Data Analysis of Private Investment Decision Making Using Tools Of Robo-Advisers in Long-Run Period

Vitaliy Kobets[1][0000-0002-4386-4103], Valeria Yatsenko[2], Anastasia Mazur[1], and Mykyta Zubrii[1]

[1] Kherson State University, 27, 40 Universitetska st. Kherson, 73000, Ukraine
vkobets@kse.org.ua, nastyamazur5@gmail.com, w7heavyrain@gmail.com
[2] Taras Shevchenko National University of Kyiv, 90-A, Vasulkivska st., Kiev, 03022 Ukraine
ValeriaYatsenko5@gmail.com

Abstract. The most popular automated systems are robo-advice services which have the mathematical algorithm based on the main principles of consumption-savings theories. The purpose of this paper is to describe data analysis of private investment decision making using developed tool of robo-advisers in long-run period. We considered consumption-saving ratio in economics, emerging trends of robo-advice (RA) services for making investment decisions. SWOT-analysis of robo-advice services and comparative characteristics of robo-advisers explain advantage of RA services. We also developed mathematical model of robo-advisor in a long-run period and described support of investment decision making in long-run period via software module of robo-advisor. The task assignment of developed IT service is to maintain a constant level of client's consumption during life-long period through automated analysis of how much he/she has to consume and save each year. Results of consumption and savings proposals can be modified if initial financial data changes.

Keywords: robo-advisor, data analysis, long life decision making, annuity.

1 Introduction

The problem of the optimal balance between consumption and savings, transformed into investments, is one of the most important issues on all levels of economic system. This is explained by the fact that the equivalence between consumer and savings flows provides for internal and external equilibrium in the economics, and, therefore, a balanced economic growth and increase of economic and social welfare. As a result, the scholarly apparatus of the subject is characterized by the variability of approaches and views of top economists, which sometimes supplement, and often directly contradict each other. However, the bottleneck of the scientific research is the analysis of consumer spending and saving patterns through adaptive or rational expectations theories. Usage of these theories is complicated in modern economic conditions, characterized by high levels of future uncertainty, volatility of the main economic indica-

tors, variability of market condition and limited ability of a person to process modern data independently, etc. In this case, the ability of economic actors to make rational economically justified solutions dramatically reduces which determines the necessity to use automated systems for making investment decisions. The most popular ones among such automated systems are robo-advice services which have the mathematical algorithm based on the main principles of consumption-savings theories.

The **purpose** of this paper is to describe data analysis of private investment decision-making using developed tool of robo-advisers in long-run period.

The paper has the following structure. Part 2 is devoted to the consumption-saving ratio in economics, emerging trends of robo-advice services for making investment decisions. Part 3 examines mathematical model of robo-advisor in long run period. Part 4 describes support of investment decision making in long-run period via software module of robo-advisor. The last part is the conclusion, which sums up the results of the research.

2 Related works

2.1. The role and place of the consumption-saving ratio in the country's economic growth

N. Kaldor believes the propensity to save on corporate profits is much higher than the propensity to save on households, which determines the necessity to change the proportion of the distribution in national income in favor of enterprises and the state in order to achieve sustainable economic growth [1]. However, the person-centered approach and statistical observations give us reason to specify households' key role in the implementation of consumer and savings potentials whose aggregate demand is the main catalyst for economic growth (fig. 1). According to some research works [3; 4], these processes form the basis for the main models of households' financial behavior: consumer, savings and investment behavior.

The study will be based on several points:

- The category of savings will be considered as a normal good: the richer the household is, the bigger share of income will be saved compared to the poorer one [5];
- We will understand savings only as an organized form, which is a source for investments in the national economy, while unorganized accumulated savings contribute to stagnation and recession of the economy;
- Disposable income is the main source of consumption and savings, which remains after payment of health insurance, utility bills, taxes and other mandatory payments, etc.

