Management of Portfolio Investment Held by Pension Funds

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Abstract. *As a result of the fact that pension funds are financial intermediaries, the value of their assets and liabilities is influenced by changing conditions in financial markets. The market image of a pension fund (and hence its perceived value) are closely tied to the "financial health" of the fund. Setting up and managing complex investment portfolios requires that pension administrators use scientific models of portfolio selection and optimization based on the risk-expected return relationship. Most investment portfolios are modified in time as result of changing stock prices and investment policy objectives. Having established investment policy guidelines, the administrators of pension funds have to determine the structure of their portfolios so that the latter meet legal requirements.*

Key words: pension funds; return; risk; optimization; portfolio; financial assets; profitability; capital market; investments.

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JEL Codes: G11, G23.
REL Codes: 11B, 11D.

Private pensions are all about investing the contributions of adherents. The second-pillar and third-pillar pensions legal framework (Law No. 411/2006 and Law No. 204/2006) that all pension funds administrators invest the contributions in an adequate manner and in the sole interest of adherents and beneficiaries such that the investment portfolio is secure, qualitative, liquid and profitable. At the same time, assets destined to the guarantee fund and to technical provisions must be invested in correlation with the rights of adherents and beneficiaries. At the same time, administrators should invest most of the contributions in instruments traded on supervised markets and should limit investments in assets traded on unsupervised markets.

According to the law, pension funds administrators are allowed to invest in:

- money market instruments such as bank deposits and certificates of deposit (20% or less of the pension fund's total assets);
- debt securities issued by the Romanian government (such as government bonds etc.) or by governments of EU/EES member states (70% or less of the fund's total assets);
- debt securities issued by local public authorities in Romania or in other EU/EES member states (30% or less of the fund's total assets);
- securities (shares/bonds) traded in supervised markets in Romania and/or EU/EES member states (50% or less of the fund's total assets)
- securities issued by governments of third party countries(1) (15% or less of the fund's total assets);
- securities issued by local public authorities in third party countries (10% or less of the fund's total assets), under the condition that the respective securities are traded in supervised markets;
- securities issued by non-governmental foreign organizations provided they are traded in supervised markets and they meet the necessary rating requirements (5% or less of the fund's total assets);
- securities issued by OPCVM from Romania or other states (5% or less of the fund's total assets);
- financial derivatives (futures, options, swaps etc.), but only for risk management purposes. Derivatives should only be used in hedging transactions and not for profit-making purposes.

Administrators are not allowed to invest contributions in assets that cannot be sold afterwards or that cannot be correctly valued. It is also forbidden to invest the assets of a pension fund in art objects, vehicles, real estates or securities issued by the administrators themselves. At the same time, a pension fund administrator is not allowed to invest more than 5% of the fund's assets in securities issued by a sole company, nor it can invest more than 10% of the fund's assets in a group of companies and other businesses affiliated to them.

Given the legal restrictions mentioned previously the only way of setting up a two-asset investment portfolio consists of buying government bonds (in a proportion of up to 70% of the fund's total assets) and listed shares (in a proportion of up to 50% of the fund's assets). In the case of any other combination of two eligible assets the sum of the legal investment limits is below one and therefore such portfolios are ruled out.

Let x_1 and x_2 be the proportions of government bonds and listed shares respectively, R_1 and R_2 the expected return on the two assets, σ_1 and σ_2 their volatilities and σ_{12} the covariance between the expected returns on the two assets. These variables have the following values:

$$R_1 = 0{,}065 \quad \sigma_1 = 0 \quad \sigma_{12} = 0$$
$$R_2 = 0{,}2203 \quad \sigma_2 = 0{,}2231.$$

The parameters' values for listed shares correspond to the minimum variance portfolio (MVP) that can be set up using shares traded in the Bucharest Stock Exchange.

