# Utrecht University School of Economics

Master's thesis

# Yield enhancement and risk management benefits of structured products from the perspective of mean-variance spanning test model

Edgaras Bikas
E.bikas@students.uu.nl

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**Abstract**

The thesis investigates whether structured products can enhance the risk-reward spectrum of the well-diversified portfolio of risky assets. The difficulties with traditional spanning tests proposed by Huberman and Kandel (1987) are, that they assume a normal distribution, give disproportionately more weight to the variance compared to the abnormal returns and do not deal well with small sample data. Therefore, the variations in spanning tests are used to overcome such difficulties.

The thesis uses general spanning test proposed by Huberman and Kandel (1987) along with the spanning test that controls for finite sample data initially proposed by Jobson and Korkie (1989) and the step-down application to get a more precise picture of what causes the rejection of spanning (*i.e.,* risk, return or both simultaneously). Furthermore, since structured products depict negative skewness the spanning test will be recalculated using Wald-GMM test proposed by Kan and Zhou (2012) to control for non-normal distribution.

The study indicates that all structured products considered in the text add significant statistical diversification benefits to the portfolio of well-diversified assets. Moreover, the diversification benefits persist after controlling for structured product benchmarks as well.

*Keywords:* Structured products, portfolio theory, spanning test, portfolio management

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Edgaras Bikas

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# 1. INTRODUCTION

This thesis investigates whether structured products[1] can add the yield enhancement or volatility reduction benefits to the well-diversified portfolio of risky assets, from the perspective of mean-variance spanning test. The mean-variance (efficient) portfolio is described as a portfolio that generates the highest expected return for a given level of volatility *i.e.,* a portfolio with the lowest variance for a given expected return. The mean-variance spanning test tries to answer the question of whether the addition of a new set of assets (in this case structured products) can add any statistically significant diversification value (either higher return, lower volatility or both) to the efficient portfolio of risky assets?

Structured products have a wide range of definitions depending on investors' risk awareness, product type or capital constraints, inter alia. Nevertheless, in general terms, structured product can be described as a structured form of investment that has the cash flows dependent on the underlying asset or derivative within the investment. Structured products can be tailored to meet specific investor requirements from either risk or return perspective. The features mentioned above allow to distinguish structured products from traditional investments.

As the monetary policy expansion continues throughout the majority of developed countries, the number of academics and market professionals note the increasing risks in the financial system. For example, Paul Singer described the current economic and financial environment as having "high uncertainty and distorted financial valuations that are induced through quantitative easing and low-interest rate". Academics notice the increasing risks formed by monetary policy expansion as well. Schularick and Taylor, (2012) found that historically, periods of financial instability were most of the time caused by credit expansion that was badly managed. Furthermore, it is well known that lower covariance between assets increases diversification value of the portfolio, by reducing overall volatility. However, in the past 4 years, the correlation between major asset classes (equities and bonds) has been converging toward 1. Table 1A in the Appendix shows the increased correlation between the United States', Europe's and Asia's equities. In addition, the correlation between the U.S. equities and high yield bonds from 2013 to 2017 increased by 13%. The lower covariance between investment graded bonds and US equities could, potentially, be explained by the record low yields that were reached partly due to the QE program. Even though the correlation between US stocks, alternative assets, and commodities show mixed results, it can be noted that equities and bonds make up the majority of the global investment universe, therefore, their correlation is of greater importance. Such a shift in the correlation increases the risk in the well-diversified portfolio. However, structured products can remain resistant to converging correlation due to the special features *e.g.*, capital protection, payoff structures or timing. There is also a possibility to increase the yield of structured products, not only by increasing leverage but by introducing additional assumptions while keeping the idiosyncratic risk constant (adding payoff if certain scenarios are met). Therefore, the two latter

[1] Structured products and structured securities will be used interchangeably throughout the text.

features make structured products an interesting subject for further studying regarding portfolio diversification.

Moreover, structured products cover a big share in global capital markets. According to Bloomberg during the three-year period from 2010 to 2013, banks in the United States (globally) issued $174 bn. ($318 bn.) worth of structured products. In addition, fixed income structured products in the U.S. throughout 2011-2013 reached a daily volume of around $32.7 bn. (on average) what made them the second largest fixed income market in the United States (Friewald et al., 2017). Thus, high interest in structured products highlights their importance to the capital markets and their relevance to the society.

In order to apply the spanning tests, two portfolios were created. The first portfolio is a global minimum variance (GMV) portfolio constructed based on Markowitz efficient portfolio theory, that is diversified among a wide range of asset classes *i.e.*, equity, bonds, alternative investments and commodities (further in the text this portfolio is also referred as a portfolio of benchmark assets). The second portfolio contains the structured products (further in the text also referred as a portfolio of test assets). Continuing in the research part the global minimum variance portfolios of benchmark and test assets are calculated in order to perform the spanning test and to answer the question of whether structured products add diversification benefit to the well-diversified portfolio of risky assets, using Wald, Likelihood Ratio, Lagrange Multiplier and small sample tests in addition to step-down and Wald-GMM procedures. Further, in the thesis, the robust check, controlling for the benchmarks of the structured products will be performed.

For the purpose of spanning tests, three Swiss indices of structured products will be used. Structured product indices are categorized by special features *i.e.*, Participation, Yield Enhancement, and Capital Protection. These three structured vehicles and their investment aspects are discussed in more detail in section 4.1. (Dataset).

Even though there has been researching done on the structured product benefits to the society, see Fusai and Zanotti (2011) or Bikas and Bikas (2016), the approach in this report is different in three aspects. First of all, I use a well-diversified global minimum variance portfolio of risky assets as a benchmark for structured products, whereas the majority of articles use national indices of their equity markets (for example S&P 500). If the benchmark portfolio is proxied to only one asset class *e.g.*, equities (see Edwards and Swidler (2005), Maringer et al., (2015)), the results for spanning test become bias (due to lack of diversification in the benchmark portfolio). Secondly, I use structured product indices in order to represent the structured products as an asset class. Whereas the overwhelming majority of the literature uses only Equity-Linked Notes (ELN) to represent the structured product universe. The use of structured product indices allows me to get a broader view related to structured products as an asset class, instead of structured products as a certain investment product. Thirdly, to the best of my knowledge, there has not been done a spanning test in the academic literature related to the diversification power of structured products in the portfolio management. Note, that there is literature that analyzes one or two aspects of the three aspects mentioned above e.g., Deng *et al.*, (2014) analyzed structured product indices, but they did not consider a well-diversified portfolio of risky assets as a benchmark, Bikas and Bikas

(2016) analyzed the Structured Product indices and used well-diversified portfolio of risky assets as a benchmark, however, they did not use spanning test to answer the question about the diversification benefits. Therefore, to the best of my knowledge none of the literature has analyzed structured products considering all three aspects simultaneously.

The rest of the thesis is organized as follows. In section 2, I review the literature related to the structured products and their benefits to the portfolio management. In section 3, I discuss the methodology used for the spanning test. In section 4, I describe the empirical analysis and in section 5, I provide the conclusions.

## 2. LITERATURE REVIEW

First and foremost, there should be a note, that benefits and drawbacks of structured products that vary depending on the type of the structured product. Therefore, the reader should be cautious in generalizing the conclusions in previous literature findings.