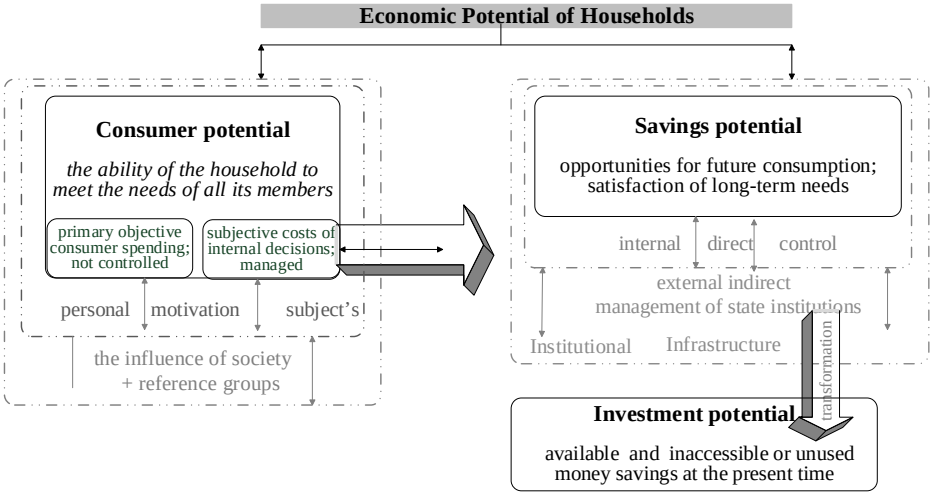

Fig. 1. Interconnection of consumer, savings and investment potential [2]

In our opinion, savings are remaining balance of the disposable income aimed at maintaining or improving the standard of living in the future. What is more, W. Sharpe calls it "deferred consumption" [6]. This view closely correlates with the process approach (fig. 2), according to which savings, transforming into investments, are directed towards final consumption in the next time period.

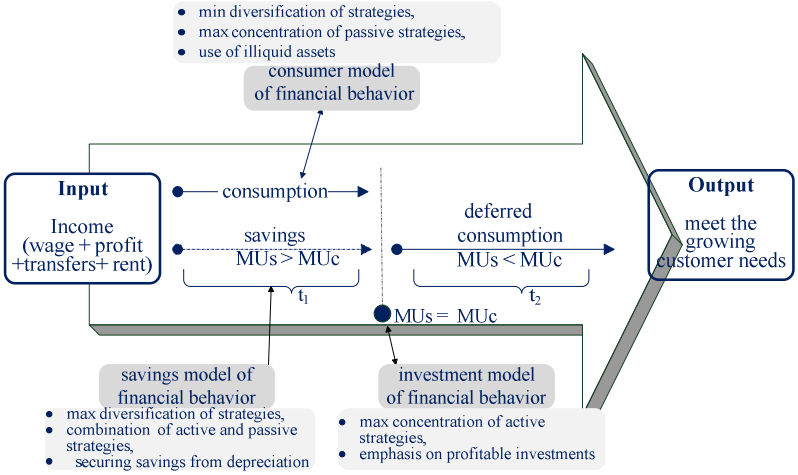

Fig. 2. Analysis of savings: process approach

Interpretation of savings greatly depends on the chosen form of manifestation: the system of economic relations, accumulated fund or business process.

The consumption process, motives and mechanisms of saving and its motives are among the central objects of the top economists' research. Nevertheless, the current stage of the economic system development partially, and sometimes downplays, some statements and assumptions of the theories. These processes require their critical re-

evaluation and a creative search for a solution of a new scientific problem: making of savings in the new globalized volatile economic system (fig. 3).

The first attempt to make holistic analysis of consumer and savings behavior was made by J. Keynes in the 1930's in the Absolute Income Hypothesis according to which there is a linear dependence between savings and income. The rejection of A. Smith's "rational-economic man" and the economic behavior analysis through "animal spirits" concept, according to which instincts and emotions are the basic determinants of consumer behavior, are the main achievements of J. Keynes. The illogical, irrational financial behavior is described by the "paradox of thrift", which argues the fear of losses leads to their occurrence and increase, since the endless reduction of consumption in favor of savings becomes a catalyst for the recession because of reducing aggregate demand. This situation can be explained by the second axiom of the Absolute Income Hypothesis well known as Keynes's psychological law, stating that people tend to increase their consumption with increasing income, but to a lesser extent than income growth, which is why, according to some scientists, the optimal share of savings should be 30% [7].

However, in our opinion, the major drawback of Keynes's theory is the use of linear functions to formalize the economic behavior, since the theory of synergetics states that modern economic processes are characterized by their complexity and nonlinearity. In this case, possibility of using simple mathematical functions in modern financial modeling is quite limited. Moreover, due to the limited human rationality, economic agents are not able to quickly and efficiently process big data with a large number of alternatives, which generates the demand for simple automated decision-making tools.