The expected return on the portfolio and the associated risk can be written as follows:

$$R_P = x_1 \times R_1 + x_2 \times R_2$$
$$\sigma_P^2 = x_1^2 \times \sigma_1^2 + x_2^2 \times \sigma_2^2 + \\ + 2 \times x_1 \times x_2 \times \sigma_{12} = x_2^2 \times \sigma_2^2$$

Differentiating the risk function with respect to x_1 and taking into account that $x_2 = 1 - x_1$ we get the following results:

$$x_1 = 1$$
$$x_2 = 0.$$

The absolute minimum variance portfolio requires that the fund's assets are invested solely in government bonds. As such, the portfolio is risk-free. However, it is impossible to set up the portfolio described above because legal investment restrictions are not satisfied.

The maximum expected return on the portfolio is attained when the pension fund administrator invests as much as legally possible in the asset with the greatest return. Hence the structure of the most profitable portfolio ($\overline{R_P}$) is $x_1 = 0.5$ and $x_2 = 0.5$:

$$\overline{R_P} = 0.5 \times 0.065 + 0.5 \times 0.2203 = \\ = 0.1427 = 14.27\%.$$

Symmetrically, the minimum possible return on the portfolio ($\underline{R_P}$) is achieved when the fund's assets are mostly placed (up to the legal limit) in government bonds:

$$\underline{R_P} = 0.7 \times 0.065 + 0.3 \times 0.2203 = \\ = 0.1116 = 11.16\%.$$

We now face the problem of determining efficient portfolios, that is, portfolios with the lowest possible risk at a given level of expected return R_P^* ($0.1116 \le R_P^* \le 0.1427$). In order to fulfill this task we have to solve the following optimization problem:

$$\begin{cases} \min \sigma_P^2 = 0.04977361 \times x_2^2 \\ \text{provided that} \begin{cases} 0.065 \times x_1 + 0.2203 \times x_2 = R_P^* \\ x_1 + x_2 = 1 \end{cases} \\ \text{subject to} \begin{cases} x_1 \le 0.7 \\ x_2 \le 0.5 \end{cases} \end{cases}$$

Since the system above contains two equations and two variables it is possible to write the proportion of each asset as function of the expected return on the portfolio. Performing the necessary calculations, we get:

$$x_1 = 1.418545 - 6.439150 \times R_P^*$$
$$x_2 = 6.439150 \times R_P^* - 0.418545$$

The table below illustrates the structure and risk of efficient portfolios corresponding to different values of the expected return:

Expected return R_P^*	x_1	x_2	σ_P^2	σ_P
0.11159	0.7000	0.3000	0.004479625	0.06693
0.112	0.6974	0.3026	0.004558815	0.067518995
0.113	0.6909	0.3091	0.004754871	0.06895557
0.114	0.6845	0.3155	0.004955054	0.070392144
0.115	0.6780	0.3220	0.005159365	0.071828719
0.116	0.6716	0.3284	0.005367803	0.073265293
0.117	0.6652	0.3348	0.005580369	0.074701867
0.118	0.6587	0.3413	0.005797062	0.076138442
0.119	0.6523	0.3477	0.006017883	0.077575016
0.12	0.6458	0.3542	0.006242831	0.07901159
0.121	0.6394	0.3606	0.006471907	0.080448165
0.122	0.6330	0.3670	0.006705111	0.081884739
0.123	0.6265	0.3735	0.006942441	0.083321314
0.124	0.6201	0.3799	0.0071839	0.084757888
0.125	0.6137	0.3863	0.007429485	0.086194462
0.126	0.6072	0.3928	0.007679199	0.087631037
0.127	0.6008	0.3992	0.007933039	0.089067611
0.128	0.5943	0.4057	0.008191008	0.090504185
0.129	0.5879	0.4121	0.008453103	0.09194076
0.13	0.5815	0.4185	0.008719327	0.093377334
0.131	0.5750	0.4250	0.008989677	0.094813909
0.132	0.5686	0.4314	0.009264155	0.096250483
0.133	0.5621	0.4379	0.009542761	0.097687057
0.134	0.5557	0.4443	0.009825494	0.099123632
0.135	0.5493	0.4507	0.010112355	0.100560206
0.136	0.5428	0.4572	0.010403343	0.10199678
0.137	0.5364	0.4636	0.010698459	0.103433355
0.138	0.5299	0.4701	0.010997702	0.104869929
0.139	0.5235	0.4765	0.011301073	0.106306504
0.14	0.5171	0.4829	0.011608571	0.107743078
0.141	0.5106	0.4894	0.011920196	0.109179652
0.142	0.5042	0.4958	0.01223595	0.110616227
0.14265	0.5000	0.5000	0.012443403	0.11155

