LUND UNIVERSITY
School of Economics and Management

Risk-Based Portfolio Allocation Strategies with a Focus on Sustainable Stocks in Sweden

Master Thesis

by

Frieda-Lotti Pauline Meyer

María del Pilar Muñoz Ruiz

May 2018

Master's Programme in Finance

Supervisor: Thomas Fischer

Declaration of Authorship

We, Frieda-Lotti Pauline Meyer and María del Pilar Muñoz Ruiz, declare that this thesis, titled "Risk-Based Portfolio Allocation Strategies with a Focus on Sustainable Stocks in Sweden" and the work presented in it are our own. We confirm that:

- This work was completed while studying for a Master's degree at this University.
- We have acknowledged all main sources of help.

Date: Lund, May 28th 2018

Signed:

____________________________ ____________________________

Frieda-Lotti Pauline Meyer María del Pilar Muñoz Ruiz

Abstract

This paper aims at analyzing the performance of six portfolio weight allocation strategies. The traditional Market Capitalization (CW), the Equal Weight (EW) and the Inverse Volatility Weighting (IVW) are heuristic based techniques and the Minimum Variance (MV), Maximum Diversification (MD) and Risk Efficient Weighting (REW) are risk-based. They are applied to a sample of Swedish stocks for an evaluation period ranging from 2004 to 2016. In addition, the same strategies are analyzed when applied to a subsample of sustainable firms.

The Market Capitalization performs the worst. When applied to a broad universe, the risk-based strategies outperform the heuristic based. For the sustainable universe, the heuristic techniques deliver superior performance than the risk-based. From the risk-based strategies, the Maximum Diversification benefits from its application to the sustainable universe. The Equal Weight strategy experiences the largest performance improvement.

Keywords: Risk Adjusted Performance, Risk-Based Portfolio Allocation Strategies, Sustainable Stocks, Variance Covariance Matrix

Acknowledgements

We would like to thank our supervisor Thomas Fischer for his valuable advice and encouragement throughout the research and writing process.

We would also like to give special recognition to Jens Forssbaeck for the coordination and organization of the course's Master Thesis.

Further, we express our gratitude to Hossein Asgharian for his guidance and support throughout the entire year.

A special thanks to our families and friends for their motivation and unconditional support.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

CW - Cap Weight (Market Capitalization)

EW - Equal Weight

IVW - Inverse Volatility Weighting

MD - Maximum Diversification

MV - Minimum Variance

REW - Risk Efficient Weighting

VCV- Variance Covariance Matrix

1 Introduction

Ever since the birth of the stock exchange, the primary objective of investors has been maximizing the returns stemming from their funds. Thereby, the construction of an optimal portfolio is one of their major concerns, so it is essential to employ a holistic strategy that maximizes returns. The Market Capitalization strategy has widely been the most popular asset weight allocation technique. However, risk is not considered by this strategy, which has lately made it unattractive to some investors. Thereby, the so-called risk-based portfolio allocation methods have gained popularity, which aim to improve investors' financial performance while minimizing the risks associated with the portfolio. Markowitz (1952) is considered the pioneer in incorporating the concept of risk with the introduction of the mean-variance theory into the weight allocation decision.

Moreover, this paper incorporates the concept of sustainability to the portfolio construction theory. It is worth mentioning that the term sustainability does not refer solely to environmental aspects, but also incorporates the social dimension. In parallel to the observed increase in society's awareness about topics such as health, ethics or the environment, investors' concern has shifted towards aligning the evolving ethical standards with their main interest, which is still maximizing financial returns. Thereby, the concept of sustainable investment arises, which consists on the construction of sustainable portfolios based on non-financial criteria. Instead of using a financial strategy, the criteria are rather based on ethical considerations, i.e. investing in firms that are environmentally responsible, or whose labor practices are considered as equally inclusive.

By combining the two concepts mentioned above, this paper aims at analyzing the performance of weight allocation strategies when they are applied to a portfolio consisting of sustainable stocks. These strategies are divided into heuristic and risk-based. The Market Capitalization technique belongs to the first group, together with the Equal Weight and the Inverse Volatility Weighting. The risk-based techniques are the Minimum Variance, Maximum Diversification and Risk Efficient Weighting. As opposed to the heuristic based ones, these techniques require the estimation of the Variance Covariance (VCV) matrix and the weights are calculated based on a minimization or a maximization problem. Therefore, throughout this paper, the risk-based strategies are sometimes also referred to as optimization based.

