occured. Thus, we will receive the following mathematical model of the problem (4):

$$
\begin{cases}
\frac{\sqrt{X^2V^2} + X'V_{ij}X}{R'X} \to min; \\
\sum_{i=1}^{n} x_i = 1; \\
x_i > 0, \quad i = 1, \dots, n.
\end{cases}
\qquad (4)
$$

Next, we will consider the architecture of a Robo-adviser based on open data about cryptocurrency (Fig. 2) for drawing up investment plans [34-37].

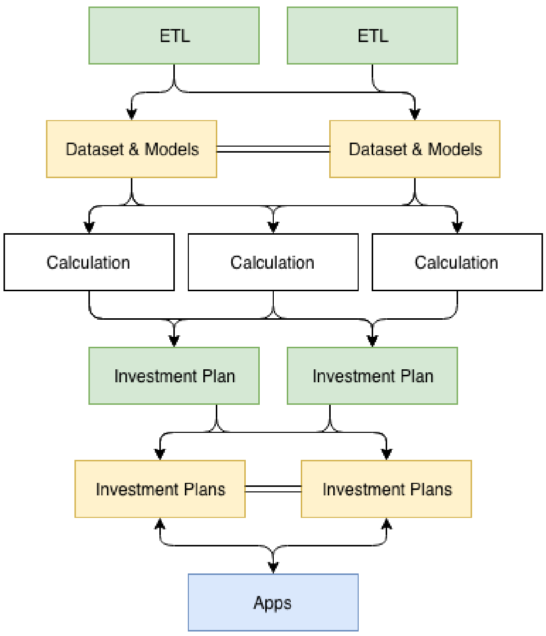

Figure 2: High-level architecture of robo-advisor [34]

In this paper, we chose cryptocurrency funds since they have low correlation with traditional assets, such as gold or stocks and can be used both for diversification portfolio or creation independent investment portfolio for a risk-averse investor or even as a hedge tool thanks to “the partial advantages of both commodities and currencies in the financial market" [38].

The distribution of cryptocurrency funds for risk-averse investors is 29% BTC-USD, 7% LTC-USD, 25% NEO-USD, 39% BCH-USD (Fig. 3). The investor's expected annual income for each currency is 23.7% per annum. To receive an income of UAH 100,000, the investor needs to invest UAH 422115 per year. The distribution of funds for a risk-neutral cryptocurrency investor is 47% BTC-USD, 24% ETH-USD, 9% LTC-USD, 9% NEO-USD, 12% BCH-USD (Fig. 3). The investor's expected annual income for each currency is 16.5% per annum. To receive an income of UAH 100,000, the investor needs to invest UAH 607,551 per year.

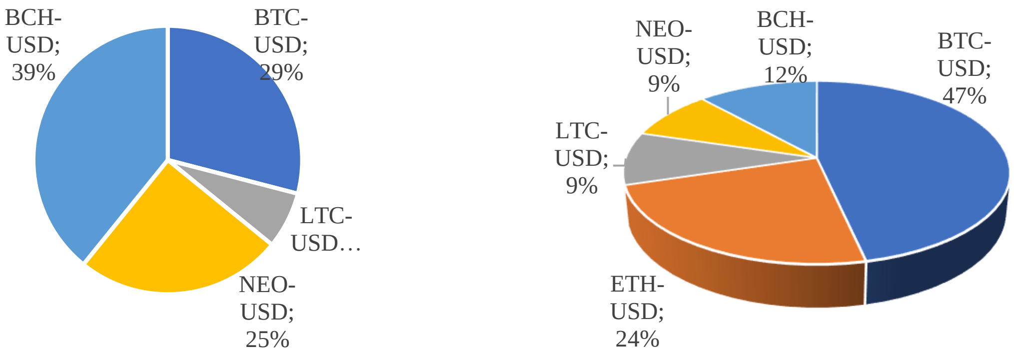

Figure 3: Investor's portfolio (left – risk-averse, right – risk-neutral)

4. Methods for identifying investor's risk attitude

The author's contribution is the development of a methodology for automated risk premium assessment for the investor through robo-advisor by transforming the results of the investor questionnaire into a utility function. The results of the investor questionnaire using Harrington's desirability function determine the type of investor via the Attitude to risk scale. Based on the investor utility function, we developed a method for determining a personalized risk premium in absolute and relative terms.

