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INVESTMENT RISK AND EFFICIENCY ANALYSIS OF CROATIAN PENSION FUNDS

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Abstrac
The object of this study is to analyze investment efficiency of pension funds by examining the portfolios of four mandatory pension funds (AZ, Erste Plavi, PBZ Croatia osiguranje and Raiffeisen). In this study, the pension system is analyzed through two step procedure. The study will first focus on pension fund portfolios, models of investments and risks that should be taken in account. Also, legal regulations are described which outline the business framework of pension funds and systems. After legal regulations short literature review is also given. Secondly, there will be an analysis of the current portfolios of pension funds and it will be tested whether they can be optimized by means of a mathematical maximization formula. In order to analyze the impact of pension funds, it was necessary to overview lists of the investments undertaken by the four mandatory pension funds in the period from 2015 to 2019. The analysis of investment optimization, together with the method for a mathematical return maximization in pension funds of category A and B, has found that there is room for increasing investments in stocks and consequently maximize returns.

Keywords: pension funds, optimization, portfolio management, risk analysis, share return

JEL Classification: M 30

INTRODUCTION

Pension funds were introduced in Croatia in 2002 and they are based on a system of three funds. Namely, the first pillar is mandatory and has characteristics of intergenerational solidarity. The second pillar is mandatory as well but it is based on individualized capitalized savings. On the other hand, the third pillar, which is also based on individualized capitalized savings, constitutes voluntary pension insurance and gives employees the freedom to choose the amount of money they want to save each month. Since the introduction of this form of pension system, Croatia has created the structure and foundations for the development of financial markets, financial institutions and capital markets. In other terms, banks are not the sole source of capital for entrepreneurs in this system because its introduction also created a new source of capital which stems from pension funds' assets (Draženović, Hodžić, and Maradin, 2019).

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Pension systems which include individualized capitalized savings are in fact based on a collective investment scheme, i.e. pension funds. When a person retires, their capitalized assets are transferred from the pension fund to a pension insurance company, which pays retirement benefits to the insured person. Such a structure of the second pillar implies that payments to the fund occur at regular time intervals and contributions paid to the fund grow over time. An indication of the expected earnings is in fact the average annual return of the pension fund. Furthermore, it should be stressed that various types of fees determine the amount of total capitalized assets, for example entry fees, management fees and custodial fees. Conceptually speaking, three components and their marginal contributions affect the assets of the insured person: the return of the fund and the growth rate of gross income, whose impact significantly increases with longer savings duration. Briefly, the longer the person works and progresses, the stronger the effect of these components (Latković and Liker, 2009).

According to the Croatian Financial Services Supervisory Agency (HANFA), the leading institution for the regulation of the capital market and pension funds, pension funds managed HRK 98 billion in assets in the end of 2018. Their remarkable asset size makes pension funds the biggest investment potential in the country, together with banks. It is also important to mention the factors influencing the management of second pillar pension funds in this type of system. Second pillar mandatory pension funds and their assets are managed by four companies established by banks and insurance companies. HANFA lays down the institutional framework and the Central Registry of Affiliates (REGOS) is the central registry and deposit bank, whose primary function is collecting contributions of members of mandatory pension funds and their capitalized savings (Draženović et al., 2019).

Another factor which additionally describes how the Croatian second pillar pension system functions is the investment policy adopted by funds. All four of the Croatian funds (PBZ Croatia osiguranje, Raiffeisen, AZ and Erste Plavi) in which taxpayers may be insured pursue very conservative investment policies regardless of their category. The majority of their assets, namely 89%, is invested in securities of Croatian issuers, while 69% of the funds' assets is invested in government bonds issued by the Republic of Croatia. By analogy, the current and future assets of taxpayers is indirectly linked to the financial position of the country and risks associated with the bond market. This type of investment structure has the following implications: companies mostly rely on bank borrowing and it is not possible to identify an adequate performance measure for each of the three fund categories since their investment strategies are so similar. To illustrate, Category A, where the undertaken risk is the highest, has earned a return of 7.04% since 2014, while a conservative Category C has similarly made a 6% return in the same period. In other terms, their returns differ in one percentage point but legal definitions of their structural investments are quite different: Category C funds hold most of their assets in Croatian government bonds, whereas Category A funds may invest in stocks. The whole system is additionally affected by the undeveloped and shallow capital market, bank interests and ownership in pension funds, quantitative legal restrictions preventing portfolio diversification, high exposure to the state and bond risks, lack of competition and transparency in measuring the performance of each fund within given categories (Draženović et al., 2019).