Existing literature assesses the performance of the strategies when they are applied to a broad index (Finnerman and Kirchmann, 2015; Knutzen and Retterholt, 2015). Nevertheless, there are few studies that analyze how they behave when applied to sustainable stocks exclusively. Hence, our study investigates this topic by analyzing how the performance of the strategies changes when they are applied to a portfolio of Swedish sustainable firms.

The remainder of this paper is structured as follows: The next section provides an overview of the existing literature in relation to this topic. Section 3 develops the research question that is addressed. Section 4 describes the methodology used for the construction of the portfolios. Section 5 and 6 provide an analysis of the main results derived from the application of the different performance measures, followed by a robustness check of the results in Section 7. Section 8 consists of a summary of the limitations of this study as well as suggestions for further research. Finally, Section 9 concludes.

2 Literature Review

This section provides an overview of the existing literature related to the topics that are addressed in our paper. First, it provides a derivation of the concept of sustainability, which is used as a framework for the construction of our sustainable portfolio. In addition, it elaborates on the historical development of portfolio weight allocation strategies. Finally, this section sheds light on the main findings from previous research concerning the performance of portfolio allocation strategies when applied to a broad and a sustainable universe.

2.1 Development of the Sustainability Concept

The wish to act upon sustainability traces back to the 1980s, when a definition of sustainable development was proposed:

“Development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. (United Nations General Assembly, p. 43, 1987).

Sustainability is a complex topic and embraces different aspects. Apart from the environmental dimension, which is the most common connotation of sustainability, this concept also involves ethical, social and political considerations. A definition that reflects this idea is the following:

"A sustainable future is one in which a healthy environment, economic prosperity and social justice are pursued simultaneously to ensure the well-being and quality of life of present and future generations. Education is crucial to attaining that future". (Learning for a Sustainable Future - Teacher Centre, UNESCO, as cited in Global Footprints, n.d.).

Social and environmental aspects are, to some extent, a requirement for companies and governments to comply with. However, many firms go beyond legal regulations in order to support sustainable development, by incorporating specific measures into their operations. Those firms are considered under the term “Sustainable” in this paper.

2.2 Historical Development of Portfolio Allocation Strategies

The interest of finding an optimal weight allocation strategy is not a recent concern. As early as 1952, Harry Markowitz formulated one of the first investment theories by introducing the mean-variance framework. Thereby, risk is considered an "undesirable thing" and expected return is considered a "desirable thing" to investors (Markowitz, 1952). James Tobin (1958) incorporated the assets that pay the risk-free rate into Markowitz' framework and showed that, with the possibility to take on leverage, the mean-variance profile could be further optimized. In 1959, Markowitz further extended his work with the concept of the optimal portfolio, which can be found along the efficient frontier, a line such that expected return is maximized and portfolio variance is minimized simultaneously (Markowitz, 1959). He also argued that the tangent portfolio of the risk-free rate and the efficient frontier is in fact the market portfolio. Building on this theory, William Sharpe (1964) formulated the Capital Asset Pricing Theory (CAPM), which argued that there is a linear relationship between the systematic risk of an asset and its expected return.

The Market Capitalization technique, also called Cap Weight (CW) technique, is the weighting technique that has traditionally been most used for index composition and thus has widely been applied for portfolio construction (Bodie et al., 2014). The idea behind this strategy consists on allocating larger weights to the companies with higher market value. The portfolio resulting from the application of the CW strategy is the tangent portfolio in the CAPM. One of the main advantages of this method is its ease of implementation.

However, the effectiveness of the CW strategy has lately been questioned (Bertrand and Lapointe, 2014; UBS, 2015; Finnerman and Kirchmann, 2015). Two of the main arguments against the Market Capitalization technique are that it usually derives an under-diversified portfolio when this is composed of a few very large companies, or that it does not consider the price volatility of stocks, which results in the poor performance of this strategy, especially in crisis periods. Hence, many other weight allocation techniques have been developed, which have been proved to outperform the traditional Cap Weight method (Bertrand and Lapointe, 2014; Finnerman and Kirchmann, 2015).

The main input for the risk-based strategies is the VCV matrix, which can be estimated using different methods. The most basic is the sample variance covariance matrix and is derived directly from the matrix of actual returns (Benninga and Czaczkes, 2008). This matrix, however, has been sharply criticized by some practitioners. For instance, Ledoit and Wolf (2003) claim that the sample variance covariance matrix, in fact, should never be used for empirical investigations due to its large estimation error. Furthermore, they argue that the use of this matrix leads to very unreliable outputs given that the optimization solution allocates bigger weights on extreme observations that have large estimation errors. This problem was introduced by Michaud (1989) as the "error maximization" problem.

