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HOW TO COMBINE THE SERBIAN STOCK INDEX WITH PRECIOUS METALS IN A MULTIVARIATE MARKOWITZ PORTFOLIO?

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Abstract: *This paper aims to determine how to combine the Serbian stock index, BELEXline, with four precious metals – gold, silver, platinum and palladium, in order to minimize risk. In the process of portfolio construction, we use the theoretical concept of Markowitz. In particular, we first determine a portfolio of five assets, then exclude an asset with the lowest share and repeat the procedure till we reach a portfolio of two assets. In this way, we construct four portfolios of five, four, three and two assets. In the five-asset portfolio, the portfolio optimization process determines a zero share of silver, because silver bears the highest risk of all other portfolio instruments. This, also, means that five- and four-asset portfolios have the same characteristics. On the other hand, in the three-asset portfolio, which contains the Serbian index, gold and platinum, we find a higher share of platinum, compared to the five-asset portfolio, because platinum has a higher negative correlation with BELEXline, vis-à-vis gold-BELEXline pair. Two-asset portfolio, which includes only the index and gold, has a higher risk in the amount of 5% and 4%, in relation to the four- and three-asset counterparts. The general conclusion is that a three-asset portfolio is the best one, since it has slightly higher risk than a five or four-asset portfolio, but it has lower transaction cost because it includes only three instruments.*

Keywords: *Serbian index, precious metals, risk-minimization, Markowitz theory, portfolio optimization*

JEL classification: *G11, Q02*

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KAKO KOMBINOVATI SRPSKI INDEKS AKCIJA SA PLEMENITIM METALIMA U MULTIVARIJANTNOM MARKOWITZ PORTFOLIU

Sažetak: *Ovaj rad pokušava da utvrdi kako da se srpski berzanski indeks, BELEXline, kombinuje sa četiri plemenita metala – zlatom, srebrom, platinom i paladijumom, kako bi se rizik sveo na minimum. U procesu konstruisanja portfolia koristimo teorijski koncept Markovica. Konkretno, prvo odredimo portfolio od pet instrumenata, zatim isključujemo onaj instrument sa najmanjim udelom i ponavljamo postupak dok ne dođemo do portfelja od dva instrumenta. Na ovaj način konstruišemo četiri portfolia od pet, četiri, tri i dva instrumenta. U portfoliu sa pet instrumenata, proces optimizacije je odredio nulti udeo srebra, jer srebro nosi najveći rizik od svih ostalih instrumenata portfolia. To, takođe, znači da portfolii sa pet i četiri sredstava imaju iste karakteristike. S druge strane, u portfoliu sa tri aktive, koji sadrži srpski indeks, zlato i platinu, nalazimo veće učešće platine u odnosu na portfolio sa pet sredstava, jer platina ima veću negativnu korelaciju sa BELEXlineom u odnosu na par zlato-BELEKSline. Portfolio sa dva instrumenta, koji uključuje samo indeks i zlato, ima veći rizik u iznosu od 5% i 4%, u odnosu na portfolie sa četiri i tri elementa. Opšti zaključak je da je portfolio sa tri instrumenta najbolji, jer ima nešto veći rizik od portfolia sa pet ili četiri instrumenata, ali ima niže transakcione troškove, jer uključuje samo tri instrumenta.*

Ključne reči: *srpski indeks, plemeniti metali, minimiziranje rizika, Markovitseva teorija, portfolio optimizacija*

1. INTRODUCTION

The introduction of the classical mean-variance portfolio theory of Markowitz (1952) has drawn a great deal of attention in academic literature. Generally speaking, this theory underlines the significance of diversification, allowing investors to find optimal weights of assets in a portfolio, which combination guarantees the lowest risk of a portfolio. In particular, portfolio optimization emphasizes the importance of the assets' variances as a measure of risk as well as the structure of the covariance matrix. The level of covariance between assets that constitute one portfolio is a very important factor for efficient portfolio construction, because assets that have a high level of correlation are not good candidates to be found in one portfolio. Markowitz's portfolio theory basically designs a minimum variance portfolio, which is a subject of interest for investors who seek minimum risk.