1. LITERATURE REVIEW

It is necessary to give an overview of several studies which deal with foreign pension systems and optimization of pension fund portfolios, or analyze characteristics of the Croatian pension system. One such study deals with the Romanian pension system and the authors (Anghelache and Armeanu, 2008) incorporated modern portfolio theory in their analysis. This study puts forward a version of optimization whose aim is risk reduction, thus the authors calculated that 70% of assets need to be invested in government bonds, while the rest should be invested primarily in bank deposits in order to achieve this goal. They also concluded that portfolio optimization must be based on diversification, as stated by the Markowitz model, emphasizing that all portfolios are affected by systemic risk in any given scenario. The authors (Badea, Stancu, and Darmaz-guzun, 2018) analyzed the Romanian pension system as well with a focus on the second pillar and optimization as a means of risk reduction. They divided the portfolio of the second-pillar pension funds into five asset categories and used three models of optimization so as to calculate the weights of each asset class taking into account different preferences of insured persons. In their case study of the Ghanaian pension system, (Owusu, Appiah, Omari-Sasu, and Owusu, 2016) also stress that efficient asset allocation in the pension system is a prerequisite for optimal portfolios. They applied the Markowitz model to calculate the application of two different models of distribution of assets in portfolios according to the associated risk and expected returns. For example, they concluded that if pension funds want to minimize the expected risk, more than half of their assets (53.65%) should be invested in student loans, whereas the weight of this asset in the maximization model is around 26%.

Among the studies dealing with foreign pension systems and optimization there is one that also incorporates both the Markowitz model and the case of the Croatian pension system. (Pavković, 2019) studied optimization of investment strategies in Croatian second-pillar pension funds. The paper presents a model which was used to calculate optimal weights of six different asset classes needed to minimize risk, and a model in which weights of particular asset classes are distributed in such a way that funds can achieve maximum returns. The author solved the dual problem of return maximization and risk minimization and calculated the optimal portfolio structure for all three categories of pension funds as well as stressed the problems associated with the state's excessive dependence on selling government bonds to pension funds. Furthermore, the authors (Beljo, Devčić, and Marijanović Bilić, 2017) should also be mentioned because they analyzed the applicability of the CAMP model on the Croatian capital market and tested the adequacy of the beta coefficient as a measure of risk and whether CROBEX is a suitable substitute for the market portfolio. Correlation and regression analysis revealed that the beta coefficient is not an adequate measure of risk on the Croatian capital market and CROBEX is not a suitable substitute for the market portfolio. The study is significant because it found that there is asymmetry between theoretical hypotheses in the field of portfolio optimization and real characteristics of the Croatian market.

Moreover, the authors (Potočnjak and Vukorepa, 2012) should also be mentioned since they conducted a study in which they analyzed and proposed several models of an optimal portfolio based on other studies and cases. They concluded that the majority of models may be implemented as standardized models of lifecycle investing because they prevent the occurrence of negative shocks associated with a sudden decrease in value. However, they indicated that most authors, e.g. Scheuenstuhla et al., conclude that the performance of lifecycle investment models depends on a substantial percentage of stocks in portfolios. In other terms, owning stocks opens the possibility of achieving higher returns, which can be used to compensate losses caused by financial shocks. Aside from

that, they also question the applicability of lifecycle pension portfolio models in Croatia due to the limited nature of the Croatian capital market and the problem of financial literacy. (Škrinjarić, 2013) also points to some problems of applying the Markowitz model to the Croatian capital market: quality approach to diversification analysis is not possible because of the characteristics of the Croatian capital market. The study's contributions are found in a comparison of ten portfolios and their level of diversification. The paper also proved that problems arise from a shallow capital market and inability to achieve an adequate level of diversification.

2. RESEARCH PROBLEM

The basic research problem of this study focuses on various issues regarding the pension fund system in the Republic of Croatia. The study deals with the issue of optimizing pension fund portfolios based on return maximization and mathematical modelling. In other words, the optimal weight of each individual financial instrument in pension fund portfolios was examined according to historical return trends of financial instruments and their weights in company portfolios. The reasons for dealing with this thesis based on issues pertaining to the management of Croatian pension funds' investments include certain structural characteristics of the current state of the capital market and portfolios owned by second-pillar pension funds. More precisely, assets of insured persons are highly exposed to government bonds and potential risks that are associated with portfolios that have such a structure. Moreover, it is important to note that there is a certain level of risk involved in investing assets of insured persons in potentially non-profitable companies and stocks may drop in value, which directly impacts future assets of insured persons. These two problems may be associated with poorly developed capital markets. Accordingly, this paper presents an analysis of the issues regarding investments in companies on the Croatian capital market and the problem of opportunity cost that may appear due to a conservative portfolio management style, which leads to lower returns. All the issues pertaining to the pension system and its functioning are additionally analyzed by studying the legal framework which lays down concrete rules for investing in particular types of financial instruments. Primary, authors stance toward described subject and problem is that investment strategy was not optimal during observed time from 2014 till 2019 so, goal is to find out optimal ratios between different assets (bonds and stocks). Also, it's very important to take into account that results received are calculated on base of ex post data. With a clearly defined research problem, the following hypothesis was formulated:

H_1: ***Portfolios of Category A and B pension funds comprise optimal weights of different financial instruments.***

The hypothesis was tested by analyzing historical returns pattern for each financial instrument from the pension funds' assets. The current weight of each security in the portfolios was examined as well. Finally, a mathematical model was used to determine an optimal portfolio which will maximize returns within legal restrictions. The current portfolio structure of the funds may be described as conservative and highly exposed to risks associated with the economic situation of the country.