Consequently, Ledoit and Wolf (2003) suggest the usage of two alternative VCV matrix estimation methods as a remedy to overcome the inaccuracy of the sample variance covariance matrix. In both methods, the sample variance remains unchanged and only the covariances between each pair of assets, the off-diagonal elements of the VCV matrix, are re-estimated.

The first method is called *single index model*, for which stock returns are regressed against the market returns in a linear equation with uncorrelated errors (Ledoit and Wolf, 2002). The idea behind this model is that stock returns have a tendency to move together and that the covariance is only conditional on the market risk and the sensitivity of the stock return to the market (Saphiro, 2008).

The second technique is the so-called *constant correlation method* which is applicable to the VCV matrix estimation of a single asset class, i.e. only stocks or only bonds (Ledoit and Wolf, 2003). The method involves the calculation of the correlation matrix of assets and the average correlation is utilized as a constant in the computation of the VCV matrix (Benninga and Czaczkes, 2008).

An alternative method is the so-called *shrinkage*, which aims at modifying the extreme values by pulling them closer to the mean (Benninga and Czaczkes, 2008). This alleviates the estimation error derived from the use of the sample variance covariance matrix. The shrinkage method combines the sample VCV matrix with another matrix consisting only of the variances.

2.3 Performance of Portfolio Allocation Strategies

Previous studies aimed to assess the performance of the weighting techniques using different measures, like average annual return, annual standard deviation, Sharpe ratio, Jensen's alpha, or multifactor models as the Fama/ French model. Furthermore, in order to evaluate the robustness of the results, they compare the performance of the strategies when applied to time periods of different length.

For instance, Finnerman and Kirchmann (2015) conclude that the MV and REW strategies present the highest average annual return for a time period of 25 years, while the lowest annual return is given by the CW and EW. Similarly, they found that MV, REW and MD present the highest Sharpe ratio, and the CW and EW the lowest. The annual standard deviation, which is a measure of risk, is the highest for the CW portfolio, and the lowest for the MD and EW. To conclude, the CW strategy underperforms the rest of strategies for long time periods. However, for a 3-year period, they conclude that the MD strategy presents the worst performance, followed by the EW and CW.

Other studies assess the robustness of the strategies by using different estimation methods for the VCV matrix. For instance, Knutzen and Retterholt (2015) found that utilizing the constant correlation model results in lower return and higher standard deviation for the MV portfolio than the single index model, what implies lower Sharpe ratios and larger maximum drawdowns. Additionally, the constant correlation method gives higher return and lower standard deviation for the EW and MD, implying higher Sharpe ratios and lower maximum drawdowns. In other words, the constant correlation model underestimates the risk less than the single index model. Moreover, when applying the MV strategy with the constant correlation method, the authors observe a larger concentration of stocks, meaning that larger weights were allocated to fewer stocks. On the other hand, when applying the MD strategy with the constant correlation method, they observe a larger diversification than with the single index method, since the resulting portfolio consists of double the amount of stocks.

2.4 Performance of Portfolio Allocation Strategies in a Sustainable Universe

The interest for sustainable investments has been increasing in recent years due to the pursuit of non-financial performance[1] by some investors, i.e. the ethical utility they get from investing in sustainable stocks. Additionally, it has been shown that the investment in sustainable stocks can also provide a higher financial performance given the lower ex ante cost of capital associated to those firms,[2] which at the same time is linked to higher long-term growth rates (Dhaliwal et al., 2011).

However, there are also studies that present arguments against the outperformance of sustainable investments with respect to traditional investments. For instance, Capelle-Blancard and Monjon (2014) argue that non-financial selection criteria impose a filter to a broader universe of stocks, resulting in a suboptimal mean-variance portfolio (market portfolio) that is derived from a reduced sample. This is translated into a lower performance.

Bertrand and Lapointe (2014) study the performance of some risk-based allocation strategies when they are applied to a sustainable universe. They found that, when the risk-based strategies are applied to a sustainable portfolio, they provide higher returns than the CW. This seems in accordance with the conclusion obtained for a broad universe of stocks, as it has been analyzed previously in this section. In terms of risk adjusted returns they obtain similar results. However, they argue that the existence of few outliers in the price observations of some stocks prevent the MD and the MV strategies from concentrating wealth on those stocks. Thus, these strategies perform better in periods of financial recession, as the stocks that are assumed to react the most to such recession are excluded from the portfolio. In other words, the non-financial filter present on the sustainable portfolio acts as a protection against unusual bad events. Other authors such as Nofsinger and Varma (2013) and Cortez and Silva (2016) support this finding.

