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COMBINATION OF MODERN PORTFOLIO THEORY AND CONSTANT PROPORTION PORTFOLIO INSURANCE STRATEGY (APPLICATION IN THE CONTEXT OF PENSION FUND MANAGEMENT)

Efficient management of assets and liabilities of the pension fund guarantees decent income and socially secured life for future retirees. To achieve these objectives, fund managers need to apply the most appropriate investment strategies.

Constant proportion portfolio insurance strategy (CPPI) is one of the widely used models in portfolio insurance. However, due to its inherent drawbacks, the CPPI model cannot be efficiently applied in real portfolio management. The main problem is that CPPI is applicable only for two-asset cases. In this paper Modern portfolio theory is included in CPPI to make it usable for multiple asset cases, which can be easily used in multi-asset portfolio management. Its effectiveness is tested for one of the Armenian mandatory pension funds. As results show, combining the Modern portfolio theory with CPPI results in a portfolio that not only overcomes both the CPPI and current portfolio in terms of returns and standard deviations but also helps get rid of the main shortcomings of CPPI and make it applicable in practice, which can be used for improving the management of Armenian pension funds.

Key words: *portfolio insurance, pension fund management, CPPI strategy, floor value, maximum drawdown, Modern portfolio theory, Sharpe ratio*.

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Introduction: Effective management of the assets and liabilities of pension plans is of great interest to several slays of society including government and other plan sponsors, the objective of who is to provide plan holders with enough income during retirement with the least expenses. Management of pension funds is somehow identical to portfolio management, both of which bank on the portfolio management theory. CPPI model has started to be used in pension fund management recently, but it still needs improving. One of the main drawbacks of CPPI is the two-asset level: the choice during rebalancing is only between a risky asset and a risk-free asset. This limits its usability in real life because pension fund assets are not just composed of two assets. So, we need to somehow extend the CPPI model to allow decent diversification. One of the ways we use is the combination of Modern portfolio theory (MPT) and CPPI strategy. The capital allocation line, which connects risk-free asset and maximum Sharpe ratio portfolio, gives us the combination of all portfolios having the same maximum Sharpe ratio. Thus, inputting the maximum Sharpe ratio portfolio as a risky asset in CPPI we come to a two-asset CPPI which also ensures proper asset diversification. Choosing the right level of floor value is also an important task when suing CPPI. We also test the current portfolio of one of the mandatory pension funds in Armenia. As a floor value, we use some percentage of assets' current value and maximum drawdown method. Another innovation we put in this model is the use of pension fund's future liabilities as floor value which will keep the funding ratio (assets/liabilities) above a hundred percent at all times.

Literature review: Modeling of pension fund asset/liability management has been a subject of researches among many economists and asset managers. Many articles in this field use several types of approaches to effectively and efficiently manage the assets and liabilities of a pension fund. One of the widespread models is CPPI. Guangyuan X., Yong X., Zongxian F., Xiaokang W. (2014)[1] have addressed the main risk of CPPI, the gap risk, which makes the CPPI model useless when risky asset returns are too volatile. They have introduced a new method for converting the static nature of the multiplicator parameter of CPPI to dynamic, which considers risky assets' volatilities. The main drawback of their model is the only-for-two-asset nature of the model, which prevents it from being applied to the multiple-asset case. J. Carvalho, R. M. Gaspar, J. Sousa (2018)[2] have highlighted the gap risks and their connection to multiplicator and time length. They have realized that the higher are the length of the insurance period and multiplicator, the higher is the probability of getting stuck on floor value (high gap risk). Nevertheless, their contribution is to emphasize the problems of CPPI without suggesting any remedies. N. Fulli-Lemaire (2013)[3] was one of the first researchers who realized the risks of the two-asset nature of CPPI. He has transformed CPPI to allow diversification to hedge inflation risks. However, his model cannot be applied for any type of floor value besides inflation. Z. Chena, B. Chena, Y. Hub, H. Zhang (2019)[4] introduced

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[1] https://www.researchgate.net/publication/270842218_Model_for_Dynamic_Multiple_of_CPPI_Strategy

[2] Carvalho J., Gaspar R. M., Sousa J., On Path–dependency of Constant Proportion Portfolio Insurance strategies. REM Working, Paper 094-2019. Portugal, 2018.

