DE GRUYTER OPEN

South East European Journal of Economics and Business
Volume 12 (1) 2017, 99-108
DOI: 10.1515/jeb-2017-0010

PORTFOLIO DIVERSIFICATION IN THE SOUTH-EAST EUROPEAN EQUITY MARKETS

Azra Zaimović, Almira Arnaut-Berilo, Arnela Mustafić

Abstract

Diversification potential enables investors to manage their risk and decrease risk exposure. Good diversification policy is a safety net that prevents a portfolio from losing its value. A well-diversified portfolio consists of different categories of property with low correlations, while highly correlated markets have the feature of low possibilities for diversification. The biggest riddle in the world of investments is to find the optimal portfolio within a set of available assets with limited capital. There are numerous studies and mathematical models that deal with portfolio investment strategies. These strategies take advantage of diversification by spreading risk over several financial assets. Modern portfolio theory seeks to find the optimal model with the best results. This paper tries to identify relationships between returns of companies traded in South-East European equity markets. A Markowitz mean-variance (MV) portfolio optimization method is used to identify possibilities for diversification among these markets and world leading capital markets. This research also offers insight into to the level of integration of South-East European equity markets. Principal component analysis (PCA) is used to determine components that describe the strong patterns and co-movements of the dataset. Finally, we combined MV efficient frontier and equity, which represent PCA components, to draw conclusions. Our findings show that PC analysis substantially simplifies asset selection process in portfolio management. The results of the paper have practical applications for portfolio investors.

Keywords: *Diversification, Stock Markets, Markowitz portfolio optimization theory, Principal component analysis*

JEL classification: *G11, G32*

1. INTRODUCTION

Diversification possibilities have always been interesting to investors, because diversification decreases risk exposure and protects investors. Hedging is also an option for protection against risk exposure, but it can be costly. Market correlations affect the possibilities of diversification; more correlated markets lower diversification possibilities.

In this paper we will investigate the integration and correlation of South-East European equity markets and their neighbouring markets. We will try to identify if there is potential for diversification, and to

Azra Zaimović, PhD
Associate professor
Sarajevo School of Economics and Business
University of Sarajevo
E-mail: azra.zaimovic@efsa.unsa.ba

Almira Arnaut-Berilo, PhD
Assistant professor
Sarajevo School of Economics and Business
University of Sarajevo
E-mail: almira.arnaut@efsa.unsa.ba

Arnela Mustafić, MA
Sarajevo School of Economics and Business
University of Sarajevo
E-mail: arnela.mustafic@gmail.com

what extent. More specifically, we shall focus our attention on addressing the following questions: Does it make sense to diversify portfolio a in the markets in question? How can we select stocks that create a diversified portfolio, and how many stocks are needed for efficient diversification? Do efficient portfolios outperform world leading stock market indices?

For the purpose of the analysis we use two methodological approaches: Principal Component Analysis and the Markowitz portfolio optimization method.

The paper is divided into five parts. The Section 2 literature review provides an overview of the theoretical background of the research on the potential gains from diversification, and shows the results of previously conducted research. Section 3 explains the methodology used for the analysis. Section 4 explains the data, gives the results of principal component analysis and identifies the diversification possibilities using the Markowitz portfolio optimization method. Finally, a brief summary and concluding remarks are given in Section 5.

2. LITERATURE REVIEW

Diversification has long been known to mankind, as reflected in the idiom: *"Never put all of your eggs in one basket"*. Lowenfeld (1909) is considered the first academic to introduce discussion on the topic of diversification. Diversification was a known subject among market practitioners. The modern understanding of diversification goes back to the work of Markowitz (1952). With his work "Portfolio Selection" in 1952, the author set the foundations for Modern Portfolio Theory and gave direction on how to distinguish between effective from ineffective portfolios. For the first time, Markowitz introduces the efficient frontier, or as the author referred to it, a set of efficient mean-variance combinations, where return is represented by the mean return of investment, and risk is represented by the square root of variance of returns. Markowitz thereby explains portfolio space as space defined by the return and risk, where efficient portfolios are those that have the highest returns for a given risk, and the lowest risk for a given return. The total risk of an asset is divided into idiosyncratic risk and systematic risk. Idiosyncratic risk is that which can be diversified, while systematic cannot be diversified. Therefore, diversification would represent a combination of assets that reduces idiosyncratic risk and leaves the group (portfolio of assets) only with, in an ideal case, systematic risk. Markowitz diversification is defined as a strategy that combines those portfolios that have correlation less than 1 (that are not perfectly correlated) with the goal of minimizing risk while not decreasing return.