The expected return is a linear function of the portfolio risk and it can be written as follows:

$$R_P = 0.065 + 0.6961\sigma_P$$

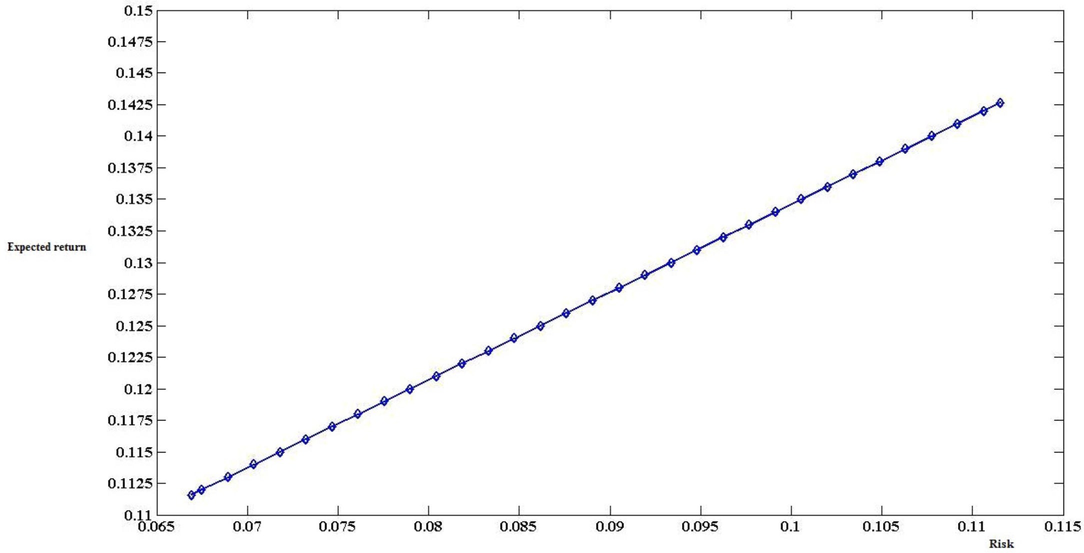

Figure 1. *The relationship between portfolio risk and expected return on the investment portfolio*