[3] Fulli-Lemaire N., A Dynamic Inflation Hedging Trading Strategy Using a CPPI. Journal of Finance & Risk Perspective, December 2012, Volume 1 (Issue2). UK, 2013.

[4] Chena Z., Chena B., Hub Y., Zhang H., Three-fund Constant Proportion Portfolio Insurance Strategy. European Financial Management Association 2019 Annual Meeting. Glasgow, UK, 2019.

the three-asset case of CPPI, which invests mainly in a risk-free fund, stock-index fund, and purpose-related fund. Their approach is mainly for risk-averse investors. However, their model succeeded to ensure higher returns and lower risk compared to other types of CPPI. B. Temocin, R. Korn, S. Kestel (2018)[5] work in this field has also been devoted to finding optimal multiplicator of CPPI. They introduced CPPI in pension funds with defined contribution where the income of retirees is also taken into account. Their research is more applicable in real life compared to others because they simulate the entire pension fund (not only portfolio but also contributions and repayments).

Though some of the researchers address the two-asset problem in CPPI, in their articles there are not any plausible offers to overcome that problem: their main concentration has been on gap risk management and dynamic multiplicator. Our research contributes to their findings by modifying CPPI in a way that allows multiple-asset case for CPPI as well as decent diversification during CPPI rebalancing.

Research methodology:

1. *Constant proportion portfolio insurance model*

To understand the main insights underlining CPPI strategy, we had better look at the modeling of strategy.

Let us assume investable money and therefore asset value at time t is AV_t; floor value at time t is Fl_t; the length of insurance time is T (0≤t≤T); C is the difference between asset value and floor value, $C_t = AV_t - Fl_t$, which is named as a cushion; m is multiplicator which, when multiplied by a cushion, will show the free amount that can be invested in the risky asset; R_t and r_t are returns for risky and risk-free assets, respectively. Floor value can be chosen differently. One can take some percent of the initial portfolio value (e.g., 90%, 150%), and hence floor value would be static. Sometimes maximum drawdown approach is used, which shows the maximum percentage loss between the asset peak value and minimum value until some point, after which it can change if a new maximum value is obtained. This method gives dynamic floor value. Another extreme way is to raise floor value by risk-free return, that can guarantee risk free return at the end of period[6].

At time t+1 asset value can be represented by the following formula:

$$AV_{t+1} = mC_t(1+R_t) + (AV_t - mC_t)(1+r_t), \quad (1)$$

for period t+n:

$$AV_{t+n} = mC_{t+n-1}(1+R_{t+n-1}) + (AV_{t+n-1} - mC_{t+n-1})(1+r_{t+n-1}). \quad (2)$$

Thus, this formula is a sort of loop: at each period asset current value and floor value are compared, which determines weights of money to be invested in risky assets until the next period when the same procedure repeats. Rebalancing the pension fund's portfolio in this way will guarantee floor value to be received when members of funds retire.

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[5] Temocin B. Z., Korn R., Selcuk-Kestel A., Constant Proportion Portfolio Insurance in Defined Contribution Pension Plan Management. Annals of Operations Research 266. Germany, 2017.

[6] Carvalho J., Gaspar R. M., Sousa J., On Path–dependency of Constant Proportion Portfolio Insurance Strategies. REM Working Paper 094-2019. Portugal, 2018, pp. 9-10.