Additionally, Bertrand and Lapointe (2014) conclude that the CW and EW are the strategies that benefit the most from the use of a sustainable universe, while the MD and MV are the most penalized. Concerning the robustness of the results when different VCV matrix estimation methods are used, they found that the shrinkage method produces the best-performing portfolios in terms of Sharpe ratio, while the Jensen's alpha and information ratio measures result in the constant correlation model being the one that yields the best performance.

---

[1] Non-financial performance refers to the externalities derived from the company's activity that are not directly linked to financial results.

[2] Ex ante cost of capital is the cost of capital associated to the full lifetime of the firm.

3 Research Question

From the previous section we obtain two main findings. Firstly, the application of the risk-based strategies for portfolio construction results in higher financial performance for investors (Bertrand and Lapointe, 2014; Finnerman and Kirchmann, 2015; Knutzen and Retterholt, 2015). Secondly, the use of the sustainability non-financial criteria in investment decisions also affects financial results positively (Bertrand and Lapointe, 2014). Consequently, we want to investigate how the combination of both strategies affects portfolio performance. Bertrand and Lapointe (2014) address this topic but only focus on Eurozone countries for a time period ending in 2012. Therefore, we aim to update the study by including more recent observations, concretely four more years. In addition, we observe a recent trend towards more awareness of sustainability in Swedish citizens' everyday life. Christiansen et al. (2018) show that Swedish citizens tend to invest in stocks listed in their home country and therefore we expect this awareness to be reflected in investors' behavior in Sweden. Thus, we focus on the Swedish stock market in order to compare if the findings from previous literature also hold true for Sweden.

Hence, our research question is formulated as follows:

How do risk-based portfolio allocation strategies perform when they are applied to a sustainable stock universe in Sweden?

To answer this question, we address five subquestions:

1. *How do portfolio allocation strategies perform when they are applied to a broad stock universe in comparison to the CW strategy?*

2. *How do portfolio allocation strategies perform when they are applied to a sustainable stock universe in comparison to the CW strategy?*

3. *How does each of the risk-based portfolio allocation strategies perform when they are applied to a sustainable stock universe in comparison to a broad stock universe?*

4. *How differently do the strategies behave under different economic conditions for each of the portfolios?*

5. *How different are the results when the strategies are applied based on a different estimation horizon?*

4 Methodology

This section provides a detailed explanation of the methodology used in order to address the above stated research questions. In 4.1, the process of data compilation is outlined, followed by the enumeration of the main assumptions underlying this analysis. Next, the VCV matrix estimation is illustrated, as well as the different portfolio allocation strategies. To end up, the methods used to assess the performance of those strategies are elucidated.

4.1 Data

The data series entails daily adjusted closing prices for Swedish stocks during the period ranging from 01.01.2002 to 31.12.2016 (3913 observations). The period is chosen in order to cover full market cycles and thereby to investigate how the previously mentioned strategies perform under different economic conditions. The sample period is divided into an estimation period and an evaluation period. The estimation period comprises the two first years, i.e. 01.01.2002 to 31.12.2003 and is used for the derivation of the VCV matrix. The evaluation period consists of the remaining 13 years and is used to measure the performance of the strategies.

In addition to the stock prices, which are converted into returns[3], market values are retrieved for all the companies. The data is obtained from DataStream for all publicly traded firms in Sweden, excluding firms that were delisted or founded during the sample period, and the ones for which the market value is not provided by the data source. Therefore, the final sample consists of a total of 193 firms. Moreover, the daily three-month Stockholm Interbank Offered Rates (STIBOR) are used as the risk-free rates and retrieved from the Swedish National Bank's website.[4] Since interest rate data does not exist for public holidays, while stock price data does, the missing risk-free rates are approximated by the STIBOR rates from the previous day. The one-day risk-free rates are derived by taking the 66^{th} root[5] of the three-month STIBOR.[6]

---

[3] This is in line with Bertrand and Lapointe (2014).

[4] This is in line with Finnerman and Kirchmann (2015).

[5] 66 is the number of trading days in 3 months.

[6] $r_{f\,(1D)} = (1+ r_{f\,(3M)})^{(1/66)} - 1$.

In the following, we will refer to three different samples of stocks, named as “Whole”, “Sustainable” and “Complement”. “Whole” contains all of the 193 stocks, from which 44 are considered sustainable and therefore constitute the “Sustainable” sample. “Complement” is composed of the remaining 149 stocks. The “Sustainable” sample is obtained from a database provided by Resility (Swedish House of Finance, 2016). Resility is a sustainability consulting firm who compiles Environmental, Social and Governance (ESG) data of Nordic companies and structures their disclosed information into a database that they call Nordic Compass. This database provides a list of variables concerning general firm facts such as industry, sales, number of employees and remuneration. Furthermore, it includes data points, both quantitative and qualitative, that address the firms’ contribution to sustainability, i.e. total CO2 emissions, total number of female employees or whether they have supplier assessments for labor practices. Based on the information from the Nordic Compass and taking into account the sustainability definition previously outlined, filters are applied to the data so that the selected fraction of sustainable firms fulfill a specific set of requirements.