Looking at structured products as a sole investment Deng *et al*., (2014) composed indices of four types of structured products *i.e.*, Reverse Convertibles, Single-observation Reverse Convertibles, Tracking Securities and Autocallable Securities. The authors analyzed the ex-post returns, earned by 20 000 individual US structured products, compared to the alternative allocations to stocks and bonds. They find that investments in a broad equity market portfolio earn a higher return than two-thirds of structured products. Deng *et al*., (2014) also argue that structured products demonstrate a high correlation to the stock indices. Therefore, it is possible to expect that structured products may not add a statically significant value to the efficient mean-variance portfolio, due to a high correlation to the broad stock market and inferior returns.

Henderson & Pearson, (2011) after analyzing more than 60 issues of popular retail structured products highlight that such investment vehicles demonstrate, on average, 8% lower abnormal returns, compared to the stocks and bonds with the same risk level. The authors also note that the returns of structured products positively covary with the broad market indices, which could imply similar problems for portfolio diversification as highlighted by Deng et al., (2014). Some of these aspects might be confirmed by looking at the summary statistics of structured products in section 4.2. of this report. However, Henderson & Pearson, (2011) did not carry any tests related to portfolio management.

Furthermore, there is a considerable amount of literature related to the structured product overpricing *e.g.*, Bernard, Boyle, & Gornall, (2011) find that structured products in their analysis set were initially overpriced by, on average, 6.5%. The overpricing of structured products is a common argument while analyzing these investment vehicles (see Benet, Giannetti and Pissaris (2006), Stoimenov and Wilkens (2005)) and Henderson and Pearson (2011). Therefore, the literature covered so far indicates that structured products might be highly inferior to their benchmarks due to mispricing, lower returns or high correlation to the broad equity market.

Edwards and Swidler (2005) reported, that synthetic Equity Linked Certificates of Deposits (ELCD) for the U.S. market, throughout the period from 1981 to 2004, on average underperformed

S&P 500 Index by 1.218%, whereas Index Powered Certificates of Deposits (IPCD) generated 6.2% lower return compared to U.S. benchmark. However, the standard deviation of both structured products has been smaller compared to S&P 500 by 1.75% and 7.095% respectively. The latter point could indicate that, even though structured products do not outperform the corresponding benchmarks, once included in the portfolio of risky assets they might reduce the overall volatility of such a portfolio. In addition, authors emphasize the fact that ELCDs have a sensitivity to the market index equal to zero in decreasing markets and the beta close to one in the increasing markets, which is expected due to the capital protection features of the ELNs.

The latter results are similar to the results of Maringer et al., (2015), who analyzed Barrier Reverse Convertibles, Bonus Certificates, Capital Protection Certificates with Participation, the Discount Certificates and Tracker Certificates with Swiss stock market as the underlying. Their analysis shows that such products have a low probability of generating a loss in calm market periods. Authors also highlight that the covariance between structured products and Switzerland's stock market exists, especially during the high volatility, turbulent, market periods. However, due to the specific structured product features (payoff structures, capital protection, different maturities), structured products are more likely to have a lower standard deviation and lower negative skewness compared to their benchmarks.

Overall, the literature related to the risk-return profile of structured products provide mixed results. Even though the majority of the authors agree that structured products generate lower returns compared to their benchmarks, there is a disagreement in the risk management front. Whilst some authors (*inter alia* Deng *at all* (2014) and Henderson & Pearson (2011)) found a high correlation to the equity market, others *e.g.,* Edwards and Swidler (2005) and Maringer (2015) find that structured products displayed a lower variance and correlation to the broad equity market.

Looking further into literature, which relates to the structured product benefits to the portfolio management, Fusai and Zanotti, (2011), investigated whether structured bonds can improve the efficient frontier in different initial market environments *e.g.*, interest rate term structure shapes, changes in volatility and correlation structures. Authors conclude that, before fees, the structured products can improve the mean-variance frontier for the retail investor. Whereas after deducting fees, structured debt securities appear to have a positive impact to the risk-return tradeoff only under certain scenarios.

Considering the portfolio optimization, Philip Hansen and Mikael Lärfars (2010) evaluated the performance of Equity-Linked Notes constructed as a long-term buy and hold portfolios. Authors used the model with stochastic volatility, random jumps, and stochastic interest rates to conclude, that structured products add the significant diversification value, once introduced to the traditional portfolio of stocks and bonds.

The literature review shows that once comparing structured products to their benchmark, the structured products most of the time depicts inferior results. This fact might be caused due to initial mispricing of the derivatives or high fees. On the other hand, the literature shows that part of the structured products expresses features, besides return, that might be beneficial to the portfolio construction *e.g.,* lower variance or lower correlation to the benchmarks throughout the decreasing markets.

To conclude, there is a considerable amount of literature related to structured product pricing or their performance compared to their benchmarks. However, structured products have not been analyzed in the environment of portfolio management through the perspective of spanning test, which would answer the question whether structured products add any significant diversification value to the portfolio management. Therefore, these remarks give the motivation to research the effects of structured products in the field of asset management in more detail.

# 3. METHODOLOGY

## *3.1. Mean-Variance Portfolio calculation*

According to modern portfolio theory, which was developed by Harry Markowitz (1952, 1959), portfolio on the efficient frontier cannot experience a reduction in risk, keeping the return constant, due to additional diversification (equivalently, it is not possible to increase the expected return without increasing a risk profile of the portfolio). The efficient frontier (also known as Mean-Variance Frontier) is a set of all portfolios, that is expected to generate the maximum possible return for a given level of risk. The efficient frontier is plotted between expected return and total risk axes. The variance represents the total risk level of the portfolio. Further in the text, the Mean-Variance Frontier of the portfolios is calculated using standard portfolio optimization, for details, see Markowitz (1952), (1929), Cheng, Chung, Ho, & Hsu, (2010).

## *3.2. Mean-Variance Spanning test*

Mean-variance spanning test was first introduced by Huberman and Kandel (1987). The method tests what kind of impact, if any, has an introduction of SP assets (test assets, structured product assets) to the mean-variance frontier of the investment opportunity set of B assets (benchmark assets). Further in the text, the union of the test assets and benchmark assets is referred as SP+B assets (augmented portfolio). In the case of spanning, the efficient frontiers of benchmark and augmented portfolios fully coincide and the difference between the two portfolios is statistically insignificant. In such a case, there is no benefit of adding the structured products to the portfolio of B assets. Therefore, the benchmark assets generate the same risk-return profile as SP+B assets.