In recent years, Serbia has implemented profound fiscal and economic reforms necessary for attracting all kinds of foreign and domestic investors – greenfield,

brownfield, as well as portfolio investors, according to Gligorijević, Ćorović and Manasijević (2020). As the investment climate improved substantially, Serbia was defined as a top investment destination for lucrative investments in Western Balkans (see Damnjanović, Stankov and Roganović, 2019; Marjanović, Domazet and Simović, 2020). Based on the aforementioned, this paper tries to investigate how an investor in the Serbian stock market should construct their portfolio if they want to achieve a minimum variance goal. In the process of multivariate portfolio construction, we combine the Serbian stock index BELEXline with four precious metal futures – gold, silver, platinum and palladium. Futures contracts are elegant auxiliary investment tools, because they do not imply the actual purchase of a particular asset, but only a contract that reads on the assets. Also, futures contracts are very liquid, and they could be sold at any point in time. We observe BELEXline as the primary instrument in the portfolio, while precious metals are auxiliary instruments. Figure 1 shows the empirical dynamics of BELEXline price and its returns. It is evident that the Serbian index exhibited significant oscillations throughout the observed period, which could mean the presence of risk that need to be hedged. In the righthand plot of Figure 1, it can be seen that the actual risk of BEELEXline index in the observed period is $\sigma = 1.123$.

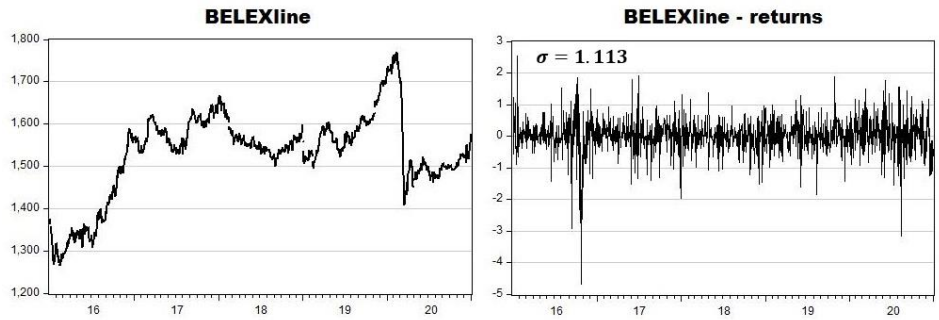

Figure 1. Empirical dynamics of BELEXline price and its returns

Note. Authors ' calculation.

On the other hand, Table 1 contains two categories that are important to know in the process of portfolio construction – the risk of auxiliary assets (precious metals) and the pairwise correlation between the Serbian index and four metals. According to Table 1, all precious metals have a higher risk than BELEXline. The fact that the Serbian stock index has a greater risk than precious metals might be surprising. However, this is somewhat expected, because the Belgrade stock exchange is a relatively illiquid market, and a relatively low level of daily transactions produces a low level of deviation from the mean. On the other

hand, the higher risk of auxiliary assets in comparison with the primary asset cannot be regarded as a favourable characteristic, because auxiliary assets should have lower risk than a primary asset in order to produce lower portfolio risk than primary asset has. However, another very important feature that precious metals have *vis-à-vis* BELEXline is a negative correlation, which means that their prices on average go in different directions. This means that precious metals are not only diversifiers but hedgers, which is their very good characteristic and the reason why they should be found in a portfolio with BELEXline.

Table 1

Risk of precious metals and correlation between precious metals and BELEXline index

	Gold	**Silver**	**Platinum**	**Palladium**
Standard deviation	1.320	3.179	1.562	1.993
Correlation	-0.037	-0.054	-0.046	-0.023

Note. Author's calculation.