For the categorization, a sustainability classification scheme is applied as follows:

Firstly, only firms based in Sweden are selected for this study. Secondly, we only consider the variables that address the firm’s contribution to sustainability. Next, mostly aspects that could be classified with dummy variables (yes or no) are considered, rather than the ones that are provided in absolute terms, such as total CO2 emissions, since it seems arbitrary to establish a representative threshold that would separate between what is considered as sustainable and what not. This leaves a total of 21 variables that are considered the definite selection. Since the fulfilment of all the 21 variables is hardly achieved by any firm, the establishment of a minimum fulfilment of 2/3 of the variables seems logical. Therefore, the firms that fulfil at least 15 out of the 21 variables are selected, which results in a sample consisting of 44 firms. Table A.1 in the Appendix compiles the selected sustainable firms with the corresponding sustainability variables.

4.2 Assumptions

Some assumptions are required when constructing the portfolios.[7] Concretely, this paper considers the following:

- For the choice of the “Sustainable” sample, the data provided by Resility is used with the assumption that the information disclosed by the firms already held true at the beginning of the evaluation period.

[7] This is in line with Finnerman and Kirchmann (2015) and Knutzen and Retterholt (2015).

- The market portfolio is composed of the 193 companies in the "Whole" sample. Even though the Swedish market is broader, in this paper the 193 stocks are considered to be the whole market.

- STIBOR rates are treated as risk-free in this study, even though they are not entirely risk-free due to the inevitable existence of some government credit risk.

- Stocks can be held in fractions, i.e. it is not required to hold entire stocks.

- Short-selling is not allowed ($0 \leq w_i \leq 1$). This means that there are only positive weights allocated to the stocks in the portfolio and the weights can never be above 1.

- For simplicity reasons, portfolios are not rebalanced and there are no transaction costs, which means that the weights are calculated at the beginning of the evaluation period and stay constant over the whole period.

- Dividends are not included in this research. Therefore, portfolio returns are not a measure of the total capital gain, but only of the raw performance.

4.3 Variance Covariance Matrix Estimation

All the calculations performed in this section are applied equally to each of the three samples mentioned above.

The estimation of the VCV matrix is the only input required for the application of the risk-based weighting techniques. Therefore, the choice of the right estimation method is of unquestionable importance. As previously mentioned, Ledoit and Wolf (2003) argue against the use of the sample variance covariance matrix. Additionally, they suggest that the constant correlation model is one of the most accurate methods and one of the easiest to implement. Furthermore, Knutzen and Retterholt (2015) found that the constant correlation model provides a more prudent estimation of risk than the single index model. For those reasons, the estimation method used in this study is the constant correlation model.

For the derivation of the VCV matrix, the calculation of the sample mean and standard deviation of the returns is required. The formulas are given by:

$$\mu_i = \frac{\sum_{t=1}^{T} r_{i,t}}{T}, \tag{4.1}$$

$$\sigma_i = \sqrt{\frac{\sum_{t=1}^{T} (r_{i,t} - \mu_i)^2}{T-1}}, \tag{4.2}$$

where:

μ_i is the sample mean of returns of each stock,

$r_{i,t}$ is the return of each stock per day,

T is the time at the end of the estimation period (521 days)

and σ_i is the sample standard deviation of each stock.

Following Benninga and Czaczkes (2008), the derivation of the VCV matrix using the constant correlation model is performed based on the following formulas:

$$\sigma_i{}^2 = \frac{\sum_{t=1}^{T}(r_{i,t} - \mu_i)^2}{T-1}, \tag{4.3}$$

$$\sigma_{i,j} = \frac{\sum_{t=1}^{T}(r_{i,t} - \mu_i)(r_{j,t} - \mu_j)}{T-1}\rho *, \tag{4.4}$$

where:

σ_i^2 are the sample variances of each stock, which constitute the diagonal elements of the matrix,

$\sigma_{i,j}$ are the covariances between each pair of stocks, the off-diagonal elements of the matrix,

and ρ^* is the correlation constant, which is calculated as the average of the correlation matrix elements minus one divided by the number of stocks in the sample.