Let us consider steps for determining the investor's risk attitude and calculating his risk premium.

1. Based on the investor's automated survey, his or her risk preferences are determined.
2. The utility function of income $U(W)$ is determined for a specific type of investor in absolute terms (monetary units).
3. Next, the distribution of his or her investment between assets and the risk premium for the investor is calculated.

Investor questionnaire on his risk appetite

Method 1. "Diagnostics of the level of personal risk readiness" (Schubert scale)

2 points - completely agree, "Yes";
1 point - rather "Yes" than "No";
0 points - no "Yes", no "No", something in between, "Hard to say";
-1 point - rather "No" than "Yes";
-2 points - totally disagree, "No".
Test value: from -50 to +50 points.

Results interpretation

from -50 to -30 points – too careful (risk-averse);
from -10 to +10 points - average values (risk-neutral);
from 20 to 50 points - inclined to take risks (risk-seeking).

A high readiness to take risks is accompanied by a low motivation to avoid failure (defence). The readiness to take risks is directly correlated to the number of made mistakes. The hybrid type of investor, depending on the chosen investment goal, is determined by intermediate values (from -30 to -10 and from 10 to 20).

Analysis of research results allows us to highlight specific patterns:
- with age, the readiness to take risks decreases;
- more experienced investors have a lower risk appetite than inexperienced ones;
- women are ready to take risks under more definite conditions than in men;
- for the military and business leaders, the willingness to take risks is higher than among students,
- groups (households) are ready to take risks more strongly than when people act alone and depends on group expectations.

Method 2. Individual-typological characteristics of risk appetite

We apply the scale of measurement – semantic, differential, unitary, inverse with boundaries answers "Definitely yes" (4) to "Definitely no" (1).

The uniqueness is the test has five scales:

1. ECR - the emotional component of risk.
2. CCR - the cognitive component of risk.
3. BCR - the behavioural component of risk.
4. CRA - compositional risk assessment.

Such semantic core differentiation of the research object will make it possible to understand its essence better. These scales will allow qualitatively operationalize the obtained results of the study. Highlighting these components reflects risk attitude appropriately. Risk readiness is a priority in our study.

Key-decoder to the test questionnaire. Answers to direct questions (identifying the degree of quality which is diagnosed) are assessed as follows: "Definitely yes" - 4 points; “Apparently yes” - 3 points; “Apparently not” - 1 point; "Definitely not" - 0 points. Answers to those questions that diagnose the absence of an assessed quality (inverse questions) are evaluated in reverse order. These answer options are scored as follows: "Definitely Yes" - 0 points; "Perhaps yes" - 1 point; "Perhaps not" - 3 points; "Certainly not" - 4 points. All points for each indicator of risk attitude are summed. The maximum number of points for each indicator is 40 points. Table 2 presents the keys used to find the numerical value of each indicator of risk appetite.

Table 2

Key-decoder for the risk attitude test questionnaire

Risk appetite indicators	Direct questions	Inverse Questions
ECR - the emotional component of risk	1,4, 5,7,8,25	2, 3, 6, 9
CCR - the cognitive component of risk	12, 14, 17,20,21	11, 15, 16, 18,35
BCR - the behavioral component of risk	13, 22, 23, 24, 26, 27, 28, 29, 30	31
CRA - compositional risk assessment	(ECR+CCR+BCR) : 3	

So, the final version of the questionnaire test contains 40 questions (10 for each indicator). Overall, the methodology includes written instructions, a list of questions; a form providing four answers for each question; keys for data pro-cessing. The calculation of individual marks consists of the summation of the points scored for each of the parameters. The highest score for each indicator is 40 points; the minimum is 0 points. The average sum of points on all scales forms a general indicator of risk appetite - a composite assessment of risk attitude (CARA).

Methodology 3. “Methods of diagnosis one’s motivation for success” (T. Ehlers) is used as a scale for “Motivation for success” in order to apply the correlation of the level of risk of investors with motivation for success.