For the general spanning tests, the methodology is adopted from the Kan and Zhou (2012) paper on spanning tests. First of all, I denote the monthly returns of B set of assets as $R_{1t}$ and the monthly returns of an SP set of test assets as $R_{2t}$. The returns of the augmented portfolio (SP+B assets) are denoted as $R_t$, and expected returns are denoted as $\mu = E(R_t) \equiv \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix}$. The variance-covariance matrix of augmented portfolio is denoted as $Var[R_t] \equiv \begin{bmatrix} V_{11} & V_{12} \\ V_{21} & V_{22} \end{bmatrix}$ where V is non-singular, $V_{11}$ and $V_{22}$ represents the variance of the structured products and benchmark assets respectively, whereas $V_{12}$ and $V_{21}$ depicts the covariance between structured products and benchmark assets. Secondly, by regressing $R_{2t}$ on $R_{1t}$ I estimate the following model using OLS estimates:

$$R_{2t} = \alpha + \beta R_{1t} + \varepsilon_t, \qquad t = 1, 2, \ldots, T \tag{1}$$

The Equation 1 can be rewritten in matrix notation as $R_{SP}$ = XY + Z, where $R_{SP}$ is the T x SP matrix of the $R_{2t}$, if SP > 1. Whereas if SP = 1, then $R_{2t}$ is a vector of the test assets at time 1, …, T. Also, X is the T x (B + 1) matrix, expressed as:

$$X = \begin{bmatrix} 1 & R_{1t} & \cdots & R_{1B} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & R_{T1} & \cdots & R_{TB} \end{bmatrix}$$

where T is the time vector, the $R_{TB}$ is the return of B set of assets at time T. The unconstrained estimates of Y and $\eta$ are described as

$$\hat{Y} \equiv [\hat{\alpha}, \hat{\beta}]' = (X'X)^{(-1)}(X'R_{SP})$$
$$\hat{\eta} = \frac{1}{T}(R_{SP} - X\hat{Y})'(R_{SP} - X\hat{Y}).$$

Under normal distribution assumption

$$\text{vec}(\hat{Y}') \sim (N(vec(\hat{Y}'), (X'X)^{(-1)} \otimes \eta)$$
$$T\,\hat{\eta} \sim W_n(T - B - 1, \eta),$$

where $W_n$ is the Wishart distribution with $T - B - 1$ degrees of freedom. Based on Huberman and Kandel (2012) $H_0$can be formulated as follows:

$$H_0 = \alpha = 0_{SP}, \; \delta = 1_{SP} - \beta 1_B = 0_{SP} \tag{2}$$

here, $0_{SP}$ and $1_{SP}$ represents the vectors whose elements are all zeroes and ones respectively. If the null hypothesis is rejected then test assets (structured products) do not span the mean-variance frontier of benchmark assets. In other words, in such a case the portfolio with benchmark assets and structured products expand their investment opportunity set. However, if the null hypothesis is not rejected, then the augmented portfolio (portfolio with structured products and benchmark assets) generate the same risk-reward spectrum as the mean-variance frontier of B assets *i.e.*, investors do not benefit from adding structured products to their portfolio.

Considering matrixes, the $H_0$ can be written as $\theta = [\,\alpha, \delta]' = O_{2xSP} = \rho Y - \varphi$, where $\rho = \begin{bmatrix} 1 & 0'_B \\ 0 & -1'_B \end{bmatrix}$ and $\varphi = \begin{bmatrix} 0'_B \\ -1'_B \end{bmatrix}$. For $H_0$ I use the maximum likelihood estimator of $\theta$ *i.e.*, $\hat{\theta} \equiv [\hat{\alpha}, \hat{\beta}]'$ $= \rho\hat{Y} - \varphi$.

Furthermore the $\widehat{\Lambda}$ and $\widehat{\mathrm{M}}$ are defined as

$$\widehat{\Lambda} = T\rho(\mathrm{Y'Y})^{(-1)}\rho' = \begin{bmatrix} 1 + \hat{\mu}_1' \hat{V}_{11}^{-1} \hat{\mu}_1 & \hat{\mu}_1' \hat{V}_{11}^{-1} 1_B \\ \hat{\mu}_1' \hat{V}_{11}^{-1} 1_B & 1_B' \hat{V}_{11}^{-1} 1_B \end{bmatrix}$$

and

$$\widehat{\mathrm{M}} = \hat{\theta}\hat{\eta}^{-1}\hat{\theta}' = \begin{bmatrix} \hat{\alpha}'\hat{\eta}^{-1}\hat{\alpha} & \hat{\alpha}'\hat{\eta}^{-1}\hat{\delta} \\ \hat{\alpha}'\hat{\eta}^{-1}\hat{\delta} & \hat{\delta}'\hat{\eta}^{-1}\hat{\delta} \end{bmatrix}.$$

Once I find the eigenvalues ($\lambda_1$ and $\lambda_2$) of $\widehat{\Lambda}\widehat{\mathrm{M}}^{-1}$ matrix, the Wald (W), Likelihood Ratio (LR) and Lagrange Multiplier (LM) tests and their significance values are calculated based on the following formulas:

$$\mathrm{W} = T(\lambda_1 + \lambda_2) \overset{A}{\sim} \chi^2_{2SP}, \quad (3)$$

$$\mathrm{LR} = T \sum_{i=1}^{2} \ln(1 + \lambda_i) \overset{A}{\sim} \chi^2_{2SP}, \quad (4)$$

$$\mathrm{LM} = T \sum_{i=1}^{2} \frac{\lambda_i}{1+\lambda_i} \overset{A}{\sim} \chi^2_{2SP}, \quad (5)$$

### *3.3. Mean-Variance Spanning test under finite sample*

Furthermore, taking into account that the data set analyzed in this thesis consists of monthly values ranging from 2009 to 2017, one can assume a finite sample, which might not be representative. Therefore, as Jobson et al., (1989) shows the exact distribution of the LR test under $H_0$ for SP > 1 is:

$$\left(\frac{1}{U^{\frac{1}{2}}} - 1\right)\left(\frac{T-B-SP}{SP}\right) \sim F_{2N,2(T-B-SP)} \quad (6)$$

In the instance of SP = 1 the following F test is used:

$$\left(\frac{1}{U} - 1\right)\left(\frac{T-B-1}{2}\right) \sim F_{2,T-B-1} \quad (7)$$

where U = $|\widehat{\Lambda}| / |\widehat{\mathrm{M}} + \widehat{\Lambda}|$. The latter F tests allow us to control for small sample size and get more accurate results. It is worth mentioning that only test based on Equation (7), with an F test for SP = 1 will be used in the thesis since I am analyzing the diversification effect of individual structured product and not the effect of the portfolio of different structured products.

### *3.4. Step-Down application*

By testing portfolios with spanning tests, the joint hypothesis of $\alpha = 0_{SP},\ \delta = 1_{SP} - \beta 1_B = 0_{SP}$ might be inaccurate. The calculations of $\delta$ are done based on the weights of the SP assets in the global minimum variance frontier (GMVF) portfolio of $B + SP$ assets, whereas the asset weights in $\alpha$ calculations are not included. Since the spanning test is a joint test of $\alpha = 0_{SP},\ \delta = 1_{SP} - \beta 1_B = 0_{SP}$ and the weights for the joint tests are based on the statistical accuracy, the slope will always receive a higher weight in the joint test because, $\delta$ is estimated significantly more accurately than $\alpha$. Thus, all of the spanning tests mentioned above puts more weight to the slope parameter. Kan and Zhou (2012) did an experience and reduced the standard deviation of augmented portfolio, compared to the benchmark portfolio by 0.3% which allowed them to reject the null hypothesis (Equation 2) with almost 100% probability once T - K[2] = 120. However, once the authors doubled the slope of the GMV frontier of test assets and kept the variance of the test assets the equal to the variance of benchmark assets, then even though the economical improvement appeared to be substantial (the portfolio of test assets generated two times higher return for one unit of risk, compared to the benchmark portfolio), the null hypothesis (Equation 2) was not rejected. Such inaccuracies might conclude a statistically insignificant effect of structured products, even though the effect might be relevant economically and vice versa.