In other sections of paper, pension fund portfolios are described with focus on relation between persons age, time left to retirement and category or fund they belong to. Furthermore, paper also explains risks that pension funds are facing while managing persons assets, and also legal regulations are mentioned which define three pension funds

of different risk profiles. Paper also provides short review of previous studies that are connected or similar to research that is conducted in this paper. After review of studies, used methodology in research, results and conclusion are given at the end of paper.
Finally, it may be concluded that the research problem of this study focuses on something that is important in any individual's life – their future. In other words, this study deals with the issue of pension funds and the way they manage assets of insured persons. Moreover, the paper also covers the risks associated with unfavorable demographic trends which may have a great impact on the living standard of future pensioners, especially when their capitalized savings are not optimally managed.

3. PENSION FUND PORTFOLIOS

All of the activities and investments in the capital market that pension funds undertake lead to the creation of portfolios, which fund managers then use as a means of providing return on behalf of insured persons, simultaneously protecting them from risks arising on the capital market. Modern portfolio theory (MPT) may be applied in the context of pension funds and their activities in cases of one-off payments into the pension fund and very long time horizons. This theory determines an optimal allocation for an investor who invests in various asset classes and it takes into account the investor's risk-aversion and parameters such as the expected return, risk and correlation between various asset classes, risk-free interest rates and time independence. However, certain characteristics of the Croatian pension system are not in accordance with basic parameters of the MPT. The first one refers to the period of investing usually spanning from 35 to 45 years. The second characteristic is the fact that payments do not occur on a one-off basis, but rather at regular intervals and they grow slowly. The third peculiarity has to do with risk aversion, which intensifies as a person nears the end of their working life and pay-out phase of their pension plan. Given these three characteristics, an optimal portfolio of the insured person is dynamic with respect to time, which means that the portfolio which was optimal when the person started accumulating contributions is different from that at the end of the accumulation period (Kovačević and Latković, 2015).

Since the value of accumulated savings may drop when a person nears their retirement age in systems in which all members have the same type of portfolio that disregards dynamics over time, it is considered that investment regulations as a tool for preventing the incurrence of losses do not suffice. Therefore, pension systems introduce lifecycle portfolio models, i.e. they implement investment strategies which vary according to the insured person's retirement age. As already noted, an individual's ability to undertake investment risks differs with respect to their preferences and age at the moment of investing. The importance of adequate portfolio organization within the pension system lies in the fact that the period of accumulating pension savings is long and life cycle itself is a factor to be considered. According to MPT, returns should be proportional to risks, i.e. the higher the risk, the higher the return. Nevertheless, the pension system is important because the accumulated assets and positive returns become the insured person's source of income after their retirement. Consequently, the moment in time when the fund does not yield adequate results is of much interest to insured persons. In other terms, problems arise when pension fund returns become negative just before the person retires, which can most probably reduce the value of their accumulated savings and all contributions they have paid up to that moment. In general, portfolios of the pension system should generate returns which are at the same level as inflation rates. Therefore, stocks in the portfolio

whose value tends to lead to negative returns are not necessary a problem for the insured person, especially early in the pension plan. By the same virtue, elderly people should not invest in stocks; i.e. it is advised that they avoid investing in risky asset classes and primarily invest in bonds, treasury bills and bank deposits, which are associated with lower risks and returns. To put it differently, lifecycle portfolio modelling entails investing assets of younger insured persons mainly in stocks, while the percentage of the portfolio held in stocks decreases as they age. However, the saver's personal risks (the possibility of losing their employment) and financial and economic disruptions should also be taken into account (Potočnjak and Vukorepa, 2012).

Lifecycle investment modelling whose goal is to optimize the insured person's portfolio can be organized by continuously modifying allocation of assets, i.e. by defining similar groups of insured persons with roughly the same amount of time left until retirement. Croatian pension system achieved this in 2014 by introducing three fund categories: A, B and C. This type of system is consistent with the concept of lifecycle investing, where the membership of the insured person is automatically transferred from a high risk fund to a lower risk fund. Moreover, this kind of model offers a possibility of changing the membership on demand when the insured person wants to align the fund's risk with their personal preferences. It should be noted that there is also a risk involved in changing the membership between funds of different risk levels at a bad moment, e.g. when the total value of the accumulated savings falls due to price drops on the capital market and there is no possibility to rebound after switching to a lower risk fund. Nonetheless, there is another variant of managing the lifecycle investment model and it entails forming several pension funds with different risk levels and achieving optimization by investing a particular percentage of savings in a particular type of pension fund. The majority of countries like Croatia uses the system with three pension funds of different risk profile: conservative, balanced and aggressive.

4. PENSION FUND RISKS

The risk associated with expected returns is considered to be the most significant risk affined with management and inflation risk (Vukorepa and Potočnjak, 2008). Given that individuals in different life stages tolerate the risk differently, implementing a system with investment strategies tailored for particular age is justified. It is crucial to prevent the accumulated assets from suddenly decreasing in value as the insured person nears their retirement (Potočnjak and Vukorepa, 2012, pp. 24). It should be stressed that by reducing the number of stock investments with the goal of minimizing the risk of negative returns, insured persons consequently miss the opportunity of possibly earning positive returns later on and they are usually encouraged to expose their funds to stocks over a longer period of time in order to benefit from market growth (Potočnjak and Vukorepa, 2012, pp. 15). The return earned by pension funds' investments should be high enough to counteract inflation risk and so that the insured person's accumulated savings do not decrease in value (Potočnjak and Vukorepa, 2012, pp. 5). Pension funds should thus adjust their expenses by taking into account not only inflation, but also demographic and individual changes (Vukorepa and Potočnjak, 2008, pp. 4).