Key. The investor receives 1 point:

- For answering "Yes" to the following questions: 2, 3, 4, 5, 7, 8, 9,10, 14,15, 16,17, 21, 22, 25, 26, 27, 28, 29, 30, 32 , 37, 41;
- For answering “no” to questions 6, 13, 18, 20, 24, 31, 36, 38, 39.

Answers to questions 1, 11, 12, 19, 23, 33, 34, 35, 40 are not counted. The amount of points scored is determined.

Result:

- Low motivation (L): from 1 to 10 points: low motivation for success;
- Average motivation (A): 11 to 16 points: average level of motivation for success;
- Moderately high motivation (MH): 17 to 20 points: moderately high level of motivation;
- High motivation (H): more than 21 points: too high level of motivation for success.

After polling investors, all three scales should be normalised to the interval Y: from -5 to +5, in which, according to experimental data, the range of investors' risk attitude [34] is found using the Harrington's desirability function. After that, for each investor, the arithmetic mean for the first two scales is determined as an indicator of risk attitude. The correlation with the third scale determines which group the investor is more likely to belong to risk averse, risk seeking or risk neutral.

Let us consider the transformation of the results of the investor's survey for the Schubert method (Table 3) using Harrington's desirability function (Fig. 4) in the form:

$$b = e^{-e^{-Y}} \tag{5}$$

Table 3

Scale 1 (Schubert's methodology)

Scale	Y=N/10	b	Scale	Y=N/10	b
-50	-5	0,00	10	1	0,69
-40	-4	0,00	20	2	0,87
-30	-3	0,00	30	3	0,95
-20	-2	0,00	40	4	0,98
-10	-1	0,07	50	5	0,99
0	0	0,37			

Then the investor's attitude to risk will be determined by the column intervals b.

Attitude to risk

[0%; 20%) - very low value (very risk averse);
[20%; 37%) - low value (risk averse);
[37%; 63%) - medium value (risk neutral);
[63%; 80%) - high value (risk seeking);
[80%; 100%] - very high value (very risk seeking).

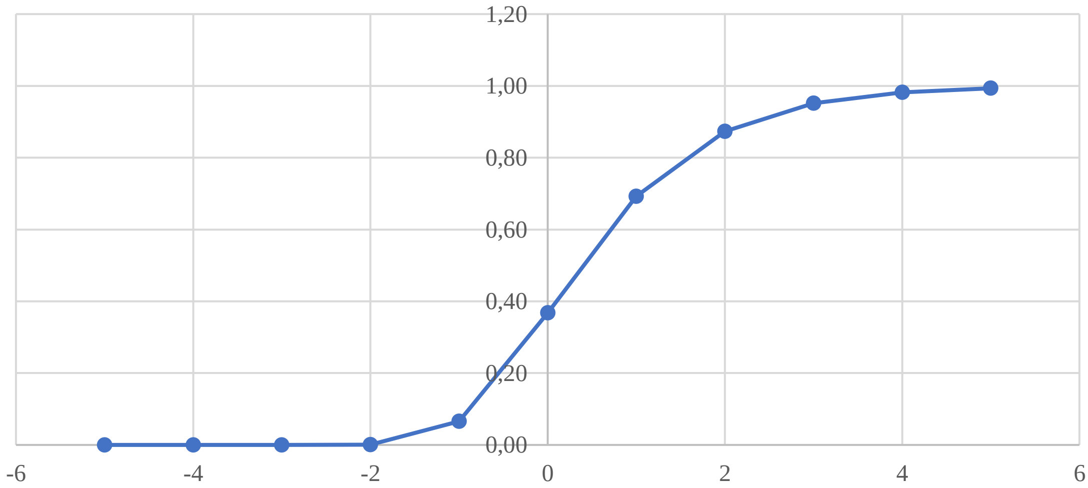

Figure 4: Harrington's desirability function for investor's risk attitude (abscissa axis is parameter of Harrington's desirability function **Y**, ordinate axis is risk attitude **b**)

Next, consider the transformation of the results of the survey of investors for methodology 2 (Table 4) using the function (5):

Table 4
Scale 2 (Individual-typological characteristics of risk appetite)