In addition to the construction of a five-asset portfolio, we also want to see what portfolio characteristics are if we combine BELEXline with less than four futures. More specifically, we first determine optimal shares of assets in the five-asset minimum-variance portfolio. Then, we exclude assets with the lowest share, and rerun portfolio optimization again. After a four-asset portfolio calculation, we exclude the asset with the lowest share and then we recalculate the optimal portfolio with three assets. The procedure ends when we come to a portfolio with two assets. For every portfolio, we calculate risks and compare them. In this way, we construct portfolios with five, four, three and two assets, which allow us to determine which portfolio has the best performing characteristics.

Besides the introduction, the rest of the paper is constructed as follows. The second section presents some existing papers in the literature. The third section explains how multivariate portfolios are made. The Forth section introduces the dataset. The fifth section *via* four subsections presents the results. The last section concludes.

2. BRIEF LITERATURE REVIEW

This section briefly presents the papers that constructed portfolios with precious metals. For instance, Zhang, Xiong, and Zou (2021) examined volatility spillovers among gold spots, gold futures, stock, bonds, and oil as well as portfolio construction. They used multivariate VAR-CCC-GARCH and VAR-

DCC-GARCH models and reported that gold is suitable for portfolio diversification and helps reduce portfolio risk. AlKhazali, Lean, Mirzaei and Zoubi (2021) researched whether the gold-oil portfolio return stochastically dominates the oil portfolio return. They found that portfolio risk decreases as more gold is added to the oil portfolios. They concluded that risk-averse investors in the oil market should include gold in their portfolios to maximize their expected utilities.

The paper of Mensi, Nekhili and Kang (2021) investigated volatility transmission between crude oil and four precious metals and also, tried to see whether oil can be considered as a hedge or safe-haven asset against four precious metals. They determined that Brent oil is a good diversification tool, but a weak safe haven for precious metals. They concluded that a portfolio composed of Brent-oil and precious metals futures yields better hedging effectiveness. Salisu, Vo and Lawal (2021) examined the role of gold as a safe haven or hedge against crude oil price risks, employing the asymmetric VARMA-GARCH model. In order to account for the impact of the COVID-19 pandemic, they divided the sample into two to reflect the periods before and during the pandemic. They found that gold is a significant safe haven against oil price risks. Hammoudehaet, Santosb and Al-Hassan (2013) analysed the market downside risk associated with investments in six key individual assets including four precious metals, oil and the S&P 500 index. They reported that the VaR-based performance measure ranks the most diversified optimal portfolio as the most efficient one, while the pure precious metals portfolio is the least efficient.

3. METHODOLOGY

This paper uses Markovitz (1952) modern portfolio theory to construct minimum variance portfolios (MVP) with a different number of assets, combining the Serbian index BELEXline with precious metals. As Figure 2 shows, the minimum variance portfolio is placed at the curvature of the efficient frontier line, which means that this portfolio has the smallest risk of all possible portfolios. The horizontal line that splits the efficient frontier line, divides all possible portfolios into sets of efficient and inefficient portfolios. Efficient portfolios have a rising risk with rising returns, which is acceptable from the investor's point of view, whereby the only question is what is the level of risk that the investor is willing to accept. On the other hand, inefficient portfolios have a rising risk with the lowering returns, which is unacceptable for any investor. All dots within the efficient frontier line represent particular assets that have inferior risk-return performances compared to the minimum variance portfolio and all efficient portfolios.