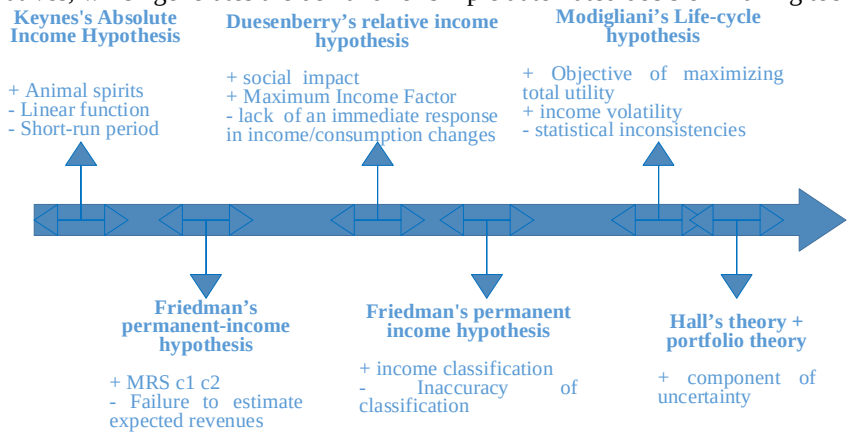

Fig. 3. Achievements and limitations of orthodox consumption-saving theories

Formalizing the consumption ratio in different time periods and introducing a category of marginal rate of substitution which reflects the amount of future consumption the consumer would be willing to substitute for one unit of present consumption [8] are the main contributions of the I. Fisher's Intertemporal choice. The thesis of I. Fischer, stating that consumption depends not only on current income but also on the expected income received throughout life improves the theory of J. Keynes and ex-

tends the scope of analysis by adding a parameter of perspective and an uncertain future. However, to our mind, such extension of the model may be meaningless, in case when the business unit makes estimation of their probable level of income independently. This is because the optimal rate of the marginal rate of substitution can be estimated incorrectly due to restrictions of deductive rationality (tunnel thinking and path dependency).

The achievement of J. Dussenberry's Relative Income Hypothesis depends not only on the household's current income, but also on the incomes of reference groups, social class, society in general and the position of the subject in the family income distribution. To our mind this contradicts the rational behavior of the economic agent and describes an additional argument in favor of using an automated financial consultant who will assess the necessity of an immediate change in the average propensity to consume, depending on the model parameters changes.

M. Friedman thought the choice between consumption and savings is based on the estimation of the average expected income received during a lifetime, which consists of two components: permanent and transitory incomes (fig. 5). According to this division it can be concluded that the share of savings increases with the increase of the transitive income rather than permanent one, since the marginal propensity to consume over transit income [0,2-0,3] is significantly lower than the marginal propensity to consume at constant income [≈ 1] [1].

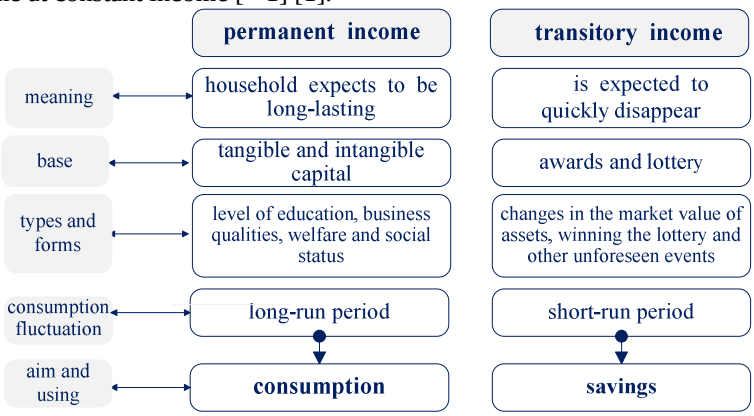

Fig. 5. Distribution of current income by M. Friedman

A significant bottleneck of M. Friedman’s theory is the inability to identify the permanent income correctly. This leads to further development of the permanent-income hypothesis in the coordinates of the rational expectations theory, which argues that the economic actors hope to maintain the trend of earned income in the future. However, this assumption often does not correspond to the real behavior of economic agents due to their inability to assess economic changes quickly and correctly, framing consciousness, psychological disregard for negative changes, and rejection to reduce private consumption when decline in income is expected in the nearest future. Thus, in our opinion, in order to actualize Friedman’s permanent-income hypothesis, its scientific view should be based on D. Kaneman and A. Tversky’s Prospect Theory.

What is more, the two-component income classification is supplemented by a third type of income – passive income, which is now becoming more and more popular.

According to F. Modigliani and R. Brumberg ‘s Life-Cycle Hypothesis, economic agent wants to maximize the total utility of consumption during his/her lifetime in the conditions of budget restrictions, and the main motivation for saving is supporting consumption level during the period of unremunerated activity [5].

The principal contribution of F. Modigliani includes two aspects:

- Income is volatile during a lifetime, therefore, the savings strategy essentially depends on the stage of the person's life cycle;
- There are some important factors influencing the savings theory: age structure of the population (as confirmed by A. Deaton and C. Paxon calculations [9]), average age of retirement, social security system development (↑ social security program → ↓ saving for old age), economic growth rate (↑ economic growth rate → ↑ income → ↑ savings) and population growth (↑ birth rate → ↓ relative proportion of pensioners and employees). An additional factor that has a significant impact on consumer and savings behavior is the cohort effect, studied by A. Kapteyn and T. Jappelli [10; 11], O. Attanasio and M. Browning [12; 13].