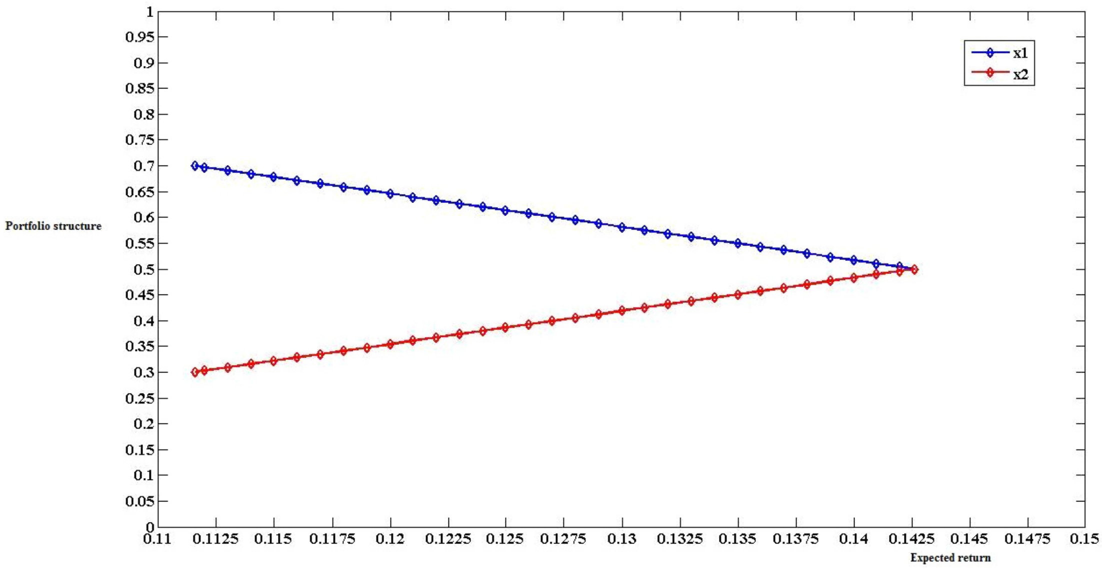

Figure 2. *The portfolio structure modification*

A thorough analysis of the above charts yields the following conclusions:

- the minimum risk portfolio (σ_P = 6.69%) consists of 70% debt securities issued by the government and 30% listed shares because government bonds are risk-free assets. The expected return on this portfolio is 11.16%;
- portfolio risk increases as the expected return increases. The maximum risk portfolio comprises 50% government bonds and 50% listed shares. The expected return is 14.27% and the corresponding risk is 11.16%;
- the proportion of government bonds in the investment portfolio decreases

as the expected return increases and at the same time the proportion of shares increases because the return on the latter is higher than the risk-free rate.

This section of our study focuses on the setting up of a three-asset portfolio comprising government debts, listed shares and bank deposits. We introduce the following notations:

- x_3 = the proportion of bank deposits in the investment portfolio;
- R_3 = the expected return on bank deposits;
- σ_3 = the volatility of bank deposits;
- σ_{13} = the covariance between the returns on government bonds and bank deposits;
- σ_{23} = the covariance between the returns on shares and bank deposits.

We have:

$$R_1 = 0.065 \quad \sigma_1 = 0 \quad \sigma_{12} = 0$$
$$R_2 = 0.2203 \quad \sigma_2 = 0.2231 \quad \sigma_{13} = 0$$
$$R_3 = 0.0974 \quad \sigma_3 = 0.0103 \quad \sigma_{23} = 0$$

The expected return on the portfolio and the associated risk are:

$$R_P^* = x_1 \times R_1 + x_2 \times R_2 + x_3 \times R_3 =$$
$$= 0.065 \times x_1 + 0.2203 \times x_2 + 0.0974 \times x_3$$
$$\sigma_P^2 = x_1^2 \times \sigma_1^2 + x_2^2 \times \sigma_2^2 + x_3^2 \times \sigma_3^2 +$$
$$= 2 \times x_1 \times x_2 \times \sigma_{12} + 2 \times x_2 \times x_3 \times \sigma_{23} +$$
$$= 2 \times x_1 \times x_3 \times \sigma_{13} = x_2^2 \times \sigma_2^2 + x_3^2 \times \sigma_3^2$$
$$\sigma_P^2 = 0.04977361 \times x_2^2 + 0.00010591 \times x_3^2$$

In order to determine the minimum absolute variance portfolio we need to solve the following system:

$$\begin{cases} x_1\left(\sigma_1^2 - 2\times\sigma_{13} + \sigma_3^2\right) + \\ + x_2\left(\sigma_{12} - \sigma_{13} - \sigma_{23} + \sigma_3^2\right) + \left(\sigma_{13} - \sigma_3^2\right) = 0 \\ x_2\left(\sigma_2^2 - 2\times\sigma_{23} + \sigma_3^2\right) + \\ + x_1\left(\sigma_{12} - \sigma_{13} - \sigma_{23} + \sigma_3^2\right) + \left(\sigma_{23} - \sigma_3^2\right) = 0 \end{cases}$$

Taking into account that government bonds are risk-free and that the three covariances are all equal to zero we have:

$$\begin{cases} x_1 \times \sigma_3^2 + x_2 \times \sigma_3^2 = \sigma_3^2 \\ x_2\left(\sigma_2^2 + \sigma_3^2\right) + x_1 \times \sigma_3^2 = \sigma_3^2 \end{cases}$$