In order to control for the possible misleading p-values in the spanning tests above, Kan and Zhou (2012) suggests testing spanning in two steps, separating tests for $\alpha$ and $\delta$. In the first step $\alpha = 0_{SP}$ is tested by not including $\delta = 0_{SP}$ in Equation (2). In the second step, the $\delta = 0_{SP}$, is tested conditionally on $\alpha = 0_{SP}$. The significance of step-down tests is measured by F tests proposed by Kan and Zhou (2012)

$$F_1 = \left(\frac{T-B-SP}{SP}\right)\left(\frac{|\bar{\eta}|}{|\hat{\eta}|} - 1\right) = \left(\frac{T-B-SP}{SP}\right)\left(\frac{\hat{\alpha} - \hat{\alpha}_1}{1+\hat{\alpha}_1}\right) \tag{8}$$

where $\hat{\eta}$ and $\bar{\eta}$ are the unconstrained and constrained estimates of $\eta$. The constraint is $\alpha = 0_{SP}$ with N and T – B – SP degrees of freedom. For the second step, the appropriate F – statistics (F2) is calculated as follows

$$F_2 = \left(\frac{T-B-SP+1}{SP}\right)\left(\frac{|\tilde{\eta}|}{|\bar{\eta}|} - 1\right) = \left(\frac{T-B-SP+1}{SP}\right)\left[\left(\frac{\hat{c}+\hat{d}}{\hat{c}_1+\hat{d}_1}\right)\left(\frac{1+\hat{a}_1}{1+\hat{a}}\right) - 1\right] \tag{9}$$

where $\tilde{\eta}$ is the constrained estimate of $\eta$ with joint constraints of $\alpha = 0_{SP}$ and $\delta = 0_{SP}$. $F_2$ has N and T – K – N + 1 degrees of freedom. Step-down test can answer the question what causes to reject the null hypothesis. If $H_0$ is rejected after the first step, it can be concluded that rejection is caused by the statistically different maximal Sharpe ratios of portfolios $B$ and $B + SP$, thus the step one takes into account the $\alpha$ value with a higher degree of accuracy. If $H_0$ is rejected after the

[2] T in the Kan and Zhou (2012) work represents the time vector, and K represents the number of benchmark assets.

second step procedure, it is due to the significant difference of the minimum variance portfolios of $B$ and $B + SP$ *i.e.*, the gap between two global minimum variance portfolios (looking from the perspective of standard deviation) and their slopes are jointly not equal to zero.

### *3.5. Mean-Variance Spanning test assuming not normal distribution*

The spanning tests in the section 3.2. are carried out using the Likelihood Ratio (LR), Wald (W) and Lagrange Multiplier (LM) tests. Berndt and Savin (1977) and Breusch (1979) argue that $W \geq LR \geq LM$. Therefore, the tests in section 3.2. under the asymptotic distribution can provide ambiguous results. There will be a higher probability to reject $H_0$ using Wald test and higher probability of accepting $H_0$ under Lagrange Multiplier test. Furthermore, there are two main limitations of the spanning test in section 3.2. *i.e.*, assumption that returns of B assets and returns of SP assets are normally distributed and the assumption that the error term in Equation (1) is homoscedastic. If error terms exhibit conditional heteroscedasticity, the Wald test is not asymptotically $\chi^2$ distributed under $H_0$, which means that spanning test statistics will provide unreliable results. To correct for these drawbacks the GMM based Wald test will be applied. I am using the methodology for Wald – GMM test proposed by Kan and Zhou (2012).

$$W_a = T \times vec(R'_{SP})'[(A_T \otimes I_N) S_T (A'_T \otimes I_N)]^{-1} vec(R'_{SP}) \overset{A}{\sim} \chi^2_{2SP} \quad (10)$$

where $x_t = [1, R'_{1t}]'$, $\epsilon_t = R_{SPt} - B'x_t$, and the momentum conditions in the GMM application for B are $\mathrm{E}[g_t] = E[x_t \otimes \epsilon_t] = 0_{(B+1)SP}$, $S_T = E[g'_t, g_t]$ and $A_T = \begin{bmatrix} 1 + \hat{a}_1 & -\hat{\mu}'_1 \hat{V}_{11}^{-1} \\ \hat{b}_1 & -1'_B \hat{V}_{11}^{-1} \end{bmatrix}$

## *4. Empirical analysis*

The empirical analysis section is structured as follows; the first sub-section describes the dataset that was used for the spanning tests. The second sub-section provides the summary statistics for individual structured products. The third sub-section interprets results from the spanning tests. The last sub-section explains the robust test that was applied.

### *4.1. Dataset*

The dataset used for spanning test calculations consists of three structured product indices (test assets), nine ETFs that represent different asset classes (benchmark assets) and three structured product benchmarks that were used in section 4.4. to perform the robust check.

Benchmark assets are composed of large and mid-capitalization segments of the United States market (MSCI US), large and mid-capitalization companies from fifteen developed markets in Europe (MSCI Europe), large and mid-capitalization companies across developed and emerging markets in Asia (MSCI Pacific) and 830 large and mid-capitalization companies across a wide range of emerging markets (MSCI Emerging Markets). Moreover, the debt instruments are divided into high yield (HYG US) and investment grade (LQD US) investment universes, where both bond ETFs represent debt issued by US companies. The alternative investment segment is represented by US real estate sector (VNQ US). In addition, 20 types of commodities are represented by Bloomberg Commodities Index (BCOM US)[3]. Even though gold is included in BCOM US exchange traded fund, I believe that it is important to stress the importance of gold as a separate asset class, due to exceptionally different correlation with other asset classes. Therefore, gold is represented separately in the thesis. Furthermore, it is important to mention that all of the benchmark assets are represented in United States dollars (USD), whereas tests assets do not have a currency *i.e.*, indices of structured products were based at 1000 at February 27th, 2009 and from that date onwards they represent the weighted changes of the products within them.

The test assets in the thesis are represented by "Participation", "Yield Enhancement" and "Capital Protection" indices of structured products. An important note is that latter indices are designed to provide investors a representative benchmark and not the investment product itself. The base universe of the structured products is considered to be all of the products in the Swiss Structured Product Association (SSPA) that are traded on the SIX Structured Product Exchange. Each index is allowed to have a maximum of 10 and a minimum of 5 products, that are weighted equally. However, all of the indices must contain only one product at the time of inclusion to SSPA category *i.e.*, if a certain product is included in the Participation structured product it cannot be included in the Capital Protection structured product.

Indices of structured securities are calculated as follows:

$$I_t = I_{t-1} + I_{t-1} \sum_{i=1}^{N} \left[ \left( \frac{P_{i,s} + a_{i,t} C_i}{P_{i,t-1} + a_{i,t-1} C_i} - 1 \right) / N \right] \tag{11}$$

where $I_t$ and $I_{t-1}$ represents the current index level at $t$, and $t-1$ respectively, $P_{i,t}$ and $P_{i,t-1}$ is a last mid-price of a security *i* at time $t$, and $t-1$ respectively. The $a_{i,t}$ and $a_{i,t-1}$ in Equation (11) is a current fraction of an interest period at time $t$ and $t-1$. $C_i$ is a payoff of security *i* per annum, in percentage form, N represents the number of securities in the index (SIX Swiss Exchange, 2013).

Each of the structured product considered throughout the analysis has specific features and represents investment securities that are created to fulfill different investors' requirements.