The correlation matrix is composed by the correlations between each pair of stocks, which are derived as:

$$\rho_{i,j} = \frac{\sum_{t=1}^{T}(r_{i,t} - \mu_i)(r_{j,t} - \mu_j)/T-1}{\sigma_i \sigma_j} \tag{4.5}$$

4.4 Portfolio Construction

The portfolios are constructed in the same way for each of the three samples ("Whole", "Sustainable", "Complement"). The methodology is similar for all the strategies, the only difference being the weight calculation.[8] The information used for the weight allocation is obtained from the estimation period, which is the two first years (from 01.01.2002 to 31.12.2003).

---

[8] The theory behind all the strategies and the formulas presented in this section are retrieved from Finnerman and Kirchmann (2015).

4.4.1 Heuristic Based Allocation Strategies

· Cap Weight (CW)

The Market Capitalization technique is the traditional asset allocation strategy, considered the market portfolio and thus used as a benchmark in most of the portfolio construction studies. The rationale behind this model is to allocate the weights based on the size of each company, so that larger companies are given larger weights. The weights for each stock are derived as a fraction of the market value of the individual stock over the sum of the market values of all stocks.

$$w_i = \frac{p_i * n_i}{\sum_{i=1}^{n} p_i * n_i}, \tag{4.6}$$

where:

w_i are the weights allocated to each stock

and (p_i*n_i) are the market values for each stock.

The only input needed for the construction of the CW portfolios is the market values of the firms at 31.12.2003, which is the last day of the estimation period. The calculated weights are multiplied by the observed daily returns in the evaluation period, ranging from 01.01.2004 to 31.12.2016. The overall portfolio return for each day is obtained by aggregating the resulting returns based on the percentage of wealth invested in each stock.

· Equal Weight (EW)

Under this technique, every stock is allocated the same weight, which depends on the total number of firms in the sample. The idea behind this strategy is to prevent the weight concentration around a few stocks. However, this strategy is rather simplistic and therefore referred to as a “naive diversification” (DeMiguel et al., 2009).

$$w_i = \frac{1}{n}, \tag{4.7}$$

where n is the number of stocks.

The portfolio construction procedure is the same as explained for the Cap Weight strategy.

· Inverse Volatility Weighting (IVW)

The IVW technique does not follow the common theory that larger risk implies higher returns, and thus, it assigns larger weights to stocks with lower volatility. The only input for the calculation of the weights is the stocks’ sample standard deviation, which is a measure of risk.

The weights are allocated based on the fraction of the inverse of the standard deviation of each stock with respect to the sum of all the inverse volatilities.

$$w_i = \frac{\frac{1}{\sigma_i}}{\sum_{i=1}^{n} \frac{1}{\sigma_i}}, \qquad (4.8)$$

Again, the calculation of the total return of the IVW portfolio is identical to the previous strategies.

4.4.2 Risk-Based Allocation Strategies

· Minimum Variance (MV)

The only input required for the weight calculation is the VCV matrix, derived based on the return observations from the estimation period. The downside of this strategy is that it leads to a concentrated portfolio, where some stocks are allocated very large weights and some are not allocated any weight. The optimization problem consists on minimizing the portfolio risk, which is measured by the VCV matrix Σ.

$$w* = \min_{w} w'\Sigma w \ , \qquad (4.9)$$

s.t. $\sum_i^n w_i = 1$

$0 \leq w_i \leq 1$

Once the optimal weights are obtained, portfolio returns are derived in the same manner as for the previous strategies.

· Maximum Diversification (MD)

Similarly to the previous method, the MD technique is based on the VCV matrix estimation, but it also incorporates the volatility of the stocks into the optimization equation. The idea behind this strategy is to resemble all stocks' contributions to portfolio risk, given an infinitesimal change in their weights (Clarke et al., 2013). Since the standard deviation has less extreme values than the variance, weight concentration around certain stocks is lower than for the MV. Therefore, the concept of diversification is introduced as a way to reduce the risks associated to the portfolio. The MD weights are obtained by maximizing the ratio of the individual stocks' volatility with respect to the overall portfolio volatility.

$$w* = \max_{w} \frac{w'\sigma}{\sqrt{w'\Sigma w}}, \qquad (4.10)$$

s.t. $\sum_i^n w_i = 1$

$0 \leq w_i \leq 1$

The portfolio return is calculated in the same way as in the previous strategies.