It follows immediately that the minimum absolute risk portfolio has the following structure: $x_1 = 1$, $x_2 = 0$ and $x_3 = 0$, that is, the pension fund's assets are invested only in government bonds. Such a portfolio cannot be set up due to the following legal limitations:

$$x_1 \le 0.7$$
$$x_2 \le 0.5$$
$$x_3 \le 0.2$$

The minimum risk portfolio that satisfies the former conditions is $x_1 = 0.7$, $x_2 = 0.1$ and $x_3 = 0.2$, which means that the pension administrator invests mostly in less risky assets (government bonds, bank deposits) and buys a relatively low amount of listed shares. The expected return on this portfolio ($\underline{R_P}$) is:

$$\underline{R_P} = 0.7 \times 0.065 + 0.1 \times 0.2203 + $$
$$+ 0.2 \times 0.0974 = 0.087 = 8.7\%,$$

and the portfolio risk ($\underline{\sigma_P}$) is:

$$\underline{\sigma_P} = 0.04977361 \times 0.1^2 + 0.00010591 \times 0.2^2 =$$
$$= 0.00050197 \Rightarrow \sigma_P = 0.0224 = 2.24\%.$$

The most profitable investment portfolio consists of 50% shares, 20% bank deposits and 30% public debt securities. The expected return ($\overline{R_P}$) and the corresponding risk ($\overline{\sigma_P}$) are determined as follows:

$$\overline{R_P} = 0.3\times 0.065 + 0.5\times 0.2203 + $$
$$+ 0.2\times 0.0974 = 0.1491 = 14.91\%$$

$$\overline{\sigma_P} = 0.04977361\times 0.5^2 + 0.00010591\times 0.2^2 =$$
$$= 0.01244764 \Rightarrow \sigma_P = 0.1116 = 11.16\%$$

In order to determine the efficient frontier we must solve the following optimization problem:

$$\begin{cases} \min \sigma_P^2 = 0.04977361\times x_2^2 + 0.00010591\times x_3^2 \\ \text{provided that} \begin{cases} R_P^* = 0.065\times x_1 + 0.2203\times x_2 + 0.0974\times x_3 \\ x_1 + x_2 + x_3 = 1 \end{cases} \\ \text{subject to} \begin{cases} x_1 \le 0.7 \\ x_2 \le 0.5 \\ x_3 \le 0.2 \end{cases} \end{cases}$$

Introducing the following expression of x_1:

$x_1 = 1 - x_2 - x_3$

in the formula of the expected return on the portfolio, we get:

$$R_P^* = 0.065\times(1 - x_2 - x_3) + 0.2203\times x_2 +$$
$$+ 0.0974\times x_3 = 0.065 + 0.1553\times x_2 +$$
$$+ 0.0324\times x_3$$

It follows that

$$x_2 = \frac{R_P^* - 0.065 - 0.0324\times x_3}{0.1553}$$

and

$$\sigma_P^2 = 2.06374593\times$$
$$\times\left(R_P^* - 0.065 - 0.0324\times x_3\right)^2 +$$
$$+ 0.00010591\times x_3^2$$

Differentiating w.r.t. x_3 and requiring that:

$$\frac{\partial x_P^2}{\partial x_3} = 0 \Rightarrow \text{ we get:}$$

$$x_3 = 29.42564746\times R_P^* - 1.91266703$$

Substituting this relationship in the formula of x_2 yields:

$$x_2 = 0.30012249\times R_P^* - 0.01950797$$

The proportion of government bonds in the optimum portfolio is:

$$x_1 = 1 - x_2 - x_3 = 2.932175 -$$
$$- 29.72576995\times R_P^*$$

The expected return on the three-asset investment portfolio varies in an interval that can be determined by requiring x_1, x_2 and x_3 to satisfy the legal limitations:

$$0 \le x_1 \Rightarrow R_P^* \le 0.09864084$$
$$x_2 \le 0.5 \Rightarrow R_P^* \le 1.73098647$$
$$x_3 \le 0.2 \Rightarrow R_P^* \le 0.07179679$$