The system of automatic shift from one fund to another fund of different risk is used to reduce the risk of assets decreasing in value; however, this only postpones the occurrence of risk instead of dealing with the core of the problem that causes this loss. Nonetheless, there is still the risk of shifting form one fund to another at a bad moment in

time, so the utility of shifting between different categories is questionable when changing funds in unfavorable times bears higher risks (Potočnjak and Vukorepa, 2012, pp. 7). Therefore, if the insured person shifts to another fund and soon after that there is a market shock, they will not be able to compensate the losses and meet all legal requirements to shift back to a less risky fund (Kovačević and Latković, 2018, pp. 19).

As opposed to well diversified portfolios, the risk of under-diversified asset allocation means that pension funds will suffer more return losses. The risk only increases as more assets are being invested in stocks, whereas significant investments in bonds reduce the risk, considering that funds mostly invest in government bonds (Angelidis and Tessaromatis, 2010, pp. 5–6). Every fund is exposed to management risk since this is a consequence of management's incompetence or fraudulent behavior. Institutional risks are associated with the problem of collecting contributions and administrative and financial accounting (Vukorepa and Potočnjak, 2008, pp. 3). Longevity risk is associated with the expected duration of the insured person's retirement, thus it is necessary that investments provide pensioners with a steady source of income (Potočnjak and Vukorepa, 2012, pp. 16).

5. LEGAL REGULATIONS

Pension fund are obliged to comply with investment regulations stipulated in the Acts on Mandatory and Voluntary Pension Funds. The implementation of acts is primarily aimed at insuring future assets of insured persons by constructing optimal portfolios with minimal levels of risk. Insured persons have a right to choose from three pension funds of different risk profiles (A, B, C) (Kolarić, 2017).

Furthermore, companies which manage pension funds and their assets in fact manage the risk by regulating their investment policies. There are two basic and one derived approach: investment policy may be regulated by portfolio limits or, alternatively, the prudent-person rule. However, the most commonly used approach includes hybrid investment rules. The system of portfolio limits is used in continental legal systems, regardless of whether the pension insurance in question is public or private. Therefore, countries impose legal regulations and provide guidance for investing. These restrictions are based on qualitative rules determining the permitted categories of investment, and quantitative rules determining the permitted levels of investment (percentage) for any given category of investment. The rules of the country of origin make up the third set of rules and they are used to limit investments in foreign assets. Finally, it may be concluded that pension funds are similar with respect to not only their structures, but also possible returns and losses. Most OECD countries have this system in place, so Croatia created its own legal system responsible for the period of accumulating capitalized savings based on rules and regulations used in Argentina, Chile, Columbia, Estonia, Hungary, Mexico, Poland, Sweden, Slovakia and Switzerland (Potočnjak and Vukorepa, 2008).

Table 1. Overview of limits with respect to the net asset value of pension funds – comparison of 2014 and 2019

	2014			2019		
Type of investment	Category A	Category B	Category C	Category A	Category B	Category C

Transferable debt securities and money market instruments (issuer: Croatia)	minimum 30%	minimum 50%	minimum 70%	minimum 30%	minimum 50%	minimum 70%
Transferable debt securities and money market instruments (guaranteed by Croatia)	maximum 30%	maximum 30%	maximum 10%	maximum 30%	maximum 30%	maximum 10%
Transferable debt securities and money market instruments (issuer: local units)	maximum 30%	maximum 30%	maximum 10%	maximum 30%	maximum 30%	maximum 10%
Transferable debt securities and money market instruments (registered office of the issuer: Croatia)	maximum 50%	maximum 30%	maximum 10%	maximum 50%	maximum 30%	maximum 10%
Transferable equity securities (registered office of the issuer: Croatia)	**maximum 55%**	**maximum 35%**	-	**maximum 65%**	**maximum 40%**	-
Investments in UCITS funds	maximum 30%	maximum 30%	maximum 10%	maximum 30%	maximum 30%	maximum 10%
Investments in open-ended / closed-ended AIFs	maximum 15%	maximum 10%	-	maximum 15%	maximum 10%	-
Deposits in credit institutions	maximum 20%	maximum 20%	maximum 20%	maximum 20%	maximum 20%	maximum 20%
Cash on cash accounts for business purposes	maximum 10%	maximum 5%	maximum 10%	maximum 10%	maximum 5%	maximum 10%

Source: created by the authors based on the Mandatory Pension Funds Act from 2014 and 2019

6. COMPARATIVE ANALYSIS OF LEGAL AND ACTUAL INVESTMENTS

Figure 1 shows investments of Category A second-pillar pension funds by asset classes, and it may be observed that the highest percentage of portfolios is allocated to bonds and stocks. Despite the assumption that Category A pension funds are based on an aggressive investment strategy and legal restrictions oblige them to allocate a minimum of 30% of their portfolios to this type of security, the average weight of assets in second-pillar pension funds invested in bonds of the Republic of Croatia equals 48.3% in the observed period of five years. Furthermore, the weight of stocks was mostly around 25% over this five-year period, except in 2015, when it was 17%. In Figure 1, the direction of the line representing the weight of stocks indicates a growing tendency of pension funds towards more aggressive and riskier investment strategies for managing taxpayers' assets, which is in accordance with the fundamental characteristics of Category A. The rest of the investments in the observed period comprises corporate and municipal bonds, as well as UCITS funds and deposits. The weight of these asset classes in Category A portfolios ranges from 1% to 3%.