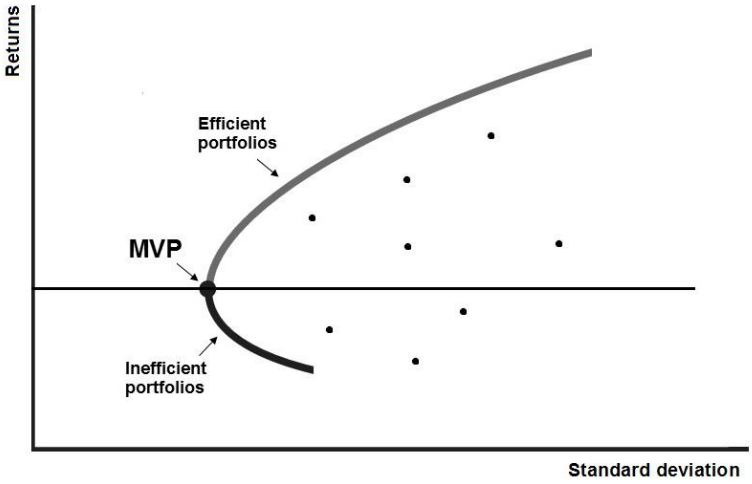

Figure 2. Empirical dynamics of BELEXline price and its returns

Note. Authors ' illustration.

Generally speaking, the minimum variance optimization procedure takes into account the variance of all assets in the portfolio as well as their pairwise correlations. The optimization process changes the weights of assets that constitute one portfolio, with an aim to find the best combination of assets that achieves minimum risk (see e.g. Armeanu & Balu, 2008; Cha & Jithendranathan, 2009; Guran, Ugurlu & Tas, 2019).

This paper tries to find a minimum variance[1] portfolio with a different number of assets. The mathematical expression of the objective function in a form of minimum portfolio variance looks like the following equation (1).

$$min\ \sigma_p^2 = min\ \sum_{i=1}^{N} w_i^2 \sigma_i^2 + \sum_{i=1}^{N} \sum_{j=1}^{N} w_i w_j \sigma_i \sigma_j \rho_{i,j} \quad (1)$$

where σ_p^2 is a portfolio variance, σ_i^2 is a variance of a particular asset *i*, w_i denotes a calculated weight of asset *i* in a portfolio, while $\rho_{i,j}$ is a correlation coefficient between the particular pair of assets (*i* and *j*).

Every portfolio with a minimum variance has a corresponding rate of returns, i.e. weighted average portfolio return (r_p), which can be calculated as in equation (2).

$$r_p = \sum_{i=1}^{N} w_i r_i \quad (2)$$

[1] Portfolio optimization was conducted by 'PortfolioAnalytics' package in 'R'.

where r_i is a particular rate of return of an asset in a portfolio.

The standard constraint in every portfolio optimization procedure is that sum of all asset weights in the portfolio must be equal to 1 (see equation 3), while the weight of every asset is in a range between zero and one (equation 4).

$$\sum_{i=1}^{N} w_i = 1 \quad (3)$$

$$0 \leq w_i \leq 1 \quad (4)$$

4. DATASET

This paper uses daily data of BELEXline index and four precious metal futures – gold, silver, platinum and palladium. The sample covers five years, from January 2016 to December 2020. BELEXline time-series are collected from the Belgrade stock exchange website (*www.belex.rs*), while precious metals futures are obtained from the *investing.com* website. All time series are transformed into log-returns ($r_{i,t}$) according to the expression $r_{i,t} = 100 \times log(P_{i,t}/P_{i,t-1})$, where P_i is the price of a particular asset. Also, all time series are synchronized according to the existing observations. Table 2 presents descriptive statistics of the selected assets.

Table 2

Descriptive statistics of the selected assets

	Mean	**Standard Deviation**	**Skewness**	**Kurtosis**	**Jarque-Bera test**
BELEXline	-0.012	1.113	-0.285	12.967	6246.098
Gold	0.045	1.320	1.217	14.962	9338.565
Silver	0.080	3.179	0.815	4.661	339.465
Platinum	-0.009	1.526	-0.562	12.785	6079.511
Palladium	0.084	1.993	-0.647	22.286	23413.390

Note. Author's calculation.