M. Browning and T. Crossley empirically confirmed the effectiveness of the hypothesis in distribution between consumption and savings by households in Great Britain and Canada [14]. However, other statistical tests revealed some contradictions: households are more likely to save in their mature years, while older people spend a small part of their savings and transfer their financial assets to inheritance.

According to R. Hall’s hypothesis consumers maximize the expected utility, rather than actual one during the life cycle against unchanged interest rate [15]. There are some assumptions of the model: the process of income generation is stochastic; the purpose of households is to maximize the expected intertemporal utility. The main conclusion of R. Hall's theory is about confirming the unpredictability of changes on the consumption and savings levels, because of the uncertainty in income changes.

Thus, the mainstream theories cannot appropriately explain the consumer, saving or investment behavior of a modern economic agent operating in the coordinates of uncertainty, asymmetric information and risk taking. The reason lies in using the "rational person" concept with its restraints and contradictions. Subsequently, these reasons promote the use of automation processes for making investment decisions on the basis of complex mathematical algorithms and processing large databases. The basic provisions of reviewed above theories can be used to specify the basic parameters and functional dependencies in the model. Whereas, the principles and purpose of the automated tools should appropriately reflect the current economic reality with its turbulence and nonergodicity of the statistical data in order to even out the elements of the irrational behavior.

2.2. Reasons for the popularity of automation mechanisms for making investment decisions

There is a large number of cognitive limitations downplaying the effectiveness of making independent decisions by economic agents [16; 17]:

- A person is more afraid of losing than gaining in the existence of risks (uneven assessment of benefits and losses $X \neq -X$);
- Problem in probability estimation:
  - Underestimation of the probability of events that are likely to occur and reassessment of much less likely events;
  - People tend to exaggerate the expected utility compared to the Neumann-Morgenstern model and underestimate the risks;
  - The Ellsberg paradox or intolerance of uncertainty - known probabilities are better than unknown ones;
- D. Kaneman and A. Tversky's Prospect Theory - averseness to reduce private consumption in the context of lower income in the near future;
- Irrational behavior
  - fear and averseness of losses lead to bigger losses;
  - looking for logic in random coincidences;
- Path dependency - most economic decisions, including investment decisions, people take unconsciously, based on past experience, stereotypes, patterns and biases;
- Tunnel thinking and framing:
  - narrowing of outlook - creating a vision framework based on past experience and averseness to learn new information;
  - concentration of attention only on significant evident facts;
- Procrastination - fears of negative consequences of decisions taken in conditions of uncertainty, hoping that everything will solve on its own;
- The Allais paradox - the agent behaves rationally when prefers absolute reliability instead of the maximum utility (it is preferred to lower income with a higher probability of receipt);
- Averseness to analyze probable scenarios as a result of rejection of changes;
- Limited deductive rationality in solving too complex tasks - the ability to analyze only parts of information with limited alternatives instead of all amount of information;
- Heuristics of human behavior - creative search, the discovery of a "new information " lead to unconscious thinking and impulsive irrational decisions;
- Asymmetric information during decision making;
- Satisficing - which, according to H. Simon, is a decision-making strategy that entails searching through the available alternatives until an acceptability threshold is met;
- Nonergodicity of the current situation with the retrospective data.

Thus, cognitive limitations of economic actors in mathematical assessment and embedded cognition specify objective demand for automatic tools of decision-making one of which is robo-advisor service gaining popularity due to wide range of benefits.

2.3. Robo-advice services and its emerging trends

The concept of “robo-advice” means the use of automation and digital techniques in order to build and manage portfolios of exchange-traded funds (ETFs) and other instruments for investors. On the other hand, it can be described as online portfolio management solution that aims to invest client assets by automating client advisory. The main principle of robo-advice services means completing a simple profile and risk tolerance questionnaire online and receive a recommended portfolio, composed mostly of low-cost exchange-traded funds (ETFs) (fig. 6).