· Risk Efficient Weighting (REW)

Following the rationale of the MV and MD techniques, the REW aims at minimizing portfolio risk by maximizing the Sharpe ratio. Similarly to MV, this strategy results in a large weight concentration around a few stocks. Apart from the VCV matrix, the inputs required are the excess returns, the risk-free rate and the market return. In this case, the risk is measured by the so-called Downside Deviation, which only considers the excess returns that are below zero.

$$Downside\ Deviation_i = \left(\frac{1}{T}\sum_{t=1}^{T} min\left(r_{i,t} - \mu_i, 0\right)^2\right)^{\frac{1}{2}} \tag{4.11}$$

For the derivation of the Sharpe ratio, the expected returns are obtained based on the CAPM expression but with the Downside Deviation replacing beta.

$$E[r_i] = r_f + Downside\ Deviation * (r_m - r_f), \tag{4.12}$$

where:

r_f is the risk-free rate, which is the average of the one-day STIBOR rates for the estimation period

and r_m is the market return, which is the average daily return of the portfolio constructed by applying the CW weights to the observed returns from the estimation period (benchmark portfolio).

Finally, the objective function is the following:

$$w *= \max_{w} \frac{w\prime E[r_i]}{\sqrt{w\prime \Sigma w}}, \tag{4.13}$$

s.t. $\sum_i^n w_i = 1$

$0 \leq w_i \leq 1$

Once the optimal weights are estimated, the portfolio return is obtained in the same manner as for the previous strategies.

4.5 Performance Measures

This section provides a brief explanation of the eight performance measures used to assess the out-of-sample effectiveness of the weighting techniques in terms of return and risk. As previously outlined, the evaluation of the strategies is performed for the period ranging from 01.01.2004 to 31.12.2016.

· Portfolio Value [9]

Portfolio values are calculated for each of the strategies and in all the three samples. The daily portfolio value at time τ is derived as the product of one plus the daily portfolio returns of all the previous days until τ.

$$Portfolio\ Value_{\tau} = \prod_{t=0}^{\tau} (1 + r_{p,t}), \tag{4.14}$$

where $r_{p,t}$ is the portfolio return at time t.

· Average Annual Return [10]

The average annual returns of the three portfolios are calculated as the average of the daily returns of the constructed portfolios for each strategy, multiplied by 260 trading days. This is a measure of the raw performance of the strategies and does not consider the inherent risk.

· Annual Standard Deviation [11]

This performance measure indicates the volatility of the returns and is calculated as the sample daily standard deviation of the returns of the constructed portfolios multiplied by the square root of 260. Contrarily to the average return, the standard deviation only considers the volatility but does not provide any information about returns.

· Sharpe Ratio [12]

The Sharpe ratio is a measure of the average excess return per unit of risk. The average excess return consists on the average annual return minus the annualized average risk-free rate. For the calculation of the Sharpe ratio, the risk is measured by the annual standard deviation of the portfolio returns. This performance measure is superior to the previous ones since it evaluates risk adjusted returns.

---

[9] The derivation of this performance measure is in line with Feibel (2003).

[10] The use and derivation of this performance measure is in line with Finnerman and Kirchmann (2015).

[11] The use and derivation of this performance measure is in line with Finnerman and Kirchmann (2015).

[12] The use and derivation of this performance measure is in line with Finnerman and Kirchmann (2015).

$$Sharpe\ Ratio_p = \frac{\overline{r_p} - \overline{r_f}}{\sigma_p}, \tag{4.15}$$

where:

$\overline{r_p} - \overline{r_f}$ is the average excess return, which consists on the average annual return minus the annualized average risk-free rate

and σ_p is the annualized standard deviation of the returns of the constructed portfolios.

· Sortino Ratio [13]

Similarly to the Sharpe ratio, the Sortino ratio evaluates the average excess return per unit of risk, which in this case is measured by the annualized downside deviation. Since investors are interested in the risk of a decline in stock price, this ratio is a more accurate assessment of risk adjusted returns than the Sharpe ratio.

$$Sortino\ Ratio_p = \frac{\overline{r_p} - \overline{r_f}}{Downside\ Deviation_p} \tag{4.16}$$

· Maximum Drawdown [14]

The Maximum Drawdown is the largest relative decrease from a peak to a trough in portfolio value. Therefore, it is an approximation of the maximum possible loss that an investor can incur by investing in the portfolio.

$$Maximum\ Drawdown_p(T) = max_{\tau \epsilon (0,T)}[max_{t \epsilon (0,\tau)}\ \frac{X(t) - X(\tau)}{X(\tau)}], \tag{4.17}$$

where X(t) is the portfolio value at time t.

[13] The use and derivation of this performance measure is in line with Knutzen and Retterholt (2015).

[14] The use and derivation of this performance measure is in line with Finnerman and Kirchmann (2015).