We now face a contradiction because the minimum possible expected return on the investment portfolio ($\underline{R_P}$) is 8.7%. The flaw of the optimization problem lies in the fact that the legal restriction of investments in bank deposits is too low. In order to derive the efficient frontier we must determine how the legal restriction of investments in bank deposits should be modified. Recall that

$$x_3 = 29.42564746\times R_P^* - 1.91266703$$

Requiring that $R_P^* \ge \underline{R_P}$, we get:

$$\frac{x_3 + 1.91266703}{29.42564746} \ge 0.087 \Rightarrow x_3 \ge 0.64736430,$$

which means that the proportion of bank deposits should be at least 64.74%.

Assuming that the pension fund administrator invests 20% of the fund's assets in bank deposits, we will try to optimize the investment portfolio. The optimization problem we now face is:

$$\begin{cases} \min \sigma_P^2 = 0.04977361 \times x_2^2 + 0.00000424 \\ \text{provided that} \begin{cases} R_P^* = 0.065 \times x_1 + 0.2203 \times x_2 + 0.01948 \\ x_1 + x_2 = 0.8 \end{cases} \\ \text{subject to} \begin{cases} x_1 \le 0.7 \\ x_2 \le 0.5 \end{cases} \end{cases}$$

The following relationships between x_1, x_2 and the expected return on the portfolio can be derived:

$$x_1 = 1.26027044 - 6.43915003 \times R_P^*$$

$$x_2 = 6.43915003 \times R_P^* - 0.46027044$$

Considering several values of the expected return on the portfolio (in the interval $[\underline{R_P}, \overline{R_P}]$) we get the following values for x_1, x_2 and x_3, as well as for the portfolio risk:

Expected return R_P^*	x_1	x_2	x_3	σ_P^2	σ_P
0.08701	0.7000	0.1000	0.2000	0.0005	0.0224
0.088	0.6936	0.1064	0.2000	0.00057	0.02382
0.089	0.6872	0.1128	0.2000	0.00064	0.02525
0.09	0.6807	0.1193	0.2000	0.00071	0.02668
0.091	0.6743	0.1257	0.2000	0.00079	0.02812
0.092	0.6679	0.1321	0.2000	0.00087	0.02955
0.093	0.6614	0.1386	0.2000	0.00096	0.03098
0.094	0.6550	0.1450	0.2000	0.00105	0.03242
0.095	0.6486	0.1514	0.2000	0.00115	0.03385
0.096	0.6421	0.1579	0.2000	0.00125	0.03528
0.097	0.6357	0.1643	0.2000	0.00135	0.03672
0.098	0.6292	0.1708	0.2000	0.00146	0.03815
0.099	0.6228	0.1772	0.2000	0.00157	0.03959
0.1	0.6164	0.1836	0.2000	0.00168	0.04102
0.101	0.6099	0.1901	0.2000	0.0018	0.04246
0.102	0.6035	0.1965	0.2000	0.00193	0.04389
0.103	0.5970	0.2030	0.2000	0.00205	0.04533
0.104	0.5906	0.2094	0.2000	0.00219	0.04676
0.105	0.5842	0.2158	0.2000	0.00232	0.0482
0.106	0.5777	0.2223	0.2000	0.00246	0.04963
0.107	0.5713	0.2287	0.2000	0.00261	0.05107
0.108	0.5648	0.2352	0.2000	0.00276	0.0525
0.109	0.5584	0.2416	0.2000	0.00291	0.05394
0.11	0.5520	0.2480	0.2000	0.00307	0.05538
0.111	0.5455	0.2545	0.2000	0.00323	0.05681
0.112	0.5391	0.2609	0.2000	0.00339	0.05825
0.113	0.5326	0.2674	0.2000	0.00356	0.05968
0.114	0.5262	0.2738	0.2000	0.00374	0.06112
0.115	0.5198	0.2802	0.2000	0.00391	0.06255
0.116	0.5133	0.2867	0.2000	0.00409	0.06399
0.117	0.5069	0.2931	0.2000	0.00428	0.06543
0.118	0.5005	0.2995	0.2000	0.00447	0.06686
0.119	0.4940	0.3060	0.2000	0.00466	0.0683
0.12	0.4876	0.3124	0.2000	0.00486	0.06973
0.121	0.4811	0.3189	0.2000	0.00507	0.07117
0.122	0.4747	0.3253	0.2000	0.00527	0.0726
0.123	0.4683	0.3317	0.2000	0.00548	0.07404
0.124	0.4618	0.3382	0.2000	0.0057	0.07548
0.125	0.4554	0.3446	0.2000	0.00592	0.07691
0.126	0.4489	0.3511	0.2000	0.00614	0.07835
0.127	0.4425	0.3575	0.2000	0.00637	0.07979
0.128	0.4361	0.3639	0.2000	0.0066	0.08122
0.129	0.4296	0.3704	0.2000	0.00683	0.08266
0.13	0.4232	0.3768	0.2000	0.00707	0.08409
0.131	0.4167	0.3833	0.2000	0.00732	0.08553
0.132	0.4103	0.3897	0.2000	0.00756	0.08697
0.133	0.4039	0.3961	0.2000	0.00781	0.0884
0.134	0.3974	0.4026	0.2000	0.00807	0.08984
0.135	0.3910	0.4090	0.2000	0.00833	0.09127
0.136	0.3845	0.4155	0.2000	0.0086	0.09271
0.137	0.3781	0.4219	0.2000	0.00886	0.09415