2. CPPI in conjunction with Modern portfolio theory

One of the shortcomings of CPPI is that it only can be applied to the two-asset case, risky and risk-free. In reality, though, pension funds invest not just in two assets, but several asset classes. Some of them are more or less risky compared to others. Thus, we need to somehow customize the CPPI strategy to apply in real pension fund case, which invests in different asset classes. The best way is to input Modern portfolio theory, which is a mean-variance diversification tool kit. Markowitz's theory gives us diversification of risky assets in which case we can obtain the efficient frontier, mean-variance best combination of risky assets. Adding risk-free asset efficient frontier is changed and becomes straight line connecting risk-free return to maximum Sharpe ratio portfolio on the previous efficient frontier. This line is called the Capital allocation line that shows all possible combinations of risky portfolios and risk-free assets giving the same maximum Sharpe ratio. Capital allocation line can be presented with the following formula:

$$R_{mix} = r + \frac{\sigma_{mix} * (SR_t - r)}{\sigma_{SR}}, \quad (3)$$

where R_{mix} is the portfolio return of risk-free asset and max Sharpe ratio portfolio; SR is the return of maximum Sharpe ratio portfolio; σ_{mix} and σ_{SR} are the standard deviations of mixed portfolio and maximum Sharpe ratio portfolios, respectively[7].

So, instead of using CPPI with risky and risk-free assets, we replace them with a maximum Sharpe ratio portfolio of risky assets and risk-free assets. In this case, the portfolio value will change according to the following rule:

$$AV_{t+1} = mC_t(1 + SR_t) + (AV_t - mC_t)(1 + r_t). \quad (4)$$

For t+n period:

$$AV_{t+n} = mC_{t+n-1}(1 + SR_{t+n-1}) + (AV_{t+n-1} - mC_{t+n-1})(1 + r_{t+n-1}). \quad (5)$$

The fund manager moves along the capital allocation line during fund life. If asset value approaches floor value, the manager moves from Max Sharpe ratio portfolio to reach risk-free asset, and if cushion value increases, manager approaches Max Sharpe ratio portfolio.

Using modern portfolio theory in CPPI, we succeed to completely do away with the two-asset problem, and hereafter we can use as many types of assets as we want. Besides, this ensures the most efficient diversification in the CPPI portfolio. These two advantages are cemented by empirical tests.

Findings, analyses:

1. Data and simulation

For testing the CPPI model and its combination with MPT, we use the actual portfolio structure of the balanced fund of C-Quadrat Asset management at the end of 2019, which is of the six mandatory pension funds in Armenia. Choosing the balanced type of funds is because the level of risky assets in the portfolio is

[7] Vukovic D.B., Prosin V., The Prospective Low Risk Hedge Fund Capital Allocation Line Model: Evidence from the Debt Market. Oeconomia Copernicana, Volume 9 Issue 3. Poland, 2018, pp. 425-427.

comparatively higher than in fixed income and conservative funds, which makes it easier to test CPPI. The main assets in the portfolio are ETFs (31%), Armenian government bonds (25%), Armenian corporate bonds (13%), and deposits in commercial banks (31%). Since ETFs are traded on exchanges and their prices constantly fluctuate, we model the future path of these assets as the Wiener process that is commonly used to model stock prices.

$$dA = \mu A dt + \sigma A dz, \quad (6)$$

$$dln(A_i) = \left(\mu_i - \frac{\sigma_i^2}{2}\right) dt + \sigma_i dz, \quad (7)$$

$$A(T)_i = A(0)_i e^{\left[\left(\mu_i - \frac{\sigma_i^2}{2}\right) T + \sigma_i \sqrt{T} \varepsilon\right]}, \quad (8)$$

where A is the value of an asset; μ and σ are mean and standard deviation, respectively; z is Wiener process; ε is a sample from a standard normal distribution[8].