After the emergence of Modern Portfolio Theory researchers investigated the possibilities of diversification in the market. Two opposite lines of thoughts emerged, one in favour and the other against diversification theory. Shawky, Kuenzel and Mikhail (1997) synthesized research in this field and argued that when looking at ex-post data, there is a potential for international diversification. On the other side, the results for ex-ante data are questionable because of changes in correlations through time. In their paper they also refer to authors who have investigated the importance and rapid growth of emerging markets and the possibilities for diversification in those markets (Claessens et al., 1995; Tesar and Werner, 1995). Finally, they conclude that it is difficult to determine an optimal investment strategy ex-ante. Unstable correlation structures and stronger co-movements among international capital markets lead to reduced possibilities for international diversification. However, they did find strong evidence supporting international portfolio diversification as a method to reduce portfolio risk without negative effects on expected return.

Analyses of South-East European (SEE) stock markets have been reported by several papers with conflicting findings, which makes this field of research interesting and challenging. Guidi and Ugur (2014) identify three reasons for increased interest in this investment region. First, both the European Bank for Reconstruction and Development (EBRD) and the European Union (EU) are encouraging financial reforms in these countries in order to enable an inflow of FDI. Second, significant integration with EU markets has been reported as a result of increased trade and direct investment flows. Finally, the market capitalization of these markets doubled as a percentage of GDP from 2000 to 2010. The authors analysed the stock markets of Bulgaria, Croatia and whether they are integrated with developed counterparts in Germany, the UK and the USA. Static cointegration analysis showed the existence of relations with German and UK markets over the period 2000-2013, but not with the US market. Further, they investigated diversification possibilities in these markets and concluded that potential exists. Diversification benefits did exist from September 2007 to June 2013 despite evidence of dynamic cointegration during most of the crisis period from September 2008 to May 2010. Syriopoulos (2011) investigated the short- and long-run behaviour of major Balkan equity markets (Romania, Bulgaria, Croatia, Turkey, Cyprus and Greece), and developed (Germany, US) stock markets and the impact of the EMU on stock market linkages, and Syriopoulos and Roumpis (2009) analyse time-varying comovements, volatility implications and dynamic correlations.

They found that correlations between Balkan and developed stock markets are modest and stable over time. In contrast, Guidi and Ugur (2014) report that Syllignakis and Kouretas (2011) show that correlations between Central and South-Eastern European markets and the USA and German markets vary over time, with a tendency to increase during periods of financial turmoil. Horvath and Petrovski (2013) compared Central and South Eastern Europe stock market integration. As countries of Central Europe they included the Czech Republic, Hungary and Poland, while the analysis of South Eastern Europe included Croatia, Macedonia and Serbia. For the analysis they used GARCH models for the period from 2006 until 2011. The analysis was divided according to these groups. As a final conclusion they reported that the correlation is much higher for Central European than for South Eastern European stock markets. The correlation is essentially zero for South Eastern European stock markets with developed markets, with the exception of Croatia, which has a slightly higher integration with Western Europe, but lower than those of Central European stock markets. Zaimović and Arnaut-Berilo (2015) conducted unique research on the subject of diversification possibilities between stock markets in Bosnia and Herzegovina and Germany. The trade of Bosnia and Herzegovina with Germany in 2015 amounted to 15.7% of total exports and 12% of total imports, implying the importance of trade with Germany for Bosnia and Herzegovina. Zaimović and Arnaut-Berilo (2015) reported that the German equity market is more mean variance efficient than the Bosnian equity market. They conclude that investment spreading among these markets can decrease portfolio risk in the pre-crisis and post-crisis periods.