The Participation index (SSPP) consists of different investment vehicles that track the underlying price one to one. SSPP allows the investor to invest in exotic markets (by doing so broadening the diversification effect) that may not be available in other exchanges and allows the same rate of participation for a lower amount of funds compared to the direct investments. Without these products, the investor would not have access to exotic markets at all or would be required to pay a higher price for such an exposure. Moreover, certificates in the Participation index can offer

[3] The main sector weights for BCOM are as follows: Energy – 29.14%, Agriculture – 29.62%, Industrial Metals – 18.49%, Precious Metals and Livestock represents 16.48% and 6.27% of the index respectively (Bloomberg, 2017).

leveraged positions *i.e.*, certificates can allow the investor to participate in the underlying changes one to one until the certain threshold is hit (predetermined strike price) however, after such strike price is broken, investor can be exposed to the higher participation rate to the underlying *e.g.*, 120%, 150% etc. In addition, Participation index contains certificates that provide the investors with profit distribution expressed as coupons. Products that are considered for the inclusion in Participation index are Tracker Certificates, Outperformance Certificates, Bonus Certificates, Bonus Outperformance Certificates and Twin-win Certificates. The Participation Index is rebalanced each month to keep the equal weighting and is benchmarked to Swiss Market Index (SMI).

The Capital Protection index (SSPC) contains certificates and convertibles that give investors a specified insurance on their invested capital. The certificates and convertibles in the SSPC index differ from each other by three[4] aspects: upside limitation, participation rate, and profit distribution. While Capital Protection with Participation (CPWPs) and Exchangeable Certificates (ECs) have no limitations on the upside, the Capital Protection with Coupon (CPCs) and Capital Protection with Knock-out (CPKOs) certificates have limited upside (either by coupons or by the predetermined cap). The participation rate among the certificates also differ *i.e.*, CPWPs have lower than 100% participation rate, ECs have 100% participation rate, CPCs have mixture of participation rates *e.g.*, 100% participation from the strike price 1 to pre-specified strike price 2 and participation rate of 0% from strike price 2 onwards (during the period when underlying price is above strike price 2, the investor receives fixed cash flow payments). Capital Protection index is rebalanced every two months and the benchmark index for SSPC is considered to be the total return index of the Swiss bond market (SZGATR)[5].

Yield Enhancement index (SSPY) contains Discount Certificates (DCs), Barrier Discount Certificates (BDCs), Barrier Reverse Convertibles (BRCs) and Express Certificates (ECs). All of the Yield Enhancement products in the index have a limited upside (or limited outperformance compared to the underlying). Due to the features of Discount Certificates, the investor has a partial capital protection as long as the underlying does not fall as much as the surplus that was created by the discount *i.e.*, does not wear down the benefit created by the discount. The profit distribution among the certificates also differ *i.e.*, the investor either receives shares of the underlying or coupons with the final value at the maturity. SSPY is rebalanced every two months and is benchmarked to the synthetic index consisting of 40% of the Swiss market bond index (SBI) and 60% of the Swiss Market Index (SMI).

For all of the calculations regarding the spanning tests and descriptive statistics the monthly data ranging from February 27$^{th,}$ 2009 to April 5$^{th,}$ 2017 is used.

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[4] There is a fourth aspect as well *i.e.*, capital protection (the degree of insurance) and it also differs within the SSPC index however, the protection level is determined by the issuers among many different certificate classes.

[5] Due to the limited information accessibility, SZGATR index in this thesis will be changed to the SBI index which tracks the performance of CHF denominated bonds that are traded on the SIX Swiss Exchange and that have a rating higher or equal to “BBB”. From the return and volatility perspective SBI index is very similar to the SZGATR index. Consequently, the benchmark for SSPY is also substituted to 60% SMI and 40% SBI instead of 60% SMI and 40% SZGATR.

### *4.2. Summary statistics*

In this sub-section, the main statistical features of structured products will be discussed. The summary statistics described further in the text allow to evaluate structured products from the perspective of a singular investment opportunity and compare them to the benchmarks based on the risk-reward criteria.

Table 1. shows that all structured products and their benchmarks demonstrate negatively skewed distributions. This fact indicates that the investment vehicles under the investigation have longer left tails compared to the normal distribution. However, it is worth noting that whilst Participation and Capital Protection structured products have lower negative skewness compared to their benchmarks, Yield Enhancement structured product demonstrate a higher risk compared to its' benchmark. One of the reasons for such a high difference between SSPY and its' benchmark might be the use of leverage. Moreover, the higher potential risk level for SSPY is also confirmed by the leptokurtic Kurtosis, which indicates that large fluctuations have a higher probability of occurring, whilst the majority of data is clustered around the mean.

**Table 1.**
Summary statistics

| Benchmark assets / Structured products | Mean return (per annum, %) | Min return (per month, %) | Max return (per month, %) | Volatility (per annum, %) | Skew-ness | Excess kurtosis | % of pos. returns | % of neg. returns | Sharpe ratio |
|---|---|---|---|---|---|---|---|---|---|
| MSCI US | 15.25% | -9.89% | 10.10% | 13.22% | -0.51 | 0.70 | 67% | 33% | 1.15 |
| VNQ | 20.90% | -9.54% | 31.39% | 19.32% | 1.30 | 7.00 | 65% | 35% | 1.08 |
| MSCI Europe | 8.45% | -14.68% | 12.51% | 17.74% | -0.27 | 0.54 | 56% | 44% | 0.48 |
| MSCI Pacific | 8.37% | -11.21% | 11.03% | 14.32% | -0.47 | 0.97 | 56% | 44% | 0.58 |
| MSCI Emerging markets | 9.55% | -17.46% | 20.73% | 21.65% | 0.22 | 1.09 | 52% | 48% | 0.44 |
| Commodities | -4.14% | -15.41% | 21.50% | 20.57% | -0.05 | 1.56 | 51% | 49% | -0.20 |
| Gold | 4.35% | -11.22% | 14.43% | 18.39% | 0.25 | -0.13 | 50% | 50% | 0.24 |
| HYG | 3.44% | -6.52% | 13.67% | 9.19% | 1.13 | 6.19 | 58% | 42% | 0.37 |
| LQD | 2.70% | -3.85% | 4.77% | 5.85% | -0.01 | 0.38 | 56% | 44% | 0.46 |
| SSPC | 3.54% | -5.37% | 4.79% | 5.53% | -0.08 | 2.14 | 60% | 40% | 0.64 |
| SSPP | 9.64% | -5.93% | 7.34% | 8.91% | -0.14 | 0.42 | 65% | 35% | 1.08 |
| SSPY | 4.51% | -5.19% | 4.49% | 4.46% | -1.16 | 6.02 | 72% | 28% | 1.01 |
| SMI | 8.19% | -8.56% | 8.76% | 11.58% | -0.24 | 0.38 | 64% | 36% | 0.71 |
| SBI | 3.34% | -1.83% | 2.35% | 2.63% | -0.22 | 0.58 | 69% | 31% | 1.27 |
| SBI (40%) SMI (60%) | 6.25% | -5.13% | 6.18% | 7.06% | -0.12 | 0.22 | 64% | 36% | 0.89 |

*The table represents the summary statistics for benchmarks and structured products, respectively: Annualized mean, Minimum return, Maximum return, Annualized volatility, Skewness, Excess Kurtosis, % of positive returns, % of negative returns and Sharpe ratio based on monthly returns from February 27th, 2009 to April 5th, 2017.*

Conversely SSPC and SSPP have a lower probability of experiencing extreme returns and both structured products display returns less clustered around the mean, compared to the normal distribution, due to platykurtic Kurtosis.