Strengths	**Weaknesses**
❖ Increased productivity; ❖ Increased accessibility for “mass-affluent, delegator” market segment through low or no minimums and fees; ❖ streamlining the account opening process, increasing ability to transfer assets; ❖ monitoring, rebalancing and reporting on portfolios; ❖ appealing to non-traditional clients, especially younger clients with fewer assets to manage; ❖ it is the ideal model for clients with simple needs, or for smaller “entry level” accounts; client-relevant digital content; ❖ diversification of portfolios by using exchange-traded funds (ETFs); ❖ has no requirement for a deep financial background; ❖ includes a wide range of technology from lower to higher one end depending on the chosen strategy; ❖ increased transparency; ❖ offers easy-to-use tools that simplify the client experience.	❖ it does not meet all needs of investors; ❖ it does not suit every investor; ❖ it uses simple surveys to profile clients and to assess their needs; ❖ it proposes fairly basic capabilities; ❖ it has minimal ability to explain complex topics, and no ability at all to follow up with questions and make recommendations based on the answers.
Opportunities	**Threats**
❖ adding new capabilities; ❖ attracting assets that are not currently in-house at wealth management firms; ❖ receiving synergy and added value in case of cooperation with financial advisers; ❖ expanding interest in passive investing; ❖ assimilating multiple goals, including college savings, planned home purchase, retirement, protection needs, estate planning and the need for health care and/or long term care coverage; ❖ including, besides ETFs, such assets as equities, fixed income and, eventually, alternative investments such as hedge funds and real estate; ❖ helping clients understand their portfolios by providing information and learning the financial results and market information being presented; ❖ considering the client’s complexities by adapting questions based on earlier responses.	❖ failure of trust to automation and digital techniques ❖ necessity of face-to-face interaction between clients and advisors

Fig. 6. SWOT-analysis of robo-advice services [12-16]

Overall, according to Deloitte prediction Robo-Advisory services will manage with assets between $ 2.2 trillion and $ 3.7 trillion in 2020. By the year 2025 this figure is expected to rise to over $ 16.0 trillion assets under management.

Robo-adviser represents an online service that helps the client to form an investment portfolio and subsequently manage it (make adjustments, advice, etc.). The consulting robot is able to analyze the user's needs and his/her risk attitude, make an investment model for him and gradually implement it by buying and selling securities in the stock market and other financial instruments. Thus, the robo-adviser actually performs the functions of the "portfolio manager".

The robot-adviser developed by us is designed primarily for private persons (investors) who invest for a long time in financial instruments in order to secure a permanent passive income at the planned retirement age with the help of a robot consultant.

The income depends on the amount invested and the degree of investment risk. It is impossible to guarantee a positive and stable profitability when trading financial instruments on the stock exchange. This is a feature of the industry itself, not just this service.

The first such services for retail customers appeared in the US in 2008. According to the ResearchHQ News specializing in research and ratings, the leaders of this market are American independent robot-advisers Wealthfront ($ 3 billion under management) and Betterment ($ 4.2 billion, 150 thousand customers). In recent years, the number of such online advisers has increased noticeably. There are more than 200 firms offering services of robo-acquiring around the world. Nowadays, they manage about $ 300 billion and, according to forecasts, this graph will grow (fig. 7).

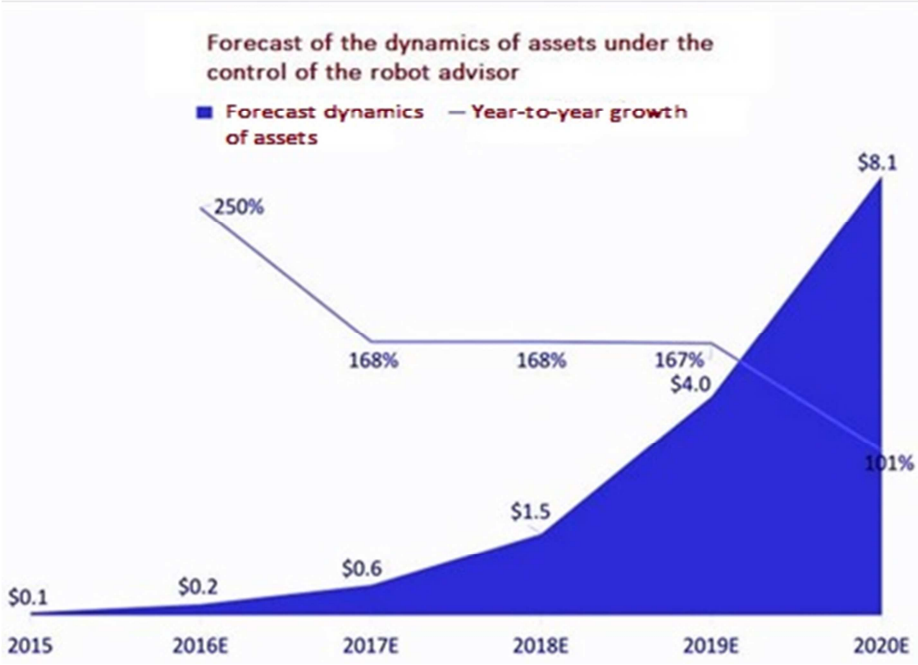

Fig. 7. The forecast of the dynamics of assets under the control of the robot advisors

Comparative characteristics of robo-advisers are given in table 1 and collected from Internet portals that analyze foreign brokerage services. The table in the left column, has the criteria, for which two leader companies are allotted, highlighted.