Several papers refer also to the diversification possibilities in a single market. Benaković and Posedel (2010) use a factor model approach to analyse the movement of returns on fourteen stocks from the Croatian capital market in the period from 2004 to 2009. Kovačić (2007) investigated the behavior of stock returns in the Macedonian Stock Exchange. Bogdan, Bareša and Ivanović (2010) analysed portfolio consisted of stocks from Zagreb Stock Exchange and questioned whether there are any diversification possibilities within this market for the chosen securities. They identify correlation coefficients among chosen stocks but were careful with reporting their results because of problems with low turnover and the liquidity of stocks in question for the analysed period.

3. METHODS AND DATA

3.1 Methods

For analysis of diversification possibilities in this paper we will use two approaches: Principal Component Analysis (PCA) and the Markowitz Mean Variance portfolio optimization method (MV). Markowitz's methodology is used to demonstrate the diversification possibilities on the selected capital markets, but also to examine mean – variance (MV) efficiency for all and selected equities. As a result of MV analysis we get a set of efficient portfolios composed of a large number of shares. Choosing a subset among a large number of shares in analysis is quite important when it comes to practical application. PCA analysis is used to identify the set of equities that best describe the variability of a selected equity market. It is an alternative for reduction in complexity and identifying uncorrelated components without losing the variation given by variances and correlations or covariance.

The classical Markowitz portfolio model is used to determine the efficient return-risk combination, i.e. the efficient frontier (EF)[1]. The efficient frontier is convex curve and lies between the portfolio with minimal standard deviation and the portfolio with a maximum rate of return (mean). The model includes portfolio expected return $\overline{R}_p = \sum_{i=1}^{n} \overline{R}_i x_i$ and portfolio variances $\sigma_p{}^2 = \sum_{j=1}^{n}\sum_{i=1}^{n} x_j x_i Cov(R_i, R_j)$, where investments satisfy the investment constraints: $\sum_{i=1}^{n} x_i = 1$ and no negativity conditions $x_i \geq 0,\ i = \overline{1,n}$.

The square root of portfolio variance is used as a measure of portfolio risk and includes correlations between equity returns. Markowitz argued that low or negative correlations will eliminate portfolio risk, measured by $\sigma_p{}^2$. In determining the efficient combination of a set of securities, several optimization problems are detected. First, the model must identify the portfolio with the lowest possible variance (the starting point of EF); second, the model must identify the portfolio with the highest return possible (the ending point of EF). In addition, for every rate of return the lowest variance portfolio must be determined, and for every variance the highest return portfolio must be determined.

If the investor considers investing in a portfolio, with a pre-determined value of expected return on investment E, we have an additional constraint:

1 The mean-variance combination of a portfolio is efficient if there are no other combinations with the same return, and a lower variance, or the same variance and higher return.

$\sum_{i=1}^{n} \overline{R}_i \cdot x_i = E$. As a result, the model represents the investment vectors that provide the absolutely minimum portfolio return variance $\sigma^2_{\min}$ with the pre-set return E. By choosing randomly expected return of investment in the range $\overline{R}_{\min} \le E \le \overline{R}_{\max}$ [2] we can determine the efficient set of the observed security (Arnaut-Berilo and Zaimović, 2012).

PCA has the ability to decompose interrelated variables into uncorrelated components. The idea then is to observe correlations in the structure of equity, identify uncorrelated risk sources in the market and chose the equity from a different risk source. We used the Kaiser – Meyer – Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity.

The KMO statistic compares the value of correlation between stock returns to those of the partial correlations. If stocks share more common, variations in the KMO will be close to 1, while a KMO close to 0 indicates that PCA will not extract much useful information.

$$KMO = \frac{\sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n} r_{ij}^2}{\sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n} r_{ij}^2 + \sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n} a_{ij}^2},$$

where r^{ij} is correlation between stock returns and $a_{ij} = r_{ij \bullet \{1,2,\ldots,n\}\setminus\{i,j\}}$ are partial correlations.