According to Table 2, BELEXline and platinum have negative mean, which indicates that average daily price movement of these instruments is negative. Standard deviation shows the risk of a particular asset, whereby BELEXline has the lowest risk compared to all precious metals, i.e. the deviation of its returns from the mean value is lowest. Silver has the highest risk, while palladium follows. Skewness suggests that BELEXline, platinum and palladium have

distribution tilted to the left, because of their negative value, while for gold and silver the reverse is true. This practically means that BELEXline, platinum and palladium have more negative returns in distribution, whereas gold and silver have more positive ones. Kurtosis tells us how many extreme values are present in each distribution, and according to Table 1, palladium has the most extreme deviations from the mean, followed by gold and BELEXline. The characteristics of the time series explained so far, especially skewness and kurtosis, show that none of the time series used in the research follow the normal or Gaussian distribution. However, the lack of normal distribution in the time series does not affect the process of portfolio optimization in any way. Jarque-Bera test confirms this claim as its values are very high. The main reason why the Jarque-Bera test values are very high is because of the high value of skewness and kurtosis, which should be around 0 and about 3 in Gaussian distribution.

5. RESEARCH RESULTS

5.1. FIVE-ASSET PORTFOLIO

This section presents the results of five-asset portfolio construction, whereby Table 3 contains calculated weights of assets in MVP, while Figure 3 depicts the efficient frontier line and spatial distribution of MVP and five assets. According to Table 3, the highest share in the portfolio has BELEXline index with 51%. Gold has the second-best share with 28%, while platinum and palladium follow with around 13% and 8%, respectively. The distribution of shares in the portfolio perfectly coincides with the level of risk of a particular asset. In other words, the highest share has the least risky BELEXline index, gold follows with somewhat higher risk, whereas platinum and palladium take third and fourth position, which is in line with their levels of risk. The portfolio optimization procedure does not include silver in the portfolio, arguably because silver has by far the highest risk of all assets (see Table 2), and including silver in the portfolio would only increase the risk of the constructed portfolio.

The Successfulness of portfolio optimization can be seen in Table 2, which shows that the standard deviation of MVP is 0.808, which is much lower than the level of risk of the least risky BELEXline index. This clearly indicates that an investor who wants to invest in the Serbian index can lower their overall risk if they combine Serbian index with three precious metals without silver.

Table 3

Calculated weights in five-asset MVP

	Minimum variance portfolio
BELEXline	51.24%
Gold	28.09%
Silver	0.00%
Platinum	12.98%
Palladium	7.68%
	Standard deviation
Minimum variance portfolio	0.808
Hedge effectiveness index	0.274

Note. Author's calculation.

Figure 3 graphically illustrates that silver has a much higher risk than other three precious metals, which is the reason why silver is excluded from the portfolio. Hedge effectiveness index in Table 2 shows how much risk reduction is achieved, compared to unhedged BELEXline index. In particular, risk reduction is somewhat more than 27%.

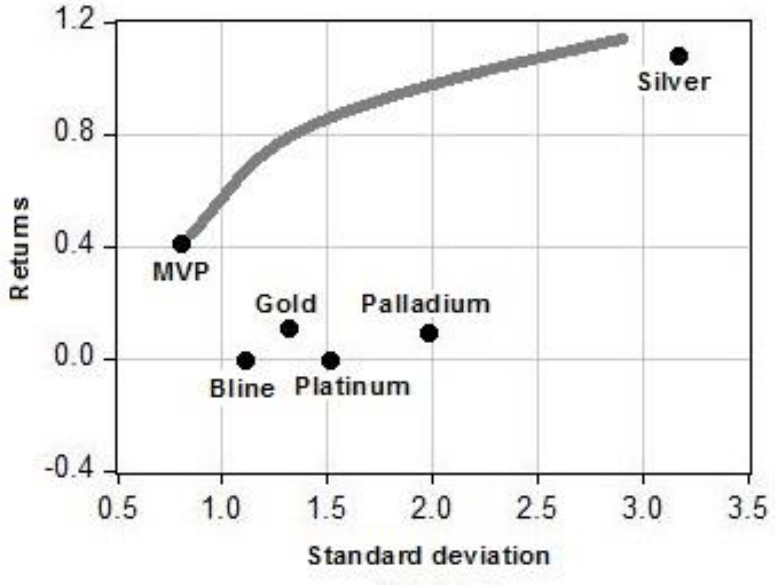

Figure 3. Bline denotes BELEXline index

Note. Authors ' calculation.