Parameters for this model, mean and standard deviation are computed as mean and standard deviations of historical data of monthly returns as of 31 December 2019. After simulating future paths of ETFs, we take the weighted average of them considering the current weights of each ETF in the risky portfolio as weights for computing the future path of ETF. Eventually, we simulate two types of ETFs, one with stock investments and another with fixed-income investments.

As for government bonds, we take one of the bond indices published by the Central bank of Armenia, namely G5I, which includes all government bonds with maturities higher than 5 years. This index is chosen because government bonds in the fund's portfolio are mainly long-term. We take the historical average and standard deviation of weighted average yields and simulates indices through the Wiener process as for ETFs. Monthly changes of simulated indices will be the returns we sought to find. Fund assets are also allocated to 13 corporate bonds. To construct an index for it, we compute the average yield spread of corporate bonds over respective government bonds, that was added to G05 index yields (because corporate bonds are usually issued with less than 5 years of maturity) to approximate average yields for corporate bonds. After that, we construct an index and calculate returns as we did for government bonds. Taking into considerations that there is a lack of real-time data for corporate bonds in the Armenian securities market, this is the most optimal way to compute corporate bond yields.

One-third of funds' assets are in deposits in banks. So, modeling deposit rates under different scenarios is another important task in this research. We take the average deposit rates denominated in Armenian dram and USD (USD rates converted to Armenian dram considering FX risks), which have maturities of more than 1 year. After that, we simulate them using Cox–Ingersoll–Ross model. The latter is one of the widely used models in finance for modeling rates, especially short-term rates. This model is the extended version of the Vasicek

[8] Hull J.C., Options, Futures, and Other Derivatives. 8th edition. USA, 2012, pp. 447-448.

model. The main idea behind this model is the mean reversion of rates towards their long-term average.

$$dr = a(\theta - r)dt + \sigma\sqrt{r}dz, \quad (9)$$

where r is the rate; a is adjustment speed; θ is the long-term average of rates; σ is the standard deviation; z is a Wiener process. Although this model is to be used for instantaneous rates or short-term rates, it is widely used for rates with all maturities, which is explained by the factor that all rates eventually approach their long-term mean values. This model solves the main problem of the Vasicek model, that is rates may become negative, by adding the square root of the rate as scaling factor for the second part of the equation[9].

Each asset has been simulated for 1000 scenarios, although graphics will be plotted with 100 scenarios to make patterns visible. Besides, returns of assets, which are denominated in foreign currency, have been converted to AMD adjusted by FX risk (the average of historical changes of foreign currency/AMD exchange rates was subtracted from or added to returns in foreign currency). We take T to equal to 216 months (18 years) because the first members of funds (born in 1974) will be paid in 18 years, though this is not essential, T can take any value.