Bartlett's test of sphericity tests the null hypothesis that the correlation matrix is equal to the unit matrix. If we accept the null hypothesis, this means that there is no intercorrelation between variables. The Bartlett Test is given by: $b = -\left(m - 1 - \frac{2n+5}{6}\right)\ln|\boldsymbol{R}|$

and follows χ^2 distributions with $df = \frac{(p-1)(p-2)}{2}$ degrees of freedom.

For the purpose of this paper we will use the principal component approach, which follows the Jolliffe (2002) variable selection method and Kaiser's rule (Kaiser, 1960).

3.2 Data

Our starting sample consisted of 47 stocks and 23 indices observed over the period from 1st January 2006 until 1st April 2016. List of stocks and indices used is provided in Table 1 and 2.

We selected stocks with sufficient liquidity, namely for a minimum of 440 trading days during the observed period. Most liquid stocks and wide indices from the analysed markets are included in the sample.

The selected stocks were being traded in the five SEE capital markets (those of Croatia, Serbia, Montenegro, Macedonia and Bosnia-Herzegovina[3]), while the analysed stock market indices covered in addition to these five SEE capital markets the capital markets of Romania and Bulgaria. Moreover, some world leading market indices were also included (representing the US, the UK, German, Austrian, Italian and Japanese capital markets).

The analysis was conducted using monthly logarithmic returns calculated based on stock prices (and in the case of indices, index values) at the beginning of each month. The price on the first trading day of each month during the analysed period was used, and if that was not available, the first prices prior to the first trading day of each month. Due to missing data, and nonsynchronous trading problems, we have excluded 10 stocks and indices from further analysis.

Table 1: List of stocks

Stock exchange	Stocks
Banja Luka SE	HETR-R-A; NOVB-R-E; TLKM-R-A; KRIP-R-A; ZPTP-R-A; BVRU-R-A
Belgrade SE	AERO; AIKB; ENHL; FITO; KMBN; NIIS; SJPT
Podgorica SE	PLAP; ATBN; PREN; PREN
Sarajevo SE	BHTSR; JPEMR; BSNLR; ENISR; ENPSR; FDSSR; HDGSR; HRBFRK2; MIGFRK2; PRPFRK2; BIGFRK3
Skoplje SE	ALK; GRNT; MTUR; TEL; MPT; TNB; PPIV; STB; TTK
Zagreb SE	ADRS-R-A; ATGR-R-A; DLKV-R-A; DDJH-R-A; ERNT-R-A; HT-R-A; LEDO-R-A; PODR-R-A; PRFC-R-A; RIVP-R-A

2 If the following is true $E > \overline{R}_{\max}$ the model would be unsolvable, and if $E < \overline{R}_{\min}$ then the solution to the system (1- 4) would not be an element of the efficient set, where $\overline{R}_{\min}$ and $\overline{R}_{\max}$ corresponds to the efficient portfolio with the lowest variance and maximum return, respectively

3 Bosnia – Herzegovina's capital market consist of two stock exchanges, Sarajevo Stock Exchange and Banja Luka stock exchange.

Table 2: List of indices

Stock exchange	Indices
Banja Luka SE	BIRS
Belgrade SE	BELEX15
Bucharest SE	BET; BET-BK; BET-C; BET-FI; BET-NG; BET-XT; ROTX
Frankfurt SE	DAX
London SE	FTSE 100
Milano SE	FTSE MIB
Podgorica SE	MNSE10
Sarajevo SE	SASX-10; SASX-30
Sofia SE	SOFIX
Tokyo SE	NIKKEI 225
Vienna SE	ATX
Zagreb SE	CROBEX; CROBEX10
Other	NASDAQ; DJIA; S&P500

4. RESULTS AND DISCUSSION

4.1 Diversifications possibilities on SEE equity markets

In order to examine the possibilities for diversification in SEE equity markets, we have used an MV efficient set, i.e. an efficient frontier. Notice, once again, that the efficient frontier is a convex curve in a mean-variance coordinate system and that every dot (representing a portfolio of stocks) inside this convex set is less efficient than portfolios on the efficient frontier.