Furthermore, looking at risk-return characteristics in Table 1, Participation and Yield Enhancement products demonstrate superior results compared to their benchmarks, depicted by higher Sharpe ratios that are mainly generated due to lower variance and not due to higher returns. Nevertheless, Capital Protection structured product is inferior to its benchmark due to higher experienced volatility.

Table 2A in the Appendix represents the correlation analysis of the structured products, benchmark assets and the benchmarks of the structured products[6]. It is important to note that S&P 500 Index has a correlation below 71% with SSPP and SSPY indices, whilst Capital Protection structured product (SSPC) has a correlation with SPX below 50%. Bonds with structured products also have a low relationship *i.e.*, structured product correlation with high yield bonds is around 50%, whereas the correlation between structured securities and investment grade bonds fluctuates around 15%. Moreover, alternative assets and structured products appear to have a low relationship due to correlation below 50%. It is important to note that when SSPP and SSPY depict a strong relationship to their benchmarks *i.e.*, correlation of 96% and 74% respectively, the SSPC has no relationship to its benchmark at all *i.e.*, correlation of 0%. Therefore, the latter results from the correlation matrix allow to anticipate the significant diversification value added from the structured products, due to, potentially, reduced idiosyncratic level of risk of the augmented portfolio.

Nevertheless, it is also important to analyze the highest potential losses of structured products compared to the benchmarks and other risky assets. Table 2, depicts the value at risk measures $(VaR)$ along with conditional value at risk measures $(CVaR)$. As was discussed above, in section 4.2., structured products do not have a perfectly normal distribution, therefore $(VaR)$ estimates are divided into the $(VaR)$ estimate assuming a normal distribution $(VaR\ (N.D.))$ and $(VaR)$ based on the historical data $(VaR\ (H))$.

Table 2. shows that almost all VaR estimates (except SSPC (95)) are higher for historical estimates, what is expected because all of the structured products display negatively skewed distributions. Capital protection structured product suggests that investor could not lose more than 2.2% of its' value per month, with 95% confidence level, whilst value at risk after investing in SSPC benchmark is two times lower *i.e.*, 1.2%. The Participation and Yield Enhancement products, however, indicate a smaller risk concentrated in the left tails, compared to their benchmarks. Nonetheless, all three structured products offer a lower value at risk at 95% confidence interval compared to other global equities, real estate, commodities or gold.

Notwithstanding, $(VaR)$ estimates might be misleading if the losses at the end of the left tail occur more frequently than projected by a normal distribution. Therefore, conditional value at

[6] Note that correlation analysis includes S&P 500 index (SPX), which is not included in the efficient portfolio of risky assets (benchmark assets) analysis or calculation. The SPX index in Table 2A is included for the correlation analysis purpose only as a well-known benchmark index.

risk estimates are calculated $(CVaR)$. However, $(CVaR\,(95))$ results demonstrate a similar structured product risk level to the one depicted by $(VaR)$ estimates, with the exception of Yield Enhancement structured product (SSPY). The latter investment vehicle seems to possess the same risk level as its benchmark looking through the expected shortfall perspective however, historical $(VaR\,(95))$ estimate imply that investor throughout the period of one month might lose almost two times less, after investing in Yield Enhancement product compared to its benchmark, with 95% confidence level.

**Table 2.**[7]

Risk measures

| | VaR (99) (N.D.) | VaR (99) (H) | VaR (95) (N.D.) | VaR (95) (H) | CVaR (99) (H) | CVaR (95) (H) |
|---|---|---|---|---|---|---|
| MSCI US | -7.6% | -9.9% | -5.0% | -6.4% | -9.9% | -8.2% |
| VNQ | -11.2% | -9.5% | -7.4% | -7.0% | -9.5% | -7.9% |
| MSCI Europe | -11.2% | -14.7% | -7.7% | -9.6% | -14.7% | -11.7% |
| MSCI Pacific | -8.9% | -11.2% | -6.1% | -7.6% | -11.2% | -9.5% |
| MSCI Emerging markets | -13.7% | -17.5% | -9.5% | -9.9% | -17.5% | -12.7% |
| Commodities | -14.2% | -15.4% | -10.1% | -11.8% | -15.4% | -13.8% |
| Gold | -12.0% | -11.2% | -8.4% | -8.9% | -11.2% | -9.9% |
| HYG | -5.9% | -6.5% | -4.1% | -4.0% | -6.5% | -5.0% |
| LQD | -3.7% | -3.9% | -2.6% | -2.5% | -3.9% | -3.4% |
| SSPC | -3.4% | -5.4% | -2.3% | -2.2% | -5.4% | -3.4% |
| SSPP | -5.2% | -5.9% | -3.4% | -4.3% | -5.9% | -4.9% |
| SSPY | -2.6% | -5.2% | -1.7% | -1.5% | -5.2% | -3.4% |
| SMI | -7.1% | -8.6% | -4.8% | -5.3% | -8.6% | -6.7% |
| SBI | -1.5% | -1.8% | -1.0% | -1.2% | -1.8% | -1.5% |
| SBI (40%) SMI (60%) | -4.2% | -5.1% | -2.8% | -3.1% | -5.1% | -3.7% |

*The table represents the Value at Risk (VaR) and Conditional Value at Risk (CVaR) statistics for benchmarks and structured products, namely: Value at Risk at 99% confidence level (VaR 99), Value at Risk at 95% confidence level (VaR 95), Conditional Value at Risk at 99% confidence level (CVaR 99) and Conditional Value at Risk at 95% (CVaR 95) based on monthly returns from February 27th, 2009 to April 5th, 2017. The abbreviations of N.D. and H means assuming a normal and historical distribution respectively.*

Overall summary statistics suggest that all of the structured products are negatively skewed and demonstrate returns more dispersed around the mean with less frequent outliers, with the exception of Yield Enhancement structured product, which has a highly negatively skewed distribution with higher probability of extreme values compared to a normal distribution. Both,

[7] Note that VaR (99) and CVaR (99) coefficients are calculated based on only one value since there are 98 months in the sample. Therefore, one must be cautious in interpreting the data.

Yield Enhancement and Participation structured securities achieved higher Sharpe ratios compared to their benchmarks, whilst Capital Protection structured product, due to high volatility, generated inferior risk-return ratio, compared to its benchmark. Nevertheless, even though SSPC demonstrates the lowest return for one unit of risk among all structured products, it also has no correlation to its benchmark. That can imply a high portfolio diversification benefit. Furthermore, both, SSPY and SSPP have a correlation above 70% to their benchmarks and lower than 70% correlation to other asset classes. Looking at the maximum amount and the average amount that could be lost with 95% confidence level, structured products appear to be superior compared to the investments in equity, alternative assets, commodities, and gold. However, latter results became mixed after comparing structured products to their benchmarks.

### *4.3. Mean-Variance Spanning analysis*

Mean-variance portfolio analysis is carried out as described in section 3. Table 3 shows the results for Wald (W), Likelihood Ratio (LR), Lagrange Multiplier (LM), Step –Down (F1 and F2) and Wald – GMM tests with the corresponding p-values over the period of 8 years, from February 27$^{th}$, 2009 to April 5$^{th}$, 2017. The p-value represents the power of the added value of the respective structured product *i.e.*, lower p-value indicates a higher positive value added (either reduced idiosyncratic risk, enhanced return or both) to the mean-variance frontier of the benchmark portfolio.