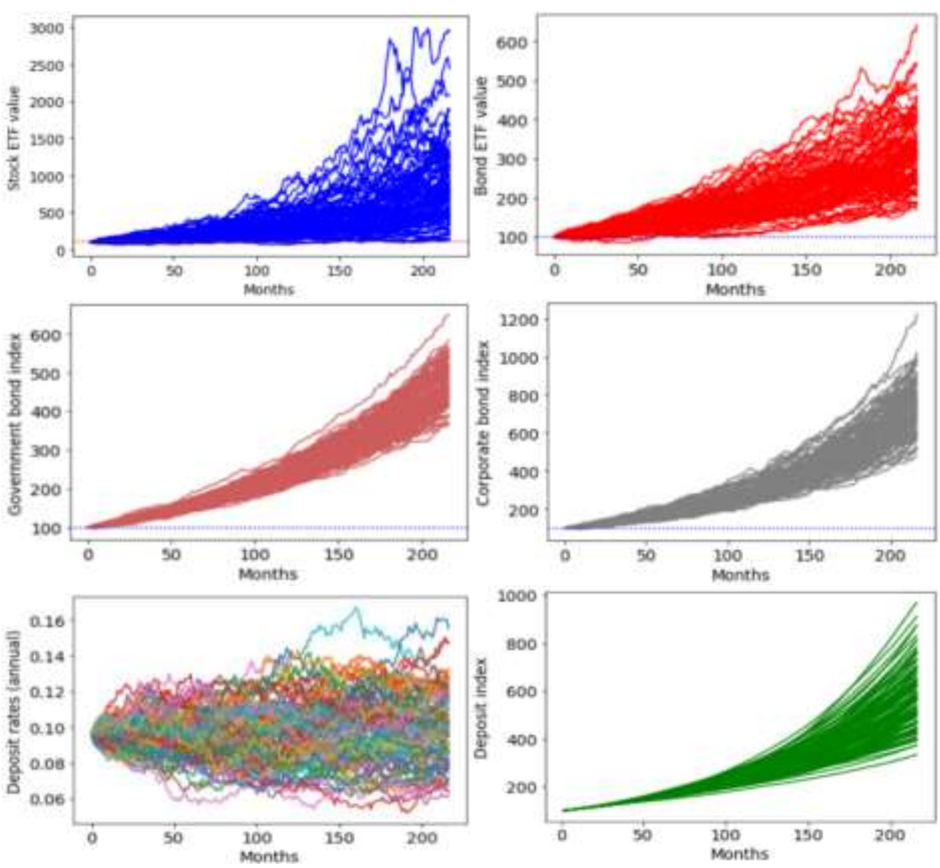


Fig. 1. ***Simulation of assets' values***

[9] Hull J. C., Options, Futures, and Other Derivatives. 8th edition. USA, 2012, pp. 685-686.

2. The application of CPPI-MPT strategy

To apply our strategy, first of all, we need to look at the patterns available in the current portfolio structure. At the end of 2019, the balanced fund invested its assets mainly in deposits, government bonds, and stock ETFs with small percentages in bond ETFs and corporate bonds. To simulate the future value of fund assets, we apply the simulated values of all asset classes and constructing fund portfolio according to the weights as of 30 December 2019 (31% in deposits, 25% in government bonds, 27% in stock ETFs, 17% in corporate bonds and 4% in bond ETFs). As a starting point, the value of the fund assets is assumed to be 100. Besides, we assume that there is no contribution from or repayment to fund members. Results are shown below.

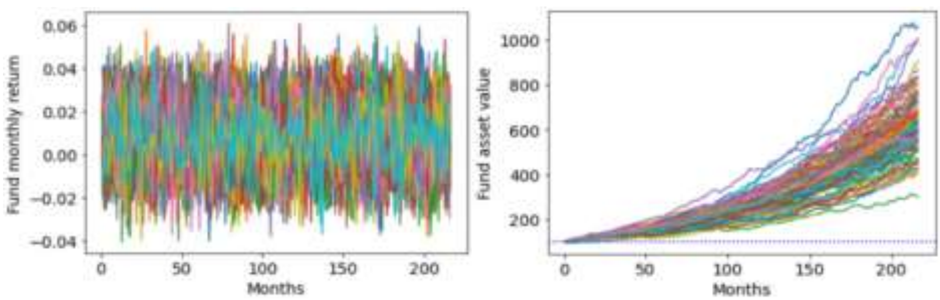


Fig. 2. *Simulation of fund monthly returns and portfolio values (existing structure)*

As we see, fund value can vary from 250 to more than 1000 in 18 years, depending on the behaviors of different asset classes. Although it seems that asset expected value can be sufficiently high, but the standard deviation of terminal values is quite high, which means that if something goes wrong, fund assets can only increase in value only two times. This scenario is the least wanted from the retirees' perspective. As an implication, we can emphasize that the current portfolio structure, if kept unchanged, can lead to very varied outcomes and sometimes end with bad scenarios.

To add Modern portfolio theory to CPPI, we have estimated expected annual returns of risky assets as well as their covariance matrix, which were inputted to optimization problem to find maximum Sharpe ratio portfolio. At each month optimizer was run to find a new max Sharpe ratio portfolio taking simulated values of assets on that particular month as expected values.