Figure 1 shows the MV efficient frontier formed by sample stocks from six stock exchanges (Sarajevo, Banja Luka, Belgrade, Zagreb, Skopje, Podgorica) and two stock exchange indices from Romanian and Bulgarian capital markets (the Bucharest and Sofia stock exchanges). The effects of diversification with a lower standard deviation for the given level of expected return, or a higher expected return for the given level of standard deviation, are visible along the whole efficient frontier.

SEE markets portfolios outperform every stock exchange efficient portfolios. Stocks on the Macedonian stock exchange were the best performing, while the Sarajevo Stock Exchange stocks were the worst performing over the observed period. The effects of diversification in terms of the value of the standard deviation on different efficient frontiers can be seen in

Figure 1: Portfolio diversification potential on SEE markets.

Source: Authors

Table 3: Diversification effects on SEE markets for pre-given level of return.

Pre-given return (%)	Risk (standard deviation as a %) of efficient portfolio from selected equity market						Risk SEE (%)	Investment weights (%)						
	Sarajevo	Zagreb	Belgrade	Podgorica	Banja Luka	Skopje		Bucharest	Sarajevo	Zagreb	Belgrade	Podgorica	Banja Luka	Skopje
0.484	19.93	11.67	9.61	7.29	6.84	5.98	4.66	8.2	6.74	23.5	0	8.4	32.54	20.63

Source: Authors

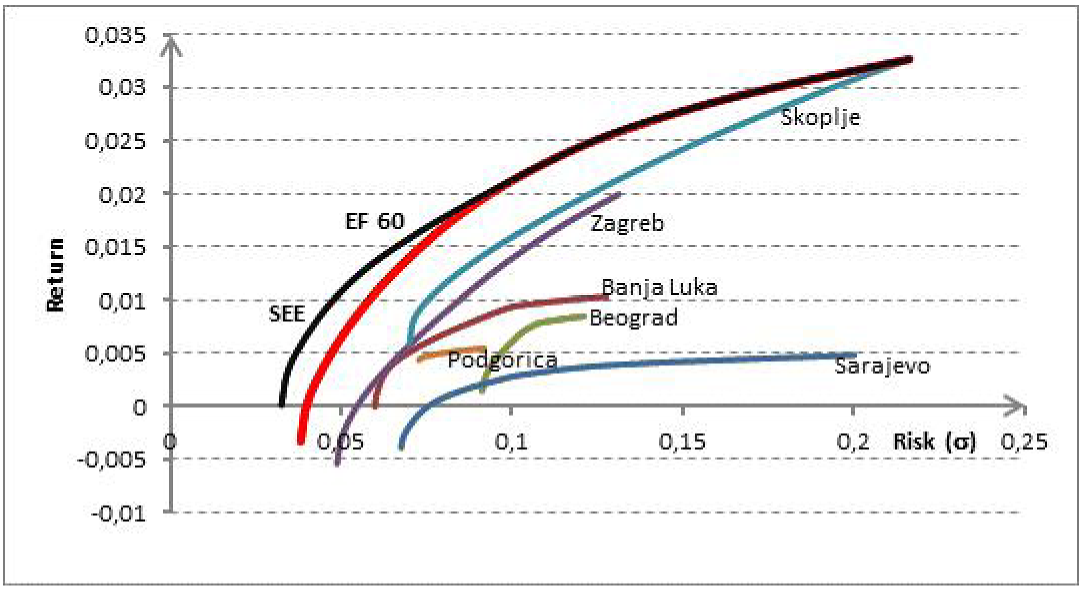
the following table. Table 3 shows efficient portfolios' standard deviations for the pre-given level of return, observed individually for every stock exchange, and combined for the whole SEE market. Risk diversification is achieved by combining stocks from different SEE markets. Table 3 also shows the investment weights for every market in the SEE efficient portfolio with the expected return of 0.484% and a standard deviation of 4.66%. Regardless of the expected high integration and low diversification possibilities of SEE equity markets, due to the increased returns correlations during and after the recent global financial crisis, we find a substantial benefit from spreading out the investments in the whole SEE region, rather than investing in one market only. As we can see form Table 3, five out of six stock exchanges take part in this efficient portfolio, i.e. Belgrade Stock Exchange is left out of the selected mean-variance efficient portfolio.