Scale N	Y=f(N)	B	Scale N	Y=f(N)	b
0	-3	0,00	25	2	0,87
5	-2	0,00	30	3	0,95
10	-1	0,07	35	4	0,98
15	0	0,37	40	5	0,99
20	1	0,69			

To convert the survey results of scale 2 to scale Y, we will perform the following transformations:
1) define the interval of the table 4, which includes the results of the poll N_0 $[N_1;\ N_2]$, that is $N_1 \leq N_0 \leq N_2$;
2) calculate the gain for the interval defined above for the polling scale $dN = (N_2 - N_1)/N_1$ and the function $dY = (Y_2 - Y_1)/Y_1$;
3) calculate the increase in the function Y falls on the increase in the survey scale $h = dY/dN$;
4) define the corresponding value of the function N_0 for the result of the poll of the investor Y_0 by the formula: $Y_0 = Y_1 \cdot (1 + dN_0 \cdot h)$.
Now let us consider the transformation of the results of the investor’s survey for the Ehlers methodology (Table 5) using the function (5):

Table 5
Scale 3 (Methods of diagnosis one’s motivation for success)

Scale N	Y=f(N)	B	Scale N	Y=f(N)	b
0	-5	0,00	17	0,3125	0,48
1	-4,6875	0,00	19	0,9375	0,68
10	-1,875	0,00	20	1,25	0,75
11	-1,5625	0,01	21	1,5625	0,81
16	0	0,37	32	5	0,99

Since the increase in the function Y for the increase in the polling scale $h = dY/dN$ is a constant value: $h = \frac{10}{32} = 0.3125$, then the conversion of the N scale into Y occurs with the proportionality coefficient h.
Using the example of an investor, we will demonstrate the application of the survey methodology. According to the results of method 1, we got $N_1 = -34$, $Y_1 = -3.4$, $b_1 = 0\%$ (very risk averse). For method 2, we have $N_2 = 9{,}67$, $Y_2 = -1.97$, $b_2 = 0.08\%$ (very risk averse). Method 3 gives $N_3 = 22$, $Y_3 = 1.875$, $b_3 = 86\%$ (very high value of motivation). The average investor's propensity to risk $\bar{Y} = \frac{Y_1+Y_2}{2} = 0.000397$ (0.04%) (very risk averse).
The more the portfolio's income deviates from the average, the riskier the portfolio is. Risk assumes the volatility of income for investment activities. If volatility is low, income can be almost guaranteed. Investors who are dealing with the same expected return tend to choose a portfolio with lower income variability.

5. Estimation of insurance premium for different risk attitude investment portfolio

In fig. 5 W^* depicts the investor's current income; $U(W)$ is a von Neumann-Morgenstern utility function and has a concave function on the W argument, reflecting the assumption of decreasing marginal utility [35]. It means that each additional monetary unit of profit adds less marginal utility to the investor. Consider two investment portfolios with the same return but with different volatility (h i $2h$). The expected utility for both deviations h and $2h$ will be, respectively:

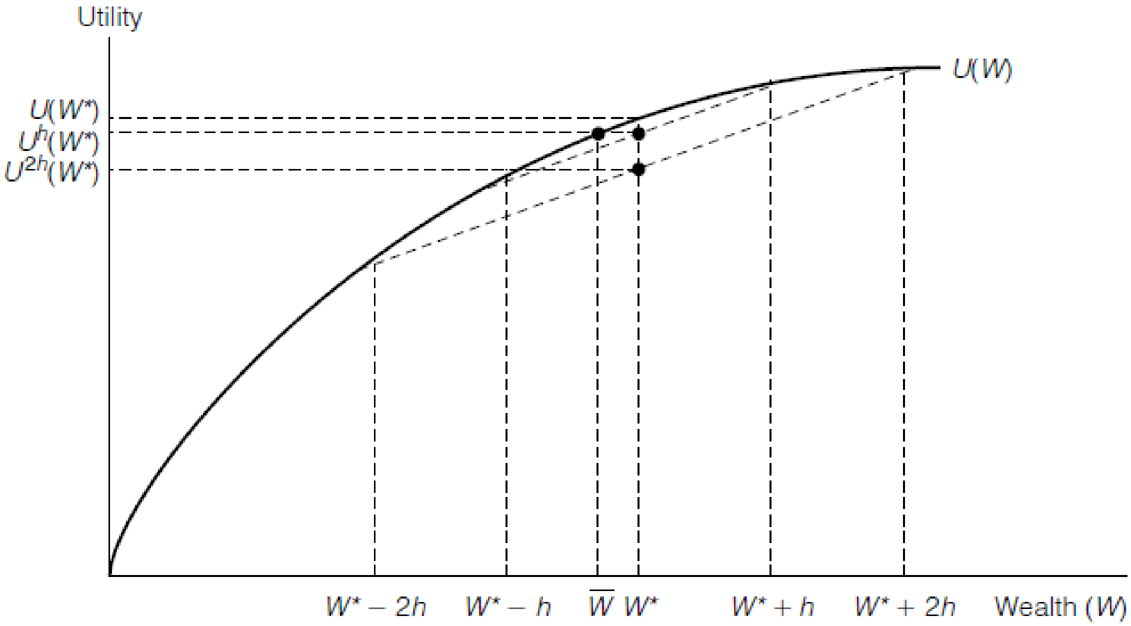

Figure 5: Utility from the profit of two investment portfolios with different volatility ($U = A + B \cdot W$) [35]

$$U^h(W^*) = 0{,}5 \cdot U(W^* + h) + 0{,}5 \cdot U(W^* - h),$$
$$U^{2h}(W^*) = 0{,}5 \cdot U(W^* + 2h) + 0{,}5 \cdot U(W^* - 2h).$$
$$U(W^*) > U^h(W^*) > U^{2h}(W^*).$$

The investor will prioritise guaranteed return with no deviations compare to volatile income and prefer less volatile income over more volatile. Less benefit from volatile income is because the gain of h brings less utility to the investor than the loss of h euros.

If an investor seeks to receive income that cannot be proved by a guaranteed return (for example, domestic government loan bonds), the investor has the opportunity to choose an investment portfolio with volatile income and at the same time pay a certain amount (insurance premium) in order to avoid the risk of volatility of the investment portfolio.

A certain guaranteed level of income $\overline{W}$ provides the investor with the same utility as an investment portfolio with volatility h, that is, $U(W^*) = U(\overline{W})$, where $W^* > \overline{W}$. Therefore, the investor can pay a maximum of $W^* - \overline{W}$, to avoid the risk. It explains why investors buy the insurance and pay premiums.

An investor who always refuses risk is called risk-averse. If an investor exhibits decreasing marginal utility from income, he will be risk-averse. As a result, the investor will want to pay insurance to avoid the risk.

An investor with a constant absolute risk aversion $U(W) = -e^{-AW}$, subject to the normal distribution of risk with mathematical expectation m_W and dispersion σ_W^2, has the following distribution function: $f(W) = \frac{1}{\sqrt{2\pi}} e^{-z^2}$, where $z = \frac{W - m_W}{\sigma_W}$. Then the expected benefits from volatile income are:

$$E\big(U(W)\big) = \int_{-\propto}^{\propto} U(W) \cdot f(W) dW = \frac{1}{\sqrt{2\pi}} \int_{-\propto}^{\propto} -e^{-AW} \cdot e^{-\left(\frac{W - m_W}{\sigma_W}\right)^2} dW$$

After the transformations, we get:

$$E\big(U(W)\big) \approx m_W - \frac{A}{2} \cdot \sigma_W^2.$$

For income of UAH 100,000, a standard deviation of UAH 10,000 and $A = 0.000397$ (risk attitude according to the survey results), have:

$$E(U(W)) = 100000 - \frac{0.000397}{2} \cdot 10000^2 = 80154.$$

Thus, having a utility function $U(W) = -e^{-0.000397 \cdot W}$, a person receives the same utility from both his volatile income in UAH 100,000 (cryptocurrency) and guaranteed income in UAH 80154 (bonds).

After polling the investor and determining his propensity to risk, the majority of investors are determined as risk-averse. Therefore, their preferences can be described by a linear function with a decreasing level of utility $U(W) = b + k \cdot W$ (Table 6).