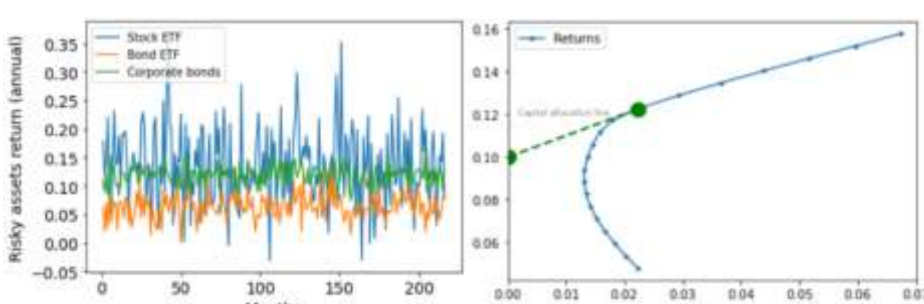


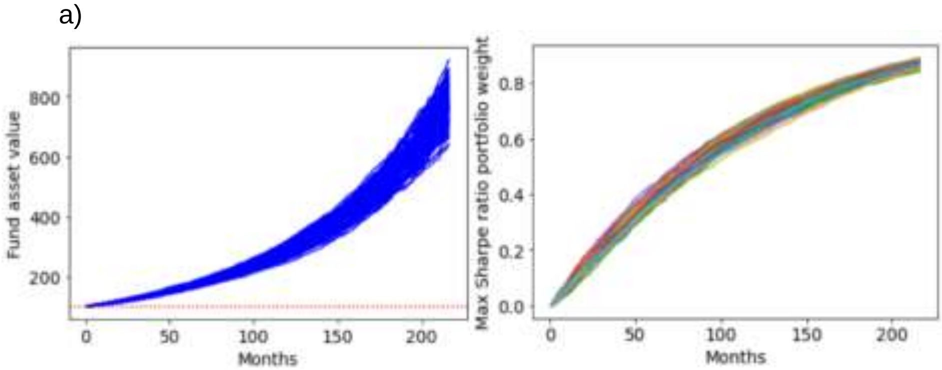
Fig. 3. *Annual returns of risky assets and efficient frontier for a particular scenario*

Fig. 4. *Dynamic weights of maximum Sharpe ratio portfolio*

On the right chart, one specific scenario is plotted with efficient frontiers with and without risk-free asset. CPPI strategy will lead the fund manager to move along the capital allocation line (green line) according to the available cushion. The lower chart shows dynamic rebalancing of maximum Sharpe ratio portfolio weights. As we see, maximum Sharpe ratio is obtained mainly by investing in stock ETFs and corporate bonds.

Now let us see the results of CPPI+MPT with floor value of 100%, m=1, and floor value of 200%, m=11.

a)



b)

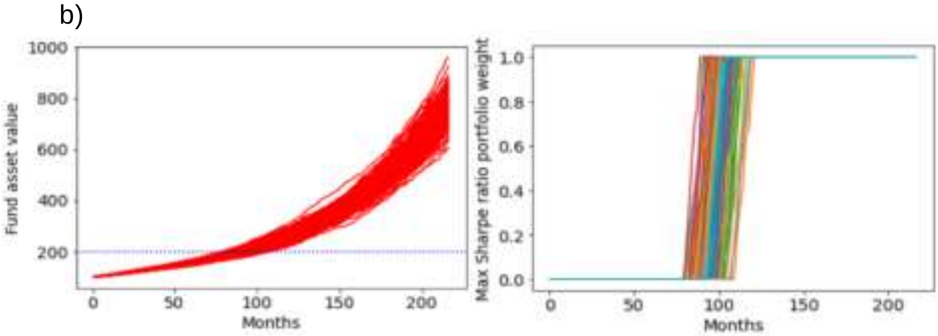


Fig. 5. *Simulation of fund portfolio values, weights in max Sharpe ratio portfolio (CPPI+MPT) (a-floor=100, m=1, b-floor=200, m=11)*