In addition, we created a mean-variance efficient frontier from all sample stocks and indices (in total 60). Besides the above SEE market stocks and indices we added the following indices: S&P, DJIA, NASDAQ, DAX, FTSE 100, Nikkei, ATX and FTSE MIB. The effects of diversification are visible in the "lower" part of the efficient frontier, i.e. in achieving lower standard deviation, Figure 2.

It is interesting to notice that the efficient frontier derived from world leading indices and stocks and indices from SEE markets together overlaps the efficient frontier of the SEE market in the "upper" part of the curve. These findings enable us to conclude that investors with low risk aversion, (investors with a flatter indifference curve), will have no benefit from spreading out their investments from SEE to the world's leading markets, and vice versa. On the other hand, investors with high risk aversion and a steep indifference curve have an additional benefit from wider diversification.

The question is whether we can choose a subset

Figure 2: Diversification potential – world indices and SEE markets.



Source: Authors

of the dataset stocks that would be simple in terms of portfolio management selection, and yet good enough to explain the previously defined efficient frontiers. We find this answer by using principal component analysis.

4.2 Results of principal component analysis

Conducting principal component analysis removes highly correlated investments in the sample and identifies correlated assets that have the same high numbered PC, each with a high loading. The procedure eliminates these highly correlated investments. In the diversification context, this elimination will result only in a small decrease in diversification potential.

In our analysis of 60 stocks and indices, four iterations have been conducted with a deletion criteria of 1 and a stopping criteria of 0.7. Principal component analysis conducted on 60 assets extracted 60 components, among which 45 components had eigenvalues lower than 1. Those 45 components with eigenvalues lower than 1 were included in further analysis, while components with eigenvalues higher than 1 were excluded. The Component Matrix was used to select which stocks or indices among the 60 should be excluded. Those components with eigenvalues lower than 1 are further analysed in the Component Matrix. Stocks and indices with extremes within the component are excluded from the next iteration. Out of 60 assets included, 36 unique stocks and indices were excluded in the first iteration of the analysis. The dimension reduction process was repeated a second time. In the second iteration 24 components were identified, among which 18 had eigenvalues lower than 1. Out of 24 investments included, 14 unique stocks and indices were excluded in the second iteration of the analysis.

The dimension reduction process was repeated a third time. In the third iteration 10 components were identified, among which 6 had eigenvalues lower than 1. Out of 10 investments included, 6 unique stocks and indices were excluded in the third iteration of the analysis. A final forth iteration resulted in 4 components and 4 assets. The last eigenvalue was 0.717, higher than the 0.7 stop criteria, and the process was finished. The results are presented in Table 4.

For all iterations a Kaiser-Meyer-Olkin Measure of Sampling Adequacy and Bartlett's Test of Sphericity allowed the conduction of PCA. See Table 5.

The principal components obtained from the selected four stocks and indices were approximately the same as the original 4 assets. When there is a low correlation among the original investments a PCA extracts little useful information. Table 6 shows the reduction of correlation among remaining assets in four iterations in PC analysis.

We further investigate the differences in the mean-variance efficiency of 4 asset portfolios obtained in the fourth iteration. The selected four PCA assets consist of Sojaprotein, Dow Jones, Telekom Srpske and ZTC Banja Vrućica.

With the selected 4 PCA assets we formed an MV efficient frontier and checked how many randomly

Table 4: Total variance explained after fourth iteration.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.677	41.919	41.919	1.677	41.919	41.919
2	.876	21.898	63.818	.876	21.898	63.818
3	.730	18.250	82.068	.730	18.250	82.068
4	.717	17.932	100.000	.717	17.932	100.000

Source: Authors

Table 5: KMO and Bartlett's Test.