Table 6

Actual and forecast of utility function of investor

№	Welfare W, UAH	Actual $U(W)$, utils
1	1000	-0,6724
2	2000	-0,4521
3	3000	-0,3040
4	4000	-0,2044
5	5000	-0,1374
6	6000	-0,0924
7	7000	-0,0621
8	8000	-0,0418
9	9000	-0,0281
10	10000	-0,0189

Based on the actual data about the investor obtained after the survey, using the trend line, his predictive utility function $U(W) = 0.000057 \cdot W - 0{,}526$ was determined, reflecting the investor's lack of exposure to risk (fig. 6). The coefficient of determination confirms the adequacy of this function to the actual preferences of the investor ($R^2 = 78.8\%$).

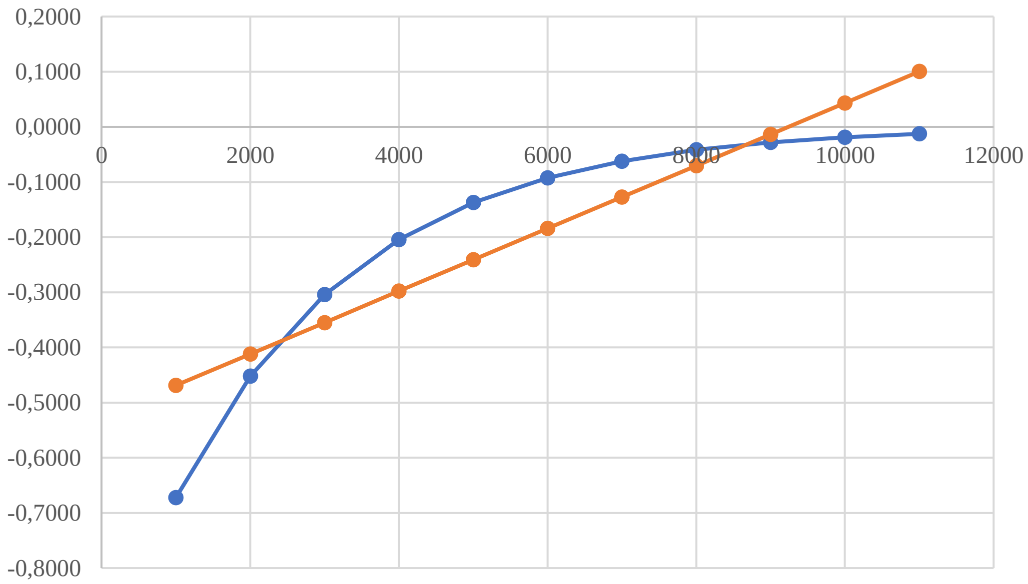

Figure 6: Utility of profit from investment portfolios with different volatility $U(W) = 0.000057 \cdot W - 0{,}526$ (abscissa axis is welfare of investor W, ordinate axis is utility of welfare $U(W)$)

For the investor's income expectations W_0 and the risk level h (fig. 6), as well as based on his utility function (fig. 5) for deviations from the expected income $W_0 \mp h$ we obtain the equation of the straight line passing through the points $(W_0 - h; b + k \cdot \ln(W_0 - h))$ i $(W_0 + h; b + k \cdot \ln(W_0 + h))$:

$$\frac{W - (W_0 - h)}{2h} = \frac{U(W) - [b + k \cdot \ln(W_0 - h)]}{k \cdot [\ln(W_0 + h) - \ln(W_0 - h)]} \tag{6}$$

Equation (6) is represented as $U(W) = \frac{k}{2h} \cdot ln\frac{W_0+h}{W_0-h} \cdot W + b + k \cdot \ln(W_0 - h) - \frac{k\cdot(W_0-h)}{2h} \cdot ln\frac{W_0+h}{W_0-h}$. Then the level of utility corresponding to the guaranteed income is $U(\overline{W}) = b + k \cdot ln(\overline{W})$. Hence, $\overline{W} = e^{\frac{U(\overline{W})-b}{k}}$ and the size of the insurance premium will be $W_0 - \overline{W}$.