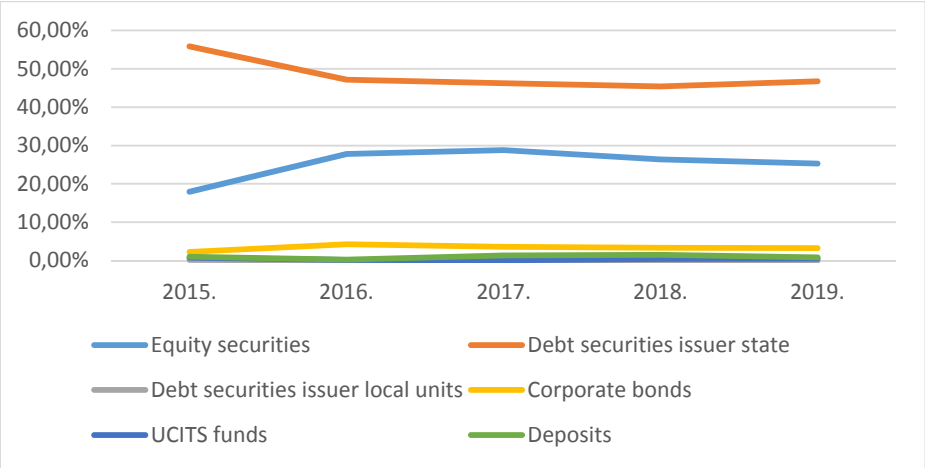

Figure 1. Weights of assets by classes of net assets in Category A second-pillar pension funds (2015-2019)
Source: created by the authors based on monthly reports by HANFA, period 2015-2019, https://www.hanfa.hr/publikacije/mjesecna-izvjesca/

When talking about the importance of increasing the weight of assets which are allocated to stocks, it is important to analyze the values of the MIREX A. MIREX indicates the average growth rate of assets managed by the four funds on the market. In the case of Category A, MIREX indicates positive and negative changes in asset value in a given category for all four funds. MIREX also shows how asset value increases in Category B and C.

Figure 2. MIREX A values for the period 2015-2019. (Source: hr.portfolio 2020)

Figure 2 shows MIREX A indices for the period 2015-2019 and a continuous asset growth in Category A funds. The asset growth caused by constant positive returns may be associated with an increased weight of assets allocated to stocks, which is illustrated by Figure 1.

Figure 3 shows weights of assets by net asset classes for Category B, i.e. how Category B second-pillar pension funds allocate assets of insured persons. It may be observed that the majority of assets is invested in bonds, namely an average of 70% was allocated to bonds in this five-year period. Although general legal regulations stipulate that the minimum weight of assets allocated to bonds must be 50%, portfolio managers tend to prefer very conservative investment policies. Figure 2 shows a difference of 20 percentage points between the actual and compulsory weights of assets allocated to bonds, which indicates that the majority of assets (future pensions) of persons insured in Category B funds depends on the economic situation of the country which issues these bonds, which is also true of the majority of all future pensioners since HANFA reports that they are mostly members of this fund category. The average weight of assets allocated to stocks equals 11%. Despite the legal restriction stipulating that the maximum weight of stocks in portfolios of Category B funds is 35%, the straight line in Figure 3 indicates a certain constancy of investment policies when it comes to bonds and stocks. The rest of the portfolio is allocated to corporate bonds, alternative investment funds, open-ended investment funds, money market instruments and deposits, but their average weight in the five-year period was just around 1%.

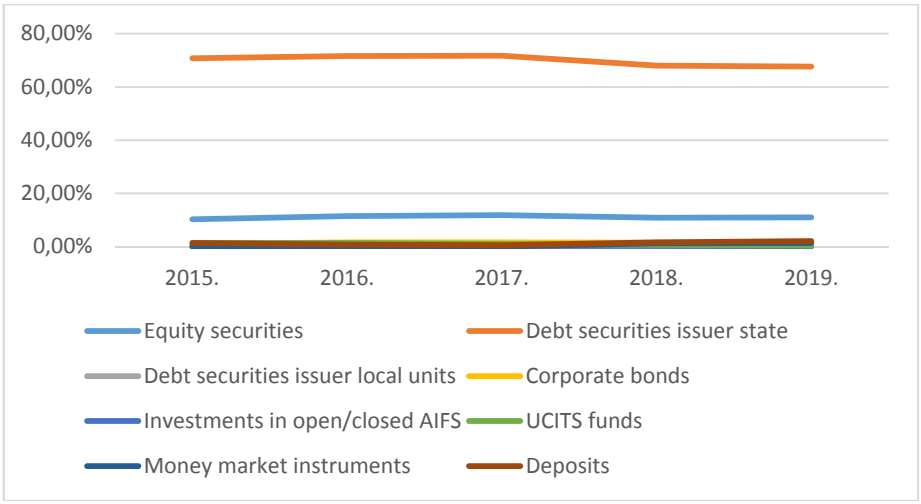

Figure 3. *Weights of assets by classes of net assets in Category B second-pillar pension funds (2015-2019)*
Source: created by the authors based on monthly reports by HANFA, period 2015-2019, https://www.hanfa.hr/publikacije/mjesecna-izvjesca/