Iteration		1	2	3	4
Kaiser-Meyer-Olkin		.645	.830	.732	.667
Bartlett's Test	Chi-Square	4831.334	1173.614	248.811	31.465
	df	1770	276	45	6
	Sig.	.000	.000	.000	.000

Source: Authors

Table 6. Maximum correlation depending on the number of stocks retained.

No. Stocks and Indices Retained	Maximum Correlation
60	0.979
24	0.735
10	0.592
4	0.281

Source: Authors

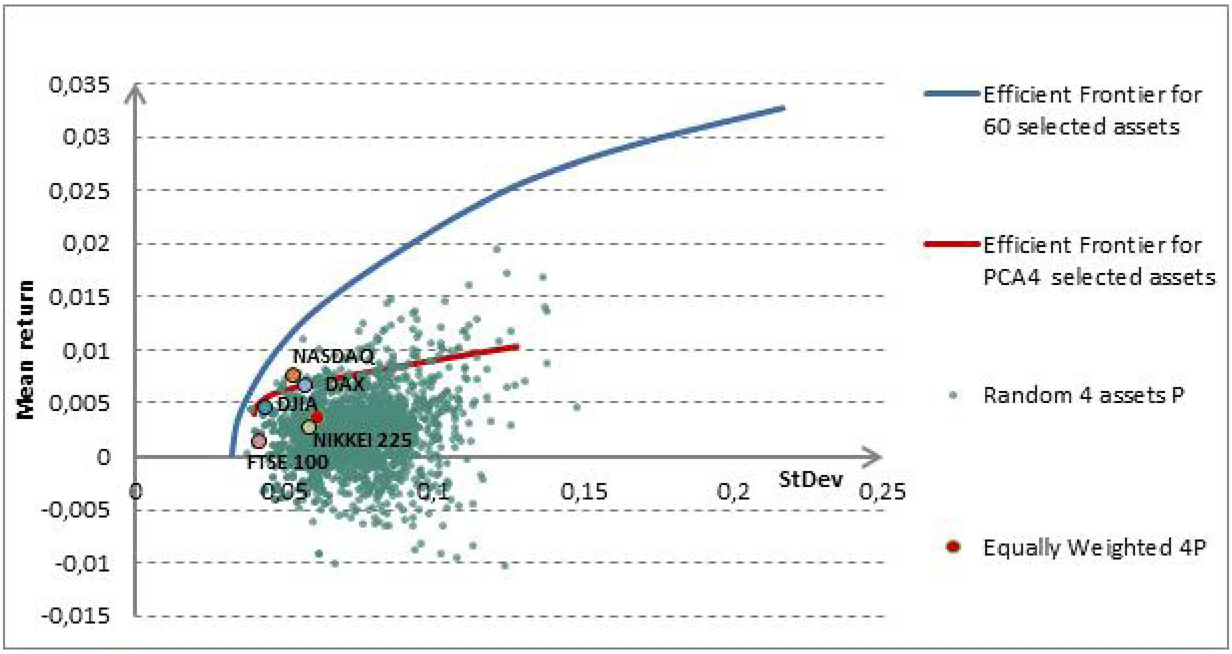
selected portfolios made up of any 4 assets were contained within this convex set. In total, we created 3000 portfolios formed from 4 randomly selected investments. The results show that only 138 portfolios could be found outside the convex region bounded by PCA 4 assets' efficient frontier. Based on these results we can conclude that efficient portfolios composed of these four assets dominate over 95% of all portfolios composed of any 4 assets in terms of the Markowitz definition of dominancy. We checked the domination of efficient sets over the randomly selected portfolio consisting of more than 4 equities and we concluded that these MV portfolios are far more homogeneous, so that this percentage is only higher. These results are not present in the paper but are available on request.

Figure 3 shows two lines, the red representing the efficient frontier derived from PCA selected assets (PCA4) and the blue representing the efficient frontier derived from all observed equities (EF 60). The green dots in the figure represent 3,000 randomly selected portfolios formed from 4 randomly selected equities. The red dot represents an equally weighted PCA 4 asset portfolio.