As can be seen from Table 3, the $H_0$ of spanning is rejected for all three structured products, looking at three spanning test statistics proposed by Huberman and Kandel (1987) *i.e.*, W, LR, LM. Thus, it is correct to conclude that added value of structured products to the well diversified portfolio of risky assets is statistically significant. Therefore, investors would either increase the return, reduce the volatility for their portfolios or achieve both simultaneously by adding structured product indices. Furthermore, note that results in Table 3 are consistent with Berndt and Savin (1977) and Breusch (1979) findings that $W \geq LR \geq LM$. In addition, after controlling for sample size (see F test in Table 3) the conclusions remain consistent with the results, from previous three tests *i.e.*, all structured products considered in the analysis add statistically significant diversification value to the benchmark portfolio.

Findings after conducting the Step-Down procedure can help to disentangle the diversification effect reported by W, LM, LR and F tests. The F1 test for all of the structured products suggest that alpha value (see Equation 1) between portfolios $B$ and $B + SP$ is statistically not different *i.e.*, maximal Sharpe ratios between the two portfolios are statistically not different, therefore we cannot reject the null hypothesis that $\alpha = 0_{SP}$ in the Equation 2. In addition, looking at the F2 test, it is clear, that global minimum variance (GMV) portfolios of $B$ and $B + SP$ are statistically different. Thus, their slopes and intersects jointly are not equal to zero (it can also be seen from the graphical representation in Graph 1A. in the Appendix).

Furthermore, results after controlling for non-normal distribution (see Wald – GMM test) indicate that all structured products have a statistically significant effect to the mean-variance frontier of the benchmark portfolio.

**Table 3.**

Spanning test results for structured products

| | W | LR | LM | F | F1 | F2 | Wald - GMM |
|---|---|---|---|---|---|---|---|
| SSPC | 60.07 | 46.85 | 37.24 | 26.97 | 0.05 | 54.48 | 58.56 |
| p-value | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.8290 | 0.0000 | 0.0000 |
| SSPP | 12.80 | 12.03 | 11.32 | 5.75 | 1.28 | 10.18 | 10.82 |
| p-value | 0.0045 | 0.0045 | 0.0045 | 0.0000 | 0.2618 | 0.0020 | 0.0045 |
| SSPY | 171.16 | 99.01 | 62.32 | 76.85 | 1.87 | 150.35 | 150.06 |
| p-value | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1750 | 0.0000 | 0.0000 |

*The table presents the spanning test statistics and corresponding p-values below the test statistics for the null hypothesis that structured products span a portfolio of well diversified risky assets during the period from February 27th, 2009 to April 5th, 2017. The W, LR and LM tests report results for Wald, Likelihood Ratio and Lagrange Multiplier tests respectively. F test (F) represents the results under the assumption of the finite sample. F1 and F2 statistics represent results for the Step-Down procedure and Wald-GMM test depicts the results after controlling for non-normal distribution.*

### 4.4. Robust checks

The results of mean-variance spanning tests in section 4.3 might be caused due to the reasons of geography or asset class that structured products represent, and not due to the features of structured products themselves. For example, there might be a case that the diversification effect of SSPP is, actually, the effect of the Swiss Market Index (which is the benchmark for SSPP) and not the effect of SSPP itself. Due to this reason, I apply the spanning tests for structured products and the benchmark portfolio, which includes the benchmarks of structured products described in section 4.1. Dataset.

After controlling for the benchmarks of the structured products, Table 4. suggests that the W, LR, LM and F-test values of SSPC and SSPY products are smaller compared to the ones in Table 3. Nevertheless, all of the latter tests remain significant. Note that participation structured product (SSPP) displays higher test values. Therefore, we can conclude that after including the benchmarks of the structured products into the well-diversified portfolio of risky assets, SSPC and SSPY add a lower diversification value to such portfolio however, it is still significant. On the other hand, after including the benchmarks of structured securities to the B assets, Participation structured product slightly increased the diversification benefits to the portfolio in question.

After including the structured product benchmarks to the benchmark assets, the $\alpha$ values of the two tangency portfolios became more important and significant for the Participation (SSPP) and Yield Enhancement (SSPY) structured products (see F1 test). From the Table 4, F1 test suggests that maximal Sharpe ratios of the two tangency portfolios of B assets (with structured product benchmarks) and SP assets are statistically different, however the maximal Sharpe ratio of SSPC remains significantly not different from the B asset portfolio with structured product benchmarks. The results from F2 test remains the same as in section 4.3. *i.e.,* the standard deviation and intersects between a GMV portfolio of B (including benchmarks of structured products) and SP assets are jointly significant.

**Table 4.**[8]
Spanning test results with benchmarks of structured products included in the benchmark asset portfolio

| | W | LR | LM | F | F1 | F2 |
|---|---|---|---|---|---|---|
| SSPC | 24.99 | 22.26 | 19.91 | 10.84 | 1.48 | 23.50 |
| p-value | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.2272 | 0.0000 |
| SSPP | 25.20 | 22.43 | 20.05 | 10.93 | 18.24 | 7.09 |
| p-value | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0093 |
| SSPY | 58.67 | 45.98 | 36.70 | 25.44 | 7.02 | 42.35 |
| p-value | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0096 | 0.0000 |

*The table presents the spanning test statistics and corresponding p-values below the test statistics for the null hypothesis that structured products span a portfolio of well diversified risky assets, that include the benchmarks of structured products during the period from February 27th, 2009 to April 5th, 2017. The W, LR and LM tests report results for Wald, Likelihood Ratio and Lagrange Multiplier tests respectively. F test (F) represents the results under the assumption of the finite sample. F1 and F2 statistics represent results for the Step-Down procedure and Wald-GMM test depicts the results after controlling for non-normal distribution.*

## 5. Conclusions

This thesis analyzed whether structured products add any diversification value to the well-diversified portfolio of risky assets. There has been investigated the effects of three structured products that differ in their risk level and return characteristics. Results suggest that all of the structured products considered in this thesis add the diversification benefit to the portfolio of well-diversified, risky assets in general conditions *i.e.,* considering Wald, Likelihood Ratio, Lagrange Multiplier tests. The diversification effect remains significant to all structured products once controlled for small sample size and non-normal distribution as well. However, the F1 test

[8] Wald-GMM test in robust check computations was not included due to the mathematical issues regard the matrix sizes and possibly inaccurate abbreviations by mathematical programs that were used.

indicates that maximal Sharpe ratios between benchmark portfolio and augmented portfolios are not statistically different.

Furthermore, after performing the robust check and controlling for the benchmarks of structured products the general conclusions remain the same *i.e.,* structured products add significant diversification benefits to the portfolio of risky assets, that includes the benchmarks of structured products. Conversely, the significant difference appears in the F1 test for Participation and Yield Enhancement structured products. After controlling for their benchmarks SSPP and SSPY have a statistically different maximal Sharpe ratios compared to the benchmark assets.

It is difficult to compare the results in the thesis to the broader literature available because there has not been a clear consensus about the benefits of structured products to the portfolio management.