Table 1. Comparative characteristics of robo-advisers

Day	Robo-advisor	Features and positioning	Marketing stock	Minimal amount	Comission
Best in total	Wealthfront	Optimization	Up to $	500$	0.25%per

indicators with the function of minimizing taxes		and indexation of taxes for accounts over $ 100,000	10,000 no commission for annual maintenance		year
Best in Total Indicators	Betterment	With the help of a user-friendly interface, it is possible to form a portfolio efficiently and cheaply	First 6 months free of charge	0$	0.15-0.35% per year
With minimal commissions	WiseBanyan	Additional services paid	none	10$	0
With minimal commissions	Charles Schwab	Recognized leader in the sphere of asset management	none	5 000$	0
Specializing in retirement plan 401K	FutureAdvisor	Operates 401K accounts serviced by the investment company Fidelity and TD Ameritrade for free	First 3 months free of charge	10 000$	0.5% per year
Specializing in retirement plan 401K	Blooom	Manages 401K accounts for a fixed fee	none	0$	$5 to $99 per month
With the services of a financial adviser	Vanguard	Services of the adviser (manager)	none	50 000$	0.30%per year
With the services of a financial adviser and function of minimizing taxes	Personal Capital	Financial Consultant (Manager) + tax optimization for accounts over $ 100,000	none	25 000$	0.49-0.89% per year

1. The commissions are charged for the use of robot-advisers, but the costs for the purchase of assets are not taken. Most of robot-advisers use ETF (Exchange Traded Funds), and managing companies that issue ETF, charge 0.1 to 0.5% per annum on funds, depending on the composition of assets. Therefore, it is necessary to add the specified commissions to these prices.
2. Optimization of taxes: the company studies the client's tax profile for the previous period in order to find inefficiently paid deductions (pension, insurance, banks, medicine, stock market), return them and reinvest to the client's account.
3. Retirement plans 401K is a popular tool in the US for saving. Money is transferred to these accounts by employers, the assets are not in pension funds, but on dedicat-

ed accounts in investment companies, taxes are not withheld from investments. Many people use several options at once, and often the calculation is based on household income.

3 Mathematical Model of Robo-Advisor in Long Run Period

Let's consider the work of robo-advisor service based on the following example. Task of the service is to determine the conditions under which an investor can carry out regular consumption both before and after retirement using a personal savings fund. To achieve this, the client of this service should answer the following questions:

1. What is the average annual income Y of the client?
2. From what age t_1 does the client plan to start a personal savings program?
3. At what age t_2 does the client plan to retire?
4. Up to what age t_3 does the client plan to use his/hers personal savings fund?
5. Which average level of 'risk-profit' ('h- i') for financial instruments is preferable for the client?
6. What is the acceptable level of annual consumption C^* for the client?

The task assignment of the IT service is to maintain a constant level of client's consumption during life-long period through automated analysis of how much he/she has to consume and save each year. Calculation of distributed income Y for consumption C and savings S:

$$C = Y - S \tag{1}$$

Table 2. Indicators of robo-advisor service

Indicators	Value of indicators
The age of the client from which the personal savings program begins	$t_1 = 35$ years
Retirement age of the client	$t_1 = 65$ years
Age up to which the client will use his savings fund	$t_1 = 80$ years.
Annual income of the client	$Y = 200000$ euro.
The desired annual real interest for risk-free investments	$i = 7\%$, $h = 0$
Acceptable level of annual consumption of the client	$Y = 180000$ euro.

The task assignment of robo-advisor consists of two parts:

1. To define the annual amount of savings using the future value of annuity FVA:

$$FVA = S \cdot \frac{(1+i)^{N_1} - 1}{i} \tag{2}$$

where i is the desired annual real interest rate on savings, $N_1 = t_2 - t_1$ is the accumulation period of a personal savings fund, S is the annual amount saved. After N_1 years the personal savings of the client will equal FVA.

2. To calculate the distribution of the savings fund on constant consumption after retirement using the present value of annuity:

$$PVA = C \cdot \frac{1-(1+i)^{-N_2}}{i} \tag{3}$$

where i is scheduled annual real return on savings, $N_2 = t_3 - t_2$ is utilization period of a personal savings fund, C is annual constant consumption of the client.

Thus the future and present values of annuities should be equal: $FVA = PVA$, that is, taking into account (1) we obtain:

$$C = \frac{Y \cdot \left((1+i)^{N_1} - 1\right)}{(1+i)^{N_1} - (1+i)^{-N_2}} \tag{4}$$

.