We find that this small number of asset portfolios (PCA 4) outperforms some of the world leading indices, i.e. DJIA, DAX, FTSE 100 and NIKKEI 225. The only index that performs better than the 4 PCA assets' portfolios in the observed period is the NASDAQ index. Also, substantial additional diversification still can be achieved by including all 60 assets in the portfolio selection process.

Note that PCA 4 stocks and indices are from three different markets. Although the Minimum Variance portfolio of PCA 4 assets does not match the Minimum Variance portfolio of 60 assets, Figure 3 shows that the efficient frontier of PCA 4 assets is very close to the efficient frontier of 60 assets in the "lower" part. From our analysis it can be concluded that PCA 4 asset-efficient frontier portfolios achieved by applying the PCA method offer a good risk reduction effect.

Figure 3: Diversification possibilities of four (PCA) asset portfolios.



Source: Authors

5. CONCLUSION

In this paper we tested portfolio diversification possibilities in South-East European equity markets. Our sample consists of stocks from capital markets in the following SEE countries: Croatia, Serbia, Montenegro, Macedonia and Bosnia and Herzegovina. In addition, we included indices from Bulgarian and Romanian capital markets and also 9 indices from capital markets in developed countries: USA, Germany, United Kingdom, Japan, Italy and Austria. The analysis was conducted with monthly stock and indices returns.

We find that national capital markets itself are quite inefficient from the mean-variance standing point of view, while the Macedonian capital market was the best performing in the observed period. Our research offers evidence that there is a benefit from spreading out portfolio investments from the abovementioned five national stock markets to the SEE region, i.e., regional capital markets offer substantial diversification opportunities. Integration among these markets is obviously not high and the SEE market efficient frontier performs much better than any national capital market efficient frontier.

We also find that there is a rather limited diversification benefit from spreading out the investments from the SEE markets to the world leading capital markets, or vice versa. The SEE market offers diversification possibilities that are similar to those of leading world capital markets, represented by the leading world indices, at least for those investors with low risk aversion. Only international investors with high risk aversion could gain some benefit by including SEE market stocks in their portfolios only. We can conclude that there is a limited diversification benefit from spreading out the investments from the SEE market to the leading world capital markets, and vice versa, due to the high integration of the SEE market with leading world markets. The high integration of international capital markets and fewer diversification possibilities are a consequence of the financial crisis, so our results are in line with most studies on this topic. It is important to keep in mind that within the analysed period, 1st January 2006 until 1st April 2016, a financial and economic crisis occurred (the period form 2008 - 2010). Financial and economic crises could have an impact on the obtained results, since PCA could have excluded stocks that were highly correlated in this period. On the other hand, investors are searching for stocks that will provide the best diversification possibilities also in periods of financial and economic crisis; therefore this argument is strong enough to exclude those correlated stocks.

The second objective of our research was to determine the subset of the observed set of investments, which is the best represented of the returns' variability. Markowitz modern portfolio theory states that portfolio risk is reduced by combining assets with low or negative correlations. That was the reason why we decided to apply the principal component analysis as criteria for asset selection. The idea then was to observe correlations in the structure of assets, identify uncorrelated risk sources in the market and choose assets from different risk sources.

The results and conclusions of this analysis rely on efficient frontier construction for the beginning set of assets as well for the selected subset of assets. We tested the selection quality by comparison with the mean-variance characteristics of randomly selected portfolios and the efficient portfolios of assets derived from PCA analysis. Based on the results of our analysis, we conclude that 4 PCA selected asset portfolios dominate over 95% of all potential portfolios composed of any 4 assets in terms of Markowitz definition of dominancy. For further analysis we recommend formulation of an efficient frontier, with 10 PCA selected assets (iteration three in the PCA analysis) and its comparison with the opportunity set of all possible portfolios of sample stocks and developed capital market indices, since 60 asset portfolios are still better performing than 4 PCA asset portfolios.

The main conclusion of our analysis is that PC analysis substantially simplifies the asset selection process in portfolio management. PCA-selected asset portfolios dominate over 95% of all potential portfolios with the same number of assets included. We hope that PCA might reduce the numerous calculations and estimations currently involved in efficient portfolio investing.

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