As we see, compared to the current structure this model gives us better results in terms of the lower standard deviation of asset values. With m=1 we restrict the fund manager to take excessive risk, but at the same time, we set a floor value of 100, which is very low and allows the fund manager to take positions in the risky portfolio. In the second case, setting m to 11, which is the most tolerable number, we allow the manager to take risks but also inhibit from taking excessive risks by setting higher floor value. That is why these two cases give identical results, but with different weights in risky portfolios.

To compare CPPI with two-asset case and CPPI mixed with Modern portfolio theory (with multi-asset case) and realize the merits of our improvement of the CPPI model let us look at the following table, which includes CPPI and CPPI (with MPT) applied with both fixed floor and dynamic floor (Maximum drawdown). (Two-asset CPPI was used by taking current weights of risky assets and creating a risky portfolio. The same was done for risk-free assets).

Table 1

CPPI vs CPPI with Modern portfolio theory

December 2037	*Current portfolio*	*m=3*				*m=11*			
		CPPI (P=1)	*CPPI+MPT (P=1)*	*CPPI (MD=5%)*	*CPPI+MPT (MD=5%)*	*CPPI (P=1)*	*CPPI+MPT (P=1)*	*CPPI (MD=5%)*	*CPPI+MPT (MD=5%)*
Terminal value (mean)	625	749	845	557	570	772	882	635	704
Terminal value (Std. Deviation)	130	327	25	72	64	354	22	149	42
Average return since inception	9.7%	10.9%	11.8%	8.8%	9.0%	11.2%	12.10%	9.8%	10.5%

As a first pattern we notice is that all strategies except for CPPI and CPPI+MPT with MD (m=3) ensure higher performance than the current strategy applied by the fund manager. Besides, our improvement of CPPI with combining maximum Sharpe ratio portfolio and risk-free asset gives higher average terminal values of fund asset, than simple two-asset CPPI. Our strategy does have another important advantage: it significantly (almost 10 times in some cases) decreases the standard deviation of assets terminal values. This ensures that the fund manager would be certain that liabilities to retirees can be honored on time and without losses.

These results again emphasize that diversification in the CPPI strategy can lead to more improved outputs for pension funds than just simply apply CPPI and Modern portfolio theory separately.

3. Conclusions

By improving the CPPI strategy combining it with Modern portfolio theory we have succeeded to prove the necessity of multi-asset diversification in the CPPI when applied in the context of pension fund management. First of all, the current portfolio structure of C-Quadrat balanced pension fund (if kept unchanged) turns out to be not appropriate because it gives lower expected values of fund assets, as well as high standard deviation, which is the main risk, sought to be eliminated by fund managers. CPPI model as a two-asset strategy improves the situation a little bit by guaranteeing the minimum value of the asset and not allowing floor value breach. Nevertheless, its two-asset nature hinders it from becoming applicable in real life and that is why it is an obsolete strategy in the financial world, especially in pension fund management. Our improvement via allowing asset diversification applying Markovitz theory allows us to apply it in real pension fund management, results of which as we saw showed significant improvement over two-asset CPPI and current portfolio structure. This model, if used with precise value of multiplicator and floor value, can improve Armenian mandatory pension funds management, which is a guarantee for a decent social life for future retirees.