5.2. FOUR-ASSET PORTFOLIO

As has been explained earlier, after the construction of the five-asset portfolio, we exclude instruments with the lowest share and rerun portfolio optimization with four instruments in order to see whether this portfolio has better risk-reducing performance than the previous one. However, due to the fact that the share of silver in the five-asset portfolio is zero, this means that silver is already excluded from the five-asset portfolio, and this means that the five-asset portfolio will not differ from the four-asset portfolio. Because of that, we do not present the results of the four-asset portfolio, since the results are exactly the same as in the case of the five-asset portfolio.

5.3. THREE-ASSET PORTFOLIO

Following the procedure, we exclude silver and palladium, as two assets with the lowest share in a portfolio, in order to construct a portfolio with three assets. Table 4 contains the calculated weights of assets in MVP, while Figure 4 illustrates the efficient frontier line. As can be seen, all assets in the three-asset portfolio have a higher share in relation to the five-asset portfolio. In particular, BELEXline and gold have an increase of a little bit over 1%, with shares of 51.5% and 29%, respectively. On the other hand, platinum has the highest increase, from 13% to over 18%. A probable reason for such a finding is the fact that platinum has a higher negative correlation with BELEXline (-0.046) than gold has with BELEXline (-0.037), and a negative correlation is always a favourable characteristic in the diversification process. According to Table 4, the portfolio with three assets has a standard deviation of 0.819, which is a risk reduction of 26.4% *vis-à-vis* unhedged BELEXline investment. Also, this portfolio has a little bit higher risk than the five-asset portfolio. Figure 3 presents efficient frontier line of three-asset MVP.

Table 4

Calculated weights in five-asset MVP

	Minimum variance portfolio
BELEXline	52.50%
Gold	29.09%
Platinum	18.41%
	Standard deviation
Minimum variance portfolio	0.819
Hedge effectiveness index	0.264

Note. Author's calculation.

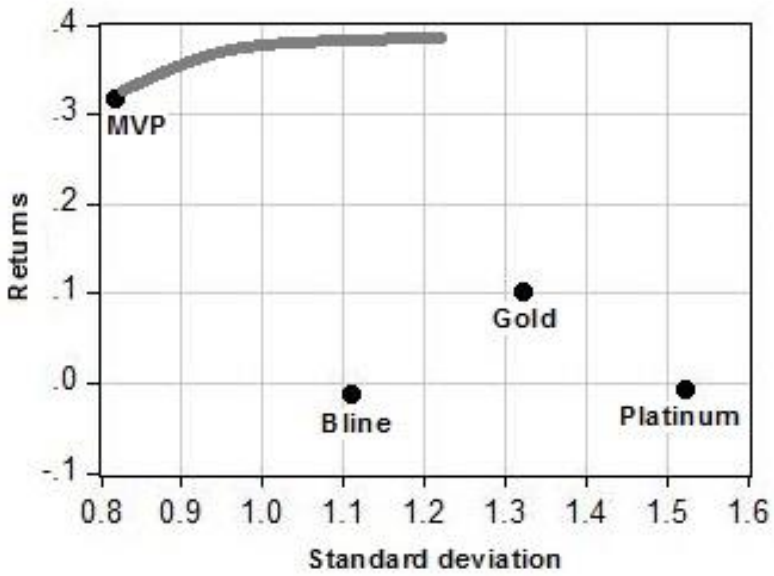

Figure 4. Efficient frontier line of three-asset MVP

Note. Authors ' calculation.