Expected return R_P^*	x1	x2	x3	σ_P^2	σ_P
0.138	0.3717	0.4283	0.2000	0.00914	0.09558
0.139	0.3652	0.4348	0.2000	0.00941	0.09702
0.14	0.3588	0.4412	0.2000	0.00969	0.09846
0.141	0.3524	0.4476	0.2000	0.00998	0.09989
0.142	0.3459	0.4541	0.2000	0.01027	0.10133
0.143	0.3395	0.4605	0.2000	0.01056	0.10276
0.144	0.3330	0.4670	0.2000	0.01086	0.1042
0.145	0.3266	0.4734	0.2000	0.01116	0.10564
0.146	0.3202	0.4798	0.2000	0.01146	0.10707
0.147	0.3137	0.4863	0.2000	0.01177	0.10851
0.148	0.3073	0.4927	0.2000	0.01209	0.10995
0.149	0.3008	0.4992	0.2000	0.01241	0.11138
0.1491	0.3000	0.5000	0.2000	0.01245	0.11157

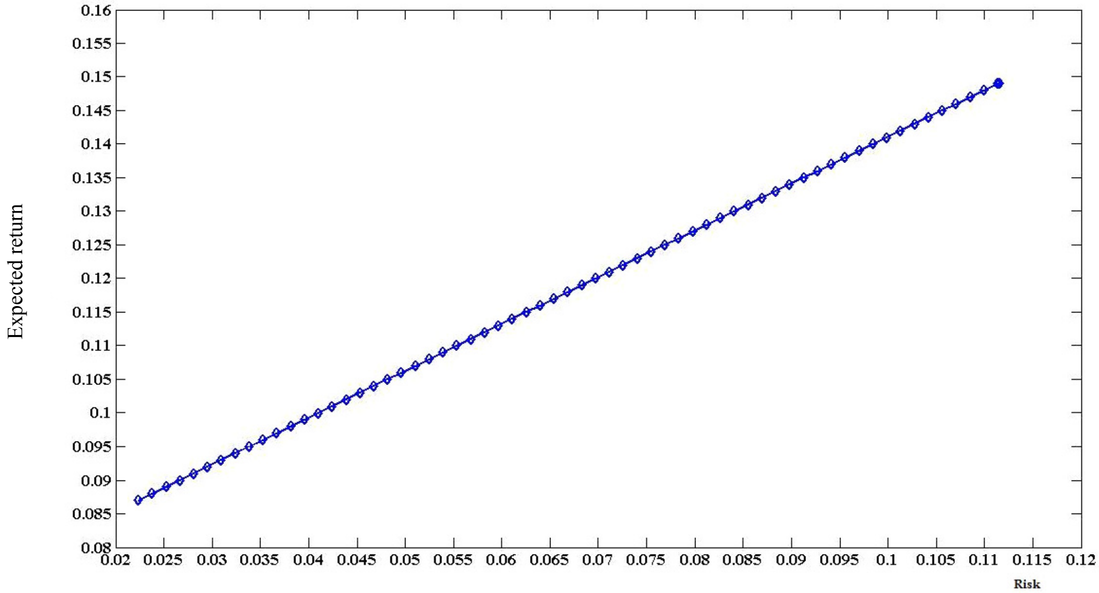

Figure 3. *The linear relationship between the portfolio risk and the expected return on the investment portfolio*

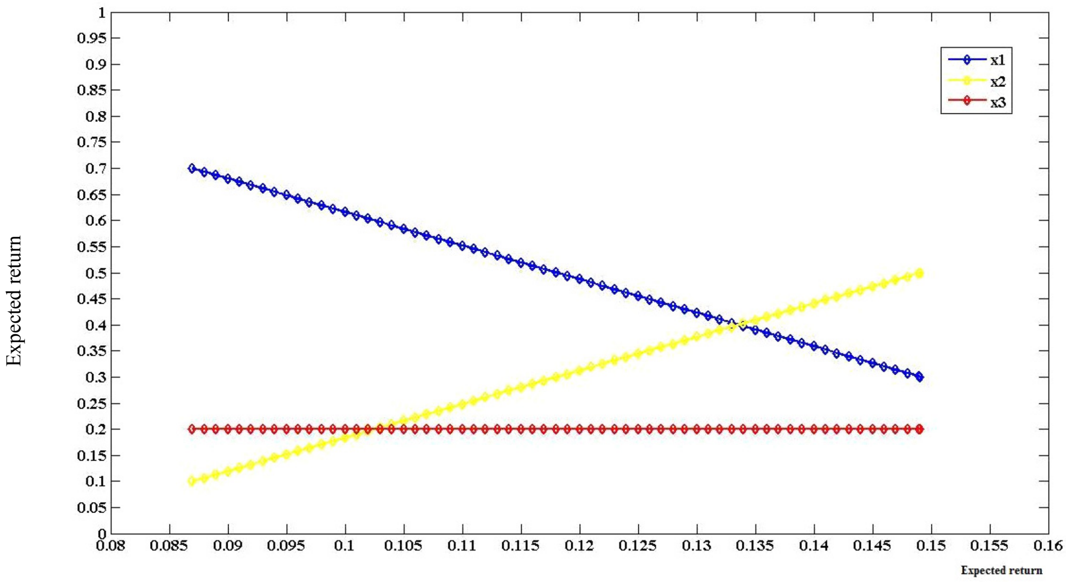

Figure 4. *The portfolio structure change*

The analysis of the above charts leads us to the following conclusions:

- the minimum variance portfolio contains 70% government bonds, 20% bank deposits and 10% listed shares. This is due to the fact that public debt securities and bank deposits are virtually riskless assets;
- the portfolio volatility increases as the expected return increases. The maximum expected return of 14.91% is attained at the expense of a 11.16% portfolio volatility;
- the proportion of bank deposits in any efficient portfolio is constant (x_3 = 20%). Bank deposits are financial assets that provide lucrative investment opportunities at minimal risk exposure. As the expected return on the portfolio grows, the proportion of listed shares grows and the proportion of government bonds decreases.

To sum up, we have shown in our study that the setting up of efficient investment portfolios and effective risk management require the use of modern financial theory. Portfolio optimization also requires modern techniques of linear and non-linear programming. Portfolio diversification, as stated by the Markowitz and CAPM models, is of utmost importance because it reduces the risk of the investment portfolio to the lowest bound possible. This bound is the market risk. As a rule of thumb, all financial securities are affected by the market (or systemic risk) and this risk cannot be avoided. If there were no market risk, it would be possible to set up portfolios that are virtually riskless.

Note

(1) Non-EU/Non-EES members.

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