Moreover, it is important to stress out the limitations of the results in the Sections 4.3. and 4.4. First of all, the structured product indices analyzed in this thesis are not available for the retail investor *i.e.*, structured product indices considered in the thesis perform only representative functions. Second of all, in this thesis, the fee effect of structured products is not considered which might have a significant effect on the conclusions in sections 4.3. and 4.4. as found by Fusai and Zanotti, (2011). Furthermore, the thesis does not control for short sale constraints, even though investor cannot sell short the structured securities or the products that are the composite parts of the structured product indices. Finally, the summary statistics in Section 4.2. and spanning tests in Section 4.3. and 4.4. are performed based on only 98-month period which might not be substantially representative.

# Appendix

**Table 1A**

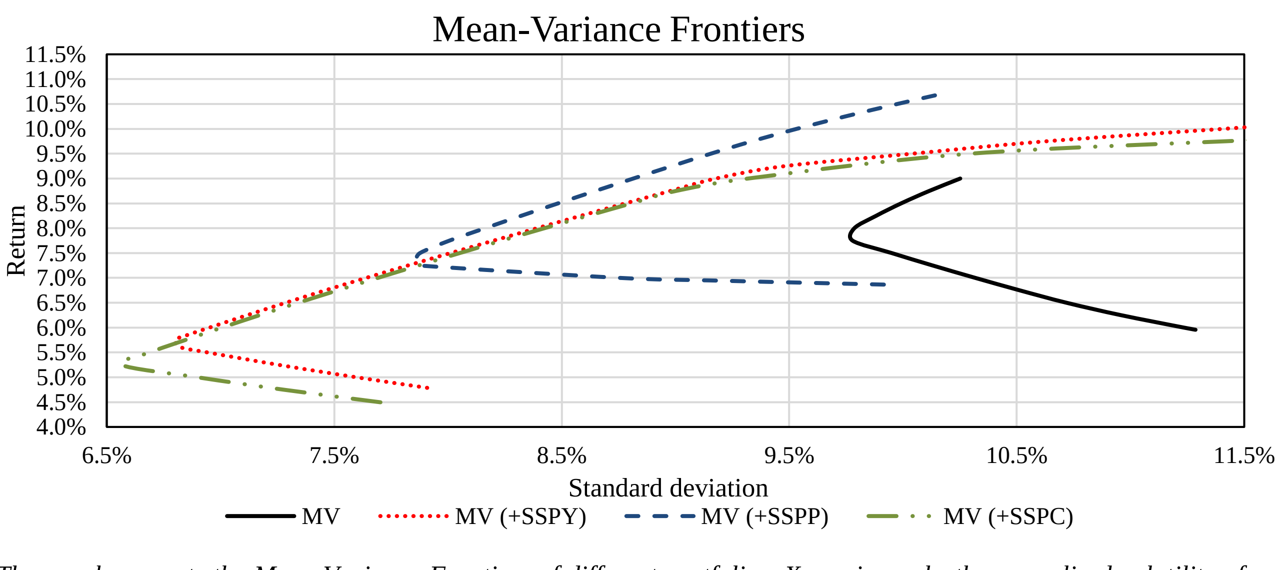
Historical correlation trend between asset classes

| | | *MSCI US* | *MSCI Europe* | *MSCI Pacific* | *MSCI Emerging market* | *HYG* | *LQD* | *VNQ* | *Commodities* | *Gold* |
|---|---|---|---|---|---|---|---|---|---|---|
| 2016-2017 | SPX | 98% | 62% | 11% | 74% | 71% | -3% | 48% | 33% | -27% |
| 2015-2016 | SPX | 98% | 56% | 16% | 80% | 65% | -12% | 71% | 42% | -15% |
| 2014-2015 | SPX | 96% | 58% | 4% | 71% | 58% | 16% | 66% | 33% | 11% |
| 2013-2014 | SPX | 96% | 58% | 4% | 71% | 58% | 16% | 66% | 33% | 11% |

*The table presents the correlation between different investment products and S&P 500 index (SPX). Different investment products are meant to represent different asset classes in order to show the convergence of correlation throughout the 4 years from 2013 to 2017. MSCI US represents the broad US equity market, MSCI Europe represents the broad Europe's equity market, MSCI Pacific represents the broad Asian Pacific equity market, MSCI Emerging market exchange traded product represents the large and mid-capitalization companies of emerging countries, HYG represents the high yield bonds in the US market, LQD represents the investment grade bonds in US market, VNQ represents the real estate market in the United States, Commodities ETF represents asset class which is diversified among the wide range of different commodities including (wheat, WTI and Brent oil, gold etc.) Gold tracks the price of gold.*

**Graph 1A.**

Geometrical representation of Mean-Variance Frontiers.




*The graph presents the Mean-Variance Frontiers of different portfolios. X – axis marks the annualized volatility of the portfolio and the Y – axis marks the annualized expected returns. MV represents the mean-variance frontier of the benchmark portfolio, MV (+SSPY) represents the mean-variance frontier of the benchmark portfolio with included SSPY structured product, MV (+SSPP) represents the mean-variance frontier of the benchmark portfolio with included SSPP structured product, MV (+SSPC) represents the benchmark portfolio with included SSPC structured product.*

**Table 2A.**

Correlation analysis of Structured Products

| | MSCI US | VNQ | MSCI Europe | MSCI Pacific | MSCI Emerging markets | Commo dities | Gold | HYG | LQD | SSPC | SSPP | SSPY | SMI | SBI | SBI (40%) SMI (60%) | SPX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSCI US | 100% | | | | | | | | | | | | | | | |
| VNQ | 64% | 100% | | | | | | | | | | | | | | |
| MSCI Europe | 85% | 59% | 100% | | | | | | | | | | | | | |
| MSCI Pacific | 73% | 54% | 81% | 100% | | | | | | | | | | | | |
| MSCI Emerging markets | 79% | 56% | 80% | 73% | 100% | | | | | | | | | | | |
| Commodities | 54% | 19% | 60% | 52% | 56% | 100% | | | | | | | | | | |
| Gold | 2% | 8% | 11% | 9% | 25% | 30% | 100% | | | | | | | | | |
| HYG | 66% | 71% | 69% | 63% | 62% | 51% | 10% | 100% | | | | | | | | |
| LQD | 14% | 47% | 26% | 29% | 31% | 10% | 29% | 49% | 100 % | | | | | | | |
| SSPC | 49% | 27% | 45% | 38% | 19% | 14% | -21% | 29% | 2% | 100% | | | | | | |
| SSPP | 69% | 46% | 66% | 55% | 44% | 28% | -21% | 48% | 13% | 83% | 100% | | | | | |
| SSPY | 71% | 55% | 70% | 60% | 59% | 30% | -16% | 55% | 15% | 57% | 78% | 100% | | | | |
| SMI | 68% | 42% | 63% | 54% | 40% | 29% | -19% | 45% | 12% | 83% | 96% | 76% | 100% | | | |
| SBI | -16% | 23% | -13% | -10% | -4% | -26% | 28% | 14% | 64% | 0% | -1% | -6% | 3% | 100% | | |
| SBI (40%) SMI (60%) | 64% | 45% | 60% | 52% | 39% | 25% | -15% | 46% | 21% | 82% | 94% | 74% | 99% | 18% | 100% | |
| SPX | 98% | 61% | 84% | 72% | 81% | 54% | 3% | 63% | 13% | 45% | 67% | 71% | 65% | -15% | 62% | 100% |

*The table presents the correlation matrix between benchmarks and structured products based on monthly returns from February 27th, 2009 to April 5th, 2017*

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