For the investor, insurance premium calculations are presented in Table 7.

Table 7
Insurance premium for investor

Expected welfare W_0, UAH	Welfare for sure W_{sure}, UAH	Insurance premium $W_0 - W_{sure}$
5000	4720	280
5500	5192	308
6000	5664	336
6500	6136	364
7000	6608	392
7500	7080	420

The insurance premium size for the investor will be 5.6% of the estimated investor's income (fig. 7). Thus, with an increase in the expected income by UAH 500, the size of the insurance premium will grow by UAH 28.

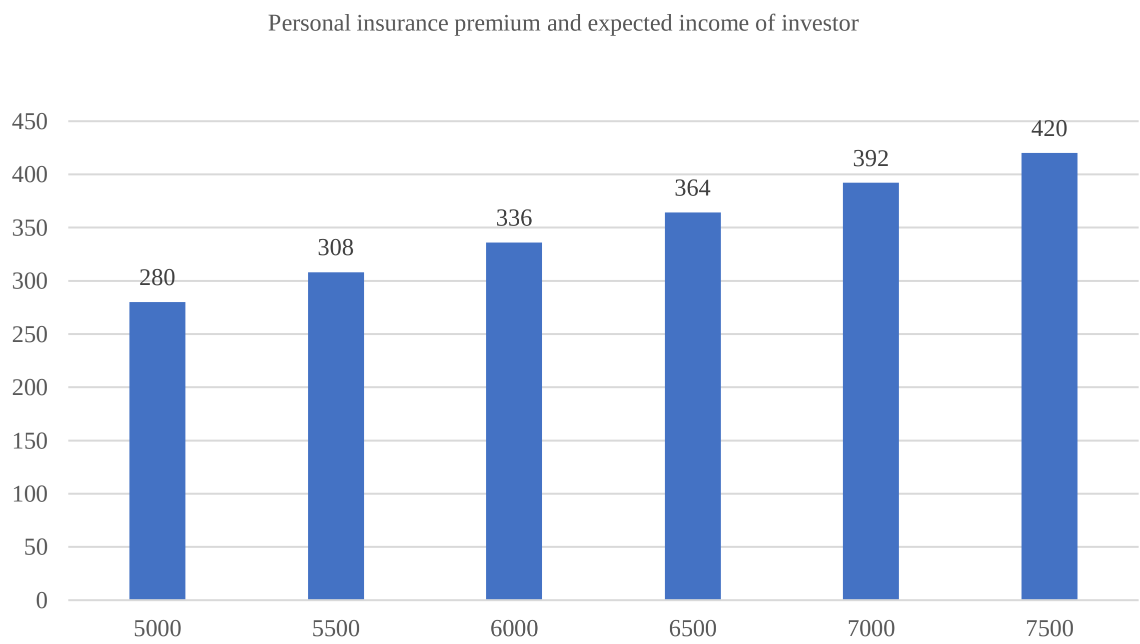

Figure 7: Impact of expected income on personal insurance premium

The model helps determine the individual size of the insurance premium for each investor profile, taking into account his risk attitude.

6. Conclusions

In this research, we present crucial importance to analyze investors' behavior, decision-making factors and the specifics of their investment portfolio formation and especially their cognitive constraints, which prevent them from effectively defining investment goals and profitable achieving them. Experienced and financially literate investors can often make significant mistakes when creating their own investment portfolios without using of robo-advisor. Thus, the use of automated tools for determining the insurance premium and the optimal investment portfolio, which is a robo-adviser, becomes relevant for persons with different incomes. The author's contribution is the development of a methodology for automated risk premium assessment for the investor through robo-advisor by transforming the results of the investor questionnaire into a utility function. The results of the investor questionnaire using Harrington's desirability function determine the type of investor via the Attitude to risk scale. Based on the investor utility function, we developed a method for determining a personalized risk premium in absolute and relative terms.

In our paper was considered automated mechanism for revealing of personal insurance premium for different risk attitude investment portfolios using robo-advisor. The model helps determine the individual size of the insurance premium for each investor profile, taking into account investor's risk attitude, to help persons make their first investment.

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