The analysis and comparison of legal restrictions and actual portfolios managed by second-pillar pension funds shed light on certain problems arising from their investment policies. Namely, it was found that under-diversification has brought about problems in terms of return losses and risks. Therefore, as (Kovačević and Latković, 2015) indicate in their study, in which they showed the expected returns and risks of pension funds, the problems are revealed when Category B and C are compared in terms of these two parameters. The difference in returns and risks in Category A and B is more than obvious: the expected return in Category B is lower than in Category A, just like the expected risk in Category B is lower than in Category A. Naturally, this is a desirable difference because Category A is legally meant to be based on investment strategies which are more aggressive than those of Category B. On the other hand, a comparison of the expected return and risks in Category B and C reveals that a decline in expected returns in not proportional to a decline in expected risks. The expected risk in Category C is lower by 4.1% than in Category B and its expected risk, whereas the return in Category C is lower by 28% than in Category B. Consequently, even though Category B and C are conservative and their investment policies are aimed at allocating the majority of their portfolios to bonds, it is questionable whether this is an optimal asset allocation considering such slight differences in their returns. Furthermore, all the points made so far indicate a low level of diversification across asset classes in pension funds because the majority of assets is allocated to bonds in both Category A and B.

7. ANALYSIS: INVESTMENT OPTIMIZATION OF SECOND-PILLAR PENSIONS

7.1. RESEARCH METHODOLOGY

General characteristics of the obtained data, i.e. their type and source are presented in this section on research methodology. Data description is accompanied by a description of the maximization method or, in other words, how Solver, a Microsoft Excel add-in program,

was used to optimize the portfolio of second-pillar pensions. The starting point was identifying all securities held by second-pillar pensions for which monthly reports on returns were available. Moreover, legal restrictions were analyzed with the goal of setting adequate variables in the calculation process of portfolio optimization. Monthly reports on returns were collected from various web pages, whereas the rest of the information on funds was retrieved from the official page of HANFA and quarterly reports of each pension fund.

7.2. DATA AND MAXIMIZATION METHOD

Five different financial instruments were taken into account when calculating the optimization of portfolio weights for second-pillar pension funds. Returns in the period January from 2015 to December 2019 were observed for each month, which revealed the percentage difference in values of particular securities in a span of two months. Data on returns on bonds, government bonds, corporate bonds, UCITS funds and deposits were also collected and analyzed. A five-year average of returns was calculated for each instrument.

The maximization method is part of a group of mathematical formulae for optimization. In mathematics, the process of optimization consists of two parts: formulating a problem and solving it within certain constraints. Mathematical optimization is alternatively called mathematical programming or numerical optimization. This branch of mathematics deals the selection of the best solution in mathematically formulated problems. It can be used to minimize the proposed problem, e.g. production costs in industry, or maximize it, e.g. profit in economics and finance. In the application of any mathematical method, it is crucial to assign the algorithm for solving the problem to the right type of problem, so that a real-life problem can be mathematically formulated and solved. It should be emphasized that variables which are taken into account when formulating the problem should be in the same format. Otherwise, the applied algorithm for solving the problem will not be able to find the optimal solution (Snyman, 2005).

The goal of applying the maximization method to the problem of maximizing the return on assets held in portfolios of second-pillar pension funds is to calculate optimal weights for each asset class in their portfolios based on historical rates of return. Described formula is displayed in follow up:

$$E(r) = \sum xi * E\ (ri)$$

In the above equation, "E" ("r") represents the portfolio return, "xi" the size of the portfolio share invested in a security multiplied by "E (ri)", which indicates the average return of an individual security. Thus, each of the four pension funds invests a certain share of portfolio assets in a certain security that generates a yield, and by adding different products of shares in certain financial instruments and their yields, the portfolio yield is obtained. So goal is to maximize yield with given restraint (see page 7 and table 1) and since the expected yields are determined by historical data, the application of tools in Excel (Solver) and linear mathematical programming will determine the optimality of investment by changing the share variable "∑ xi"- required share for maximum yield.

Table 2 shows the constraints used in making the calculations, which are in line with the legally prescribed restrictions on investing in different types of securities.