After substitution of the values from table 1 in formula (4) we get: $C = 182411.7$ euro is the annual constant level of consumption, which is not less than the desired expenditure level on the annual consumption of the client $C^* = 18000$ euro. At the same time, the annual level of client's savings should be 17588.3 euro. If $i \ll 100\%$, then we can rewrite (4) as following $C = \frac{Y \cdot N_1}{N_1 \cdot N_2}$ and savings fund is $C = \frac{Y \cdot N_2}{N_1 \cdot N_2}$.

The formation of a personal consumption fund in graphic form is presented in fig. 8.

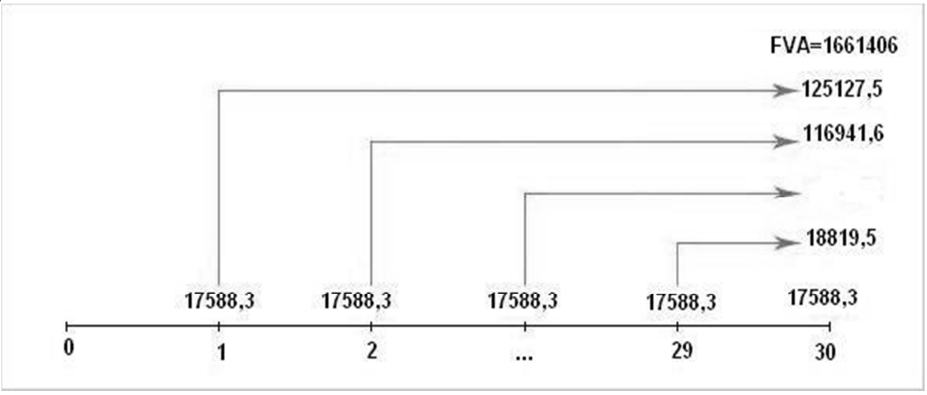

Fig. 8. Formation of a personal savings fund FVA

Distribution of personal savings funds to a constant consumption level of 182411.7 euro is presented in fig. 9.

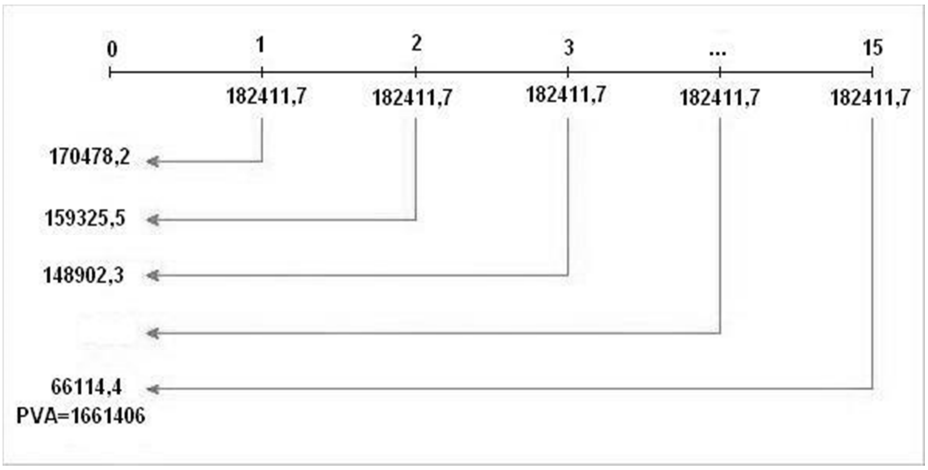

Fig. 9. Distribution of personal savings fund PVA

4 Support of Investment Decision Making in Long-Run Period via Software Module of Robo-Advisor

To implement the practical part we were developed a program module as desktop robo-advisor using .Net technology. In its final form the robo-advisor will have the architecture depicted in fig. 10.

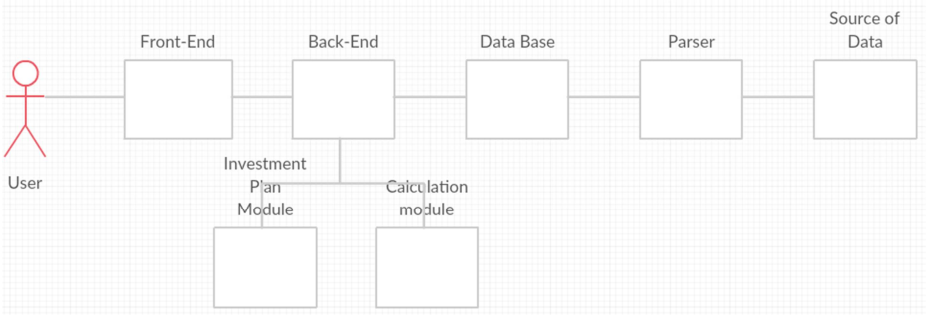

Fig. 10. Robo-Advisor architecture

The overview of the practical module is the following: the application is presented in following figures 11 and 12. On the main page the user has to first enter the input data required for further calculations, and then click on the Calculate button.