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ՏԻԳՐԱՆ ԴԱՎԹՅԱՆ

ԵՊՀ տնտեսագիտության և կառավարման ֆակուլտետի ասպիրանտ

Ժամանակակից պորտֆելային տեսության և ֆիքսված համամասնությամբ պորտֆելի ապահովագրման ռազմավարության միավորումը (կիրառությունը կենսաթոշակային ֆոնդի կառավարման համատեքստում).– Կենսաթոշակային ֆոնդի ակտիվների և պարտավորությունների արդյունավետ կառավարումը երաշխավորում է պատշաճ եկա-

մուտ և սոցիալապես ապահով կյանք ապագա թոշակառուների համար: Այս նպատակներին հասնելու համար ֆոնդի կառավարիչները պետք է կիրառեն արդյունավետ ներդրումային ռազմավարություն:

Ֆիքսված համամասնությամբ պորտֆելի ապահովագրման ռազմավարությունը (CPPI) պորտֆելի ապահովագրության ամենահաճախ օգտագործվող մոդելներից է: Այնուամենայնիվ, իր թերությունների պատճառով CPPI մոդելը չի կարող արդյունավետորեն կիրառվել իրական պորտֆել կառավարելիս: Հիմնական խնդիրն այն է, որ CPPI-ը գործածելի է միայն երկու ակտիվների պարագայում: Սույն հոդվածում ժամանակակից պորտֆելային տեսությունը ներառվում է CPPI մոդելում (տարբեր ակտիվների դեպքում կիրառելի դարձնելու համար) և կարող է օգտագործվել բազմաթիվ ակտիվներից բաղկացած պորտֆելի կառավարման մեջ: Դրա արդյունավետությունը թեստավորվում է Հայաստանի պարտադիր կենսաթոշակային ֆոնդերից մեկի համար: Ինչպես ցույց են տալիս արդյունքները, ժամանակակից պորտֆելային տեսության և CPPI-ի միավորումը հանգեցնում է այնպիսի պորտֆելի ստեղծմանը, որը ոչ միայն եկամտաբերության և ստանդարտ շեղման տեսակետից երկու ակտիվի համար նախատեսված CPPI մոդելի և առկա պորտֆելի կառուցվածքի համեմատությամբ ավելի արդյունավետ է, այլ նաև թույլ է տալիս խուսափել CPPI մոդելի հիմնական խնդիրներից: Գործնականում դրա կիրառությամբ կարելի է բարելավել Հայաստանի կենսաթոշակային ֆոնդերի կառավարումը:

Հիմնաբառեր. *պորտֆելի ապահովագրություն, կենսաթոշակային ֆոնդի կառավարում, CPPI ռազմավարություն, հատակի արժեք, առավելագույն կորուստ, ժամանակակից պորտֆելային տեսություն, Շարպի գործակից:*

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Сочетание современной теории портфеля и стратегии страхования постоянного портфеля (применение в контексте управления пенсионным фондом). – Эффективное управление активами и обязательствами пенсионного фонда гарантирует будущим пенсионерам достойный доход и социально обеспеченную жизнь. Управляющим фондами необходимо применять наиболее подходящие инвестиционные стратегии для достижения этих целей.

Стратегия страхования портфеля с постоянной пропорцией (CPPI) - одна из широко используемых моделей в страховании портфеля. Однако из-за присущих ей недостатков модель CPPI не может быть эффективно применена в управлении реальном портфелем. Основная проблема в том, что CPPI применима только для случаев с двумя активами. В этой статье современная теория портфеля включена в CPPI, чтобы сделать ее пригодной для использования с различными активами и может быть легко использована в управлении портфелем с несколькими активами. Ее эффективность проверена на одном из обязательных пенсионных фондов Армении. Как показывают результаты, сочетание теории современного портфеля с CPPI приводит к созданию портфеля, который не только преодолевает CPPI и текущий портфель с точки зрения доходности и стандартных отклонений, но также помогает избавиться от основных недостатков CPPI. На практике с его применением можно улучшить управление пенсионными фондами Армении.

Ключевые слова: *страхование портфеля, управление пенсионным фондом, стратегия CPPI, минимальная стоимость, максимальная просадка, современная теория портфеля, коэффициент Шарпа.*

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