Table 2. Constraints applied in calculations are based on Table 1 and column from 2014 (Overview of limits with respect to the net asset value of pension fund)

Type of investment		A category		B category
Transferable equity securities (registered office of the issuer: Croatia)	55%	Category type A can invest maximum 55% of asset in equity securities.	35%	Category type B can invest maximum 35% of asset in equity securities.
Transferable debt securities and money market instruments (issuer: Croatia)	30%	Category type A should invest minimum 30% of asset in debt securities.	50%	Category type B should invest minimum 30% of asset in debt securities
Transferable debt securities and money market instruments (registered office of the issuer: Croatia	50%	Category type A can invest maximum 50% of asset in debt securities registered office of the issuer Croatia.	30%	Category type b can invest maximum 30% of asset in debt securities registered office of the issuer Croatia
Deposits in credit institutions	20%	Category type A can invest maximum 20% of asset in deposits.	20%	Category type B can invest maximum 20% of asset in deposits.
Investments in UCITS funds	30%	Category type A can invest maximum 30% of asset in UCITS fund.	30%	Category type B can invest maximum 30% of asset in UCITS fund.

Source: created by the authors based on the Mandatory Pension Funds Act from 2014

Theoretically, the expected return of a portfolio can be calculated by multiplying each security's weight by their respective expected return, which is in fact a weighted sum of expected returns of each individual security in the portfolio. In this case, the variables are weights of assets, while the expected return of each security is the arithmetic mean of the returns on this asset achieved in the period January 2015-December 2019.

8. RESEARCH RESULTS

The objective of this paper was to determine the optimal weight (percentage) of each individual security for Category A and B with respect to the limits provided in Table 1. Also, its necessary to take into account limitations of such approach because historical data is used in calculations.

Table 2 provides the covariance matrix which was calculated for Category A based on the expected returns. The covariance matrix was calculated in Microsoft Excel by using add-in programs for data analysis and the Covariance function.

Table 3. Covariance matrix for Category A

	Stocks	*Government bonds*	*Corporate bonds*	*Deposits*	*UCITS*
Stocks	0.01869643	0.001865844	0.00016897	-7.8968E-05	0.00207426
Government bonds	0.00186584	0.001242731	3.62241E-06	-9.7914E-06	0.00024027

Corporate bonds	0.00016897	3.62241E-06	5.17961E-05	6.536E-07	2.9055E-05
Deposits	-7.897E-05	-9.79143E-06	6.53604E-07	2.4182E-05	-8,311E-06
UCITS	0.00207426	0.000240266	2.90546E-05	-8.3114E-06	0.00039353

Source: created by the authors based on the Mandatory Pension Funds Act from 2014 and 2019, Zagreb Stock Exchange, FTSE Euro Corporate Bond Index, hr.portfolio, HNB)

Based on the legal restrictions and covariance matrix, the variables from Table 3 were entered in the calculation. The table actually explains key indicators affecting the return that insured persons can achieve if their pension funds reallocate their investments according to the optimal weights of assets calculated by the program. Sharpe ratio as an indicator measures the risk-adjusted return which is achieved by investing in certain asset classes. The expected return of a portfolio actually explains the level of return that may be expected when weights of particular assets and their respective returns are compared against the current ratio of each security's weight in the portfolio. Return of a portfolio is an essential variable in the context of optimization because it describes the return of the portfolio which will be achieved by implementing the optimization. Portfolio variance deals with the issue of covariance and indicates correlation coefficients for particular securities. In other terms, portfolio efficiency is achieved by investing in securities with negative variance correlation. Standard deviation of a portfolio as an indicator measures how much returns differ from the mean return that is expected according to some probability (Hargrave, 2019).

Table 4. Variables used to calculate the solution

Variables	Formulae
Sharpe ratio	Calculated by subtracting the risk-free rate of return from the expected return and dividing the result by the standard deviation of the return.
Expected return of the portfolio	Calculated by using the SUMPRODUCT formula and taking into account the current weights of assets and data on average returns.
Return of the portfolio	Calculated by using the MMULT function, which calculates the return that may be expected after implementing the solution (the proposed weights of assets), and the current levels of return.

Portfolio variance	Calculated by combining the MMULT and TRANSPOSE functions in Microsoft Excel by using the weights proposed by the solution and covariance matrix. It shows the level of the portfolio's risk, and the goal is to minimize risk as much as possible.
Standard deviation of the portfolio	Calculated as the square root of the variance, indicating how much the portfolio's actual returns deviate from the expected return.

Source: created by the authors and (Hargrave, 2019).

It was necessary to use five iterations in order to obtain the optimization solution for Category A. According to the parameters, restrictions and variables for achieving the maximum level of returns, assets of Category A pension funds should be allocated in the following manner: 45% of assets needs to be invested in government bonds, while the remaining 55% needs to be invested in stocks. If the proposed allocation is implemented, the following values of the items from Table 3 are obtained.

Sharpe ratio equals 0.07, which shows us that pension funds in category A achieve a higher level of return than risk free investment, but it also shows that the level of return is not correlated with the level of risk that investors are exposed to. The expected return of the portfolio, calculated by using the current weighs of assets and their respective returns, equals 0.679%. The return of the portfolio, as the most important indicator, increased from 0.679% up to 1.019% after the optimization. The portfolio variance decreased to 0.0068, whereas the standard deviation of the portfolio equals 0.08. An analysis of Figure 1 and the results leads to the conclusion that the current asset allocation is below the optimal level, according to the calculation. Based on Figure 1, an average of 25% of assets in Category A pension funds is invested in stocks, while an average of 48.3% of assets is invested in bonds; therefore, it is necessary to reallocate assets according to the proposed solution. Namely, with all legal restrictions taken into account and with the aim of achieving higher returns, 55% of assets in Category A should be invested in stocks, while 45% should be allocated to bonds, which is a safer form of investing.