The system includes methods for calculating S (Payment of customer), C (Permanent consumption of client), FVA (Future Value of An Annuity), PVA (Present Value of an Annuity), provided in the application model, which uses input data, provided by the user.

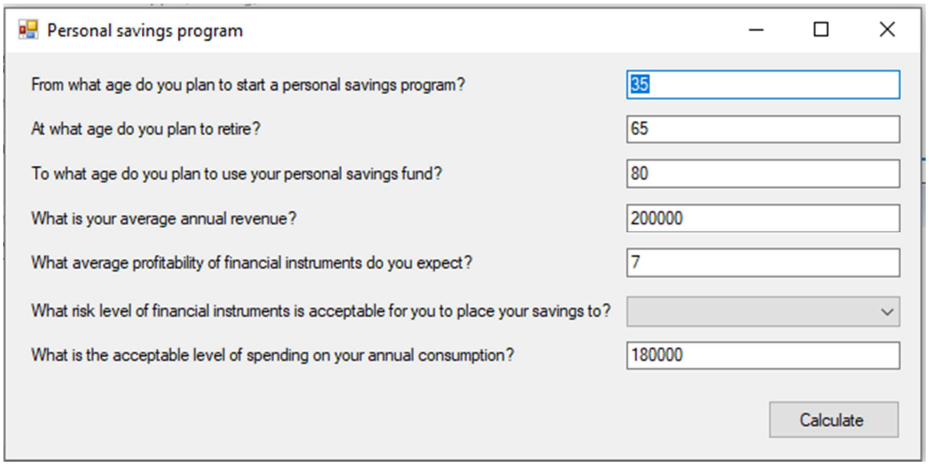

Fig. 11. Robo-Advisor: data input

After calculations, the system displays the calculated savings S and consumption C to the user during long-life period which is based on the input data.

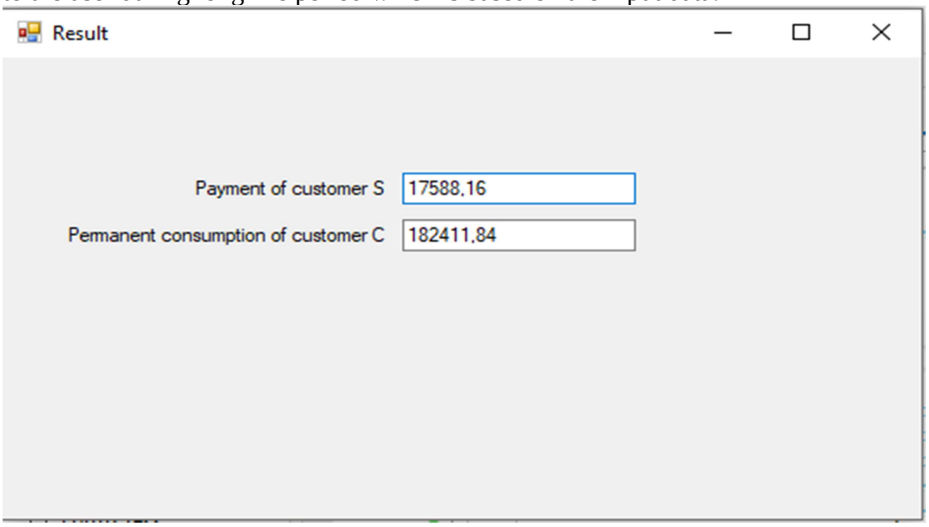

Fig. 12. Robo-Advisor: output data

Conclusions can be modified if the initial data changes. In the future it is planned to expand the system in the following directions: develop a web-based version of the application, add integration with external services to find financial instruments for investment, add administration system and improve the application interface.

5 Conclusions and Outlook

In our opinion, savings are remaining balance of disposable income directed to maintaining or improving the standard of living in the future. This fact describes an additional argument in favor of using an automated financial consultant who will assess the necessity of an immediate change in the average propensity to consume, depending on the model parameters changes. The concept of "robo-advice" means using of automation and digital techniques to build and manage portfolios of exchange-traded funds and other financial instruments for investors. Robo-adviser represents an online service that helps the client to form an investment portfolio and subsequently manage it.

The robot-adviser developed by us is designed primarily for private persons (investors) who invest for a long time in financial instruments in order to secure a permanent passive income at the planned retirement age with the help of a robot consultant. The task assignment of our IT service is to maintain a constant level of client's consumption during life-long period through automated analysis of how much he or she has to consume and save each year. To define the annual amount of savings to guarantee constant level of consumption for each private person during long life period we use present and future value of annuity.

In the future it is planned to expand the system in following directions: develop a web-based version of the application, add integration with external services to find financial instruments for investment, add administration system and improve the application interface.

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