5.4. TWO-ASSET PORTFOLIO

In the last step, we make a portfolio with only the two least risky assets – BELEXline and gold. Table 5 presents calculated weights, while Figure 5 gives a graphical illustration of an efficient frontier line. In the two-asset portfolio, BELEXline has the highest share of 59%, and gold has 41%. Two-asset MVP has a level of risk of 0.864 and risk reduction in the amount of 22.4%. Compared to five- and three-asset portfolios, the two-asset portfolio decreased the risk by 5% and 4% less than the previous two portfolios.

Having an insight into all created portfolios with a different number of assets, it can be seen that gold is a constituent part of every portfolio. These results are very much in line with the previous papers that included gold in a portfolio. For instance, AlKhazali et al. (2021) asserted that a portfolio risk decreases as more gold is added to the oil portfolios. On the other hand, Salisu et al. (2021) contended that gold is a significant safe haven against oil price risks, and this statement can easily be transferred to our research, because we also find significant risk reduction when making portfolio with gold.

Table 4

Calculated weights in two-asset MVP

	Minimum variance portfolio
BELEXline	58.89%
Gold	41.11%
	Standard deviation
Minimum variance portfolio	0.864
Hedge effectiveness index	0.224

Note. Author's calculation.

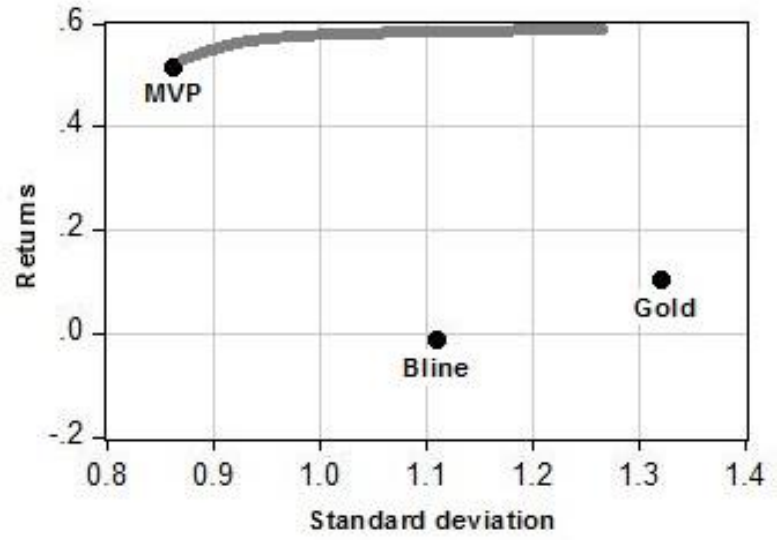

Figure 4. Efficient frontier line of two-asset MVP

Note. Authors ' calculation.

6. CONCLUSION

This paper uses the theoretical underpinning of Markowitz in order to construct multivariate portfolios with a different number of assets, with the aim to minimize the risk of such portfolios. More specifically, we combine the Serbian stock index – BELEXline with four precious metals futures – gold, silver, platinum and palladium.

In the five-asset portfolio, all selected assets have a certain share, except silver, which has zero share. The portfolio optimization process excluded silver from MVP because silver bears the highest risk of all other portfolio instruments.

This is the reason why we skip the construction of a four-asset portfolio, i.e. five- and four-asset portfolios have the exact same characteristics. On the other hand, in the three-asset portfolio, which comprises the index, gold and platinum, we find a higher share of platinum, compared to the five-asset portfolio, because platinum has a higher negative correlation with BELEXline, *vis-à-vis* gold-BELEXline pair. Also, the three-asset portfolio has a slightly higher risk than the five-asset portfolio. Two-asset portfolio, which includes only the index and gold, has a higher risk in the amount of 5% and 4%, in relation to four- and three-asset counterparts.

Based on the results, it can be concluded that the Serbian stock index can be hedged when it is combined with precious metals in multivariate portfolios. Also, comparing different-asset portfolios, the five (four)-asset portfolio has slightly lower risk, compared to the three-asset portfolio. However, a portfolio with more instruments also implies higher transaction costs, so taking into account this fact, maybe a better option for the investor would be a three-asset portfolio.

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