The procedure used to solve the optimization problem for Category B pension funds is analogous to the one used for Category A pension funds. The covariance matrix provided in Table 4 was calculated according to the return of each individual financial instrument achieved in the observed period January 2015-December 2019.

Table 5. Covariance matrix for Category B

	Stock	*Government bonds*	*Corporate bonds*	*Deposits*	*UCITS*
Stock	0.018696435	0.001865844	0.00016897	-7.8968E-05	0.00214491
Government bonds	0.001865844	0.001242731	3.62241E-06	-9.7914E-06	0.00022018

Corporate bonds	0.00016897	3.62241E-06	5.17961E-05	6.53604E-07	2.5716E-05
Deposits	-7.8968E-05	-9.79143E-06	6.53604E-07	2.41821E-05	-1.0097E-05
UCITS	0.002144909	0.000220185	2.57163E-05	-1.0097E-05	0.00026805

Source: created by the authors based on the Mandatory Pension Funds Act from 2014 and 2019, Zagreb Stock Exchange, FTSE Euro Corporate Bond Index, hr.portfolio, HNB

Afterwards, optimal weights of assets invested in particular financial instruments were calculated based on the covariance matrix and restrictions pertaining to Category B, which are somewhat different from those that were used for Category A. It should be noted that the model for solving the optimization problem for Category A and B incorporates legal restrictions from 2014. In other words, the constraints of the equation which are necessary to calculate the optimization were defined on the basis of the legal restrictions provided in Table 1. Table 4 shows how the optimization problem was formulated for Category B and how parameters and variables were defined for this category in order to maximize investments of pension funds. After conducting five iterations based on the parameters, constraints and variables aimed at maximizing returns, it was concluded that assets of Category B pension funds should be allocated in the following manner: 65% of assets should be invested in government bonds, while the remaining 35% should be invested in stocks.

Therefore, the expected return for the current weight of assets for each type of financial instrument amounts to 0.68%. The return of the portfolio, which is a crucial factor for persons insured in Category B funds, amounts to 0.927% if pension funds implement the proposed optimal solutions. Compared to the current return of 0.68%, this is certainly a significant difference considering that the majority of persons is insured in Category B pension funds, according to a report by (HANFA, 2020). A variance of 0.003, which was calculated for the portfolio B is naturally smaller than the portfolio variance for Category A (0.006) since Category B pursues conservative investment strategies. The standard deviation is correspondingly lower than in the case of Category A (0.08) and it equals 0.06. The values of all the variables mentioned above, except for the expected return of the portfolio, were calculated in Solver in a scenario where the optimal solution has been implemented.

The current weights of different financial instruments in Category B pension funds should be compared against the solution. The current data provided in Figure 3 show that an average of 11% of Category B pension funds' assets is invested in stocks from the Croatian capital market, whereas government bonds issued by the Republic of Croatia comprise 70% of their portfolios. According to the proposed solution and current weights, the weight of government bonds should be reduced by five percentage points and assets which are currently invested in UCITS funds, corporate bonds and deposits should be reallocated to stocks. In simpler terms, assets of Category B funds need to be reallocated so that bonds comprise 65% of their portfolios and stocks comprise 35% if optimization is to be achieved.

CONCLUSION

This paper focused on the issue of optimizing investments of pension funds in the Republic of Croatia; i.e. its fundamental goal was to test whether the current weights of each financial instrument can be distributed in a different and potentially more profitable way for the maximum benefit of insured persons. The research was centered around historical returns of each of the four pension funds in Category A and B and the current weights of assets with a focus on optimizing returns within legal restrictions by using mathematical models. Research methods used in this research primarily include Microsoft Excel and its add-in Solver, whereas the sources consist of web pages and scholarly articles dealing with the issues in question.

Optimization analysis was conducted in Microsoft Excel and Solver and the goal was to calculate the optimal weight of each asset in Category A and B pension funds. Moreover, the objective was to confirm or reject the hypothesis H1: Portfolios of Category A and B pension funds comprise optimal weights of different financial instruments. The results of the optimization calculation show that portfolios of Category A and B pension funds do not comprise optimal weights of different financial instruments and the hypothesis H1 is rejected. The reason for rejecting this hypothesis lies in the fact that the set model has shown an increase in the level of expected returns when there is a restructuring in the ratios of investments in certain types of assets.

Implementing the results of this research has two potential outcomes. The first one refers to increasing the level of capital available to companies. The second outcome refers to increasing pension funds' returns and consequently boosting pensions of insured persons.

RESEARCH LIMITATIONS

In the conducted research it is necessary to mention certain important limitations: 1. the authors used historical data within the calculations as a basis for optimization calculations with the aim of maximizing the yield 2. pension funds invest in shares of foreign companies whose yield is not taken into account 3. The proposed reallocation of investment set out in the conclusion is for further discussion given that historical data should be taken with a grain of salt when developing an investment strategy for the future.

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