· Value at Risk [15]

Considering a loss being the opposite of a return, the probability of observing a loss L that is higher than the Value at Risk represents 1-α[16]. Hence, this measure enables the comparison of portfolios with different distributions.

$$\Pr(L > VaR_{\alpha}(L)) = 1 - \alpha, \tag{4.18}$$

· Expected Shortfall [17]

Expected Shortfall is the average of all the losses that are higher than the Value at Risk. Therefore, it is an assessment of the average loss that could be incurred in the unlikely (1% probability) event of experimenting a loss that is larger than the Value at Risk.

$$ES_{\alpha}(L) = E\,[L : L > VaR_{\alpha}(L)] \tag{4.19}$$

---

[15] The use and derivation of this performance measure is in line with Hull (2015).

[16] α is the confidence level, which is set to 99% in this study.

[17] The use and derivation of this performance measure is in line with Hull (2015).

5 Results

The Descriptive Statistics of the constructed portfolio returns are compiled in table A.2 in the Appendix. Since the EW assigns the same weight to all the stocks, the results of this technique are a good indication of the statistical properties of the portfolio returns, independently of the strategy that is implemented. It can be seen from table A.2 that the mean of the daily return for the “Sustainable” portfolio under this technique is much higher than for the other two portfolios. The standard deviation is also higher. This means that the firms in this sample deliver on average higher returns and have higher volatilities, regardless of the strategy used.

In order to compare the effectiveness of the portfolio allocation strategies, the results from the application of the different performance measures are presented in tables 5.1 to 5.7 and described in this section. The highlighted values in those tables indicate the best performing strategy for each of the three samples.

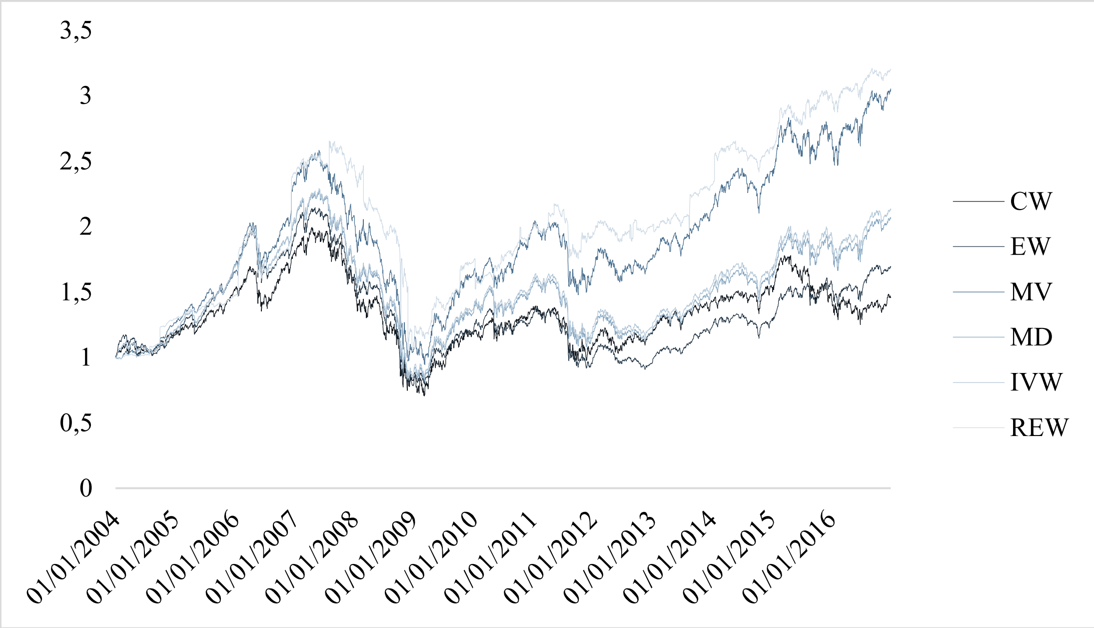
5.1 Portfolio Values

Figures 5.1 to 5.3 show the evolution of portfolio values over the evaluation period.

From figure 5.1 an increase in portfolio values can be observed from 2004 until mid-2007 for all the strategies, where the REW presents the highest value and the CW lies below the remaining strategies. At this point, the values experience a pronounced decline, which continues until 2009. That decline in portfolio values is due to the 2008 financial crisis. From that date on, the values increase exponentially, so that at the end of the evaluation period, the REW and the MV strategies lie substantially above the other strategies, with 3,2 and 3,1 million SEK. The CW portfolio is the worst performing, with a final value of 1,5 million SEK, given that it experiences a decline from 2015. Portfolio values for the “Complement” sample behave similarly to “Whole”, as can be seen from figure 5.3. This is due to the fact that “Complement” contains most of the stocks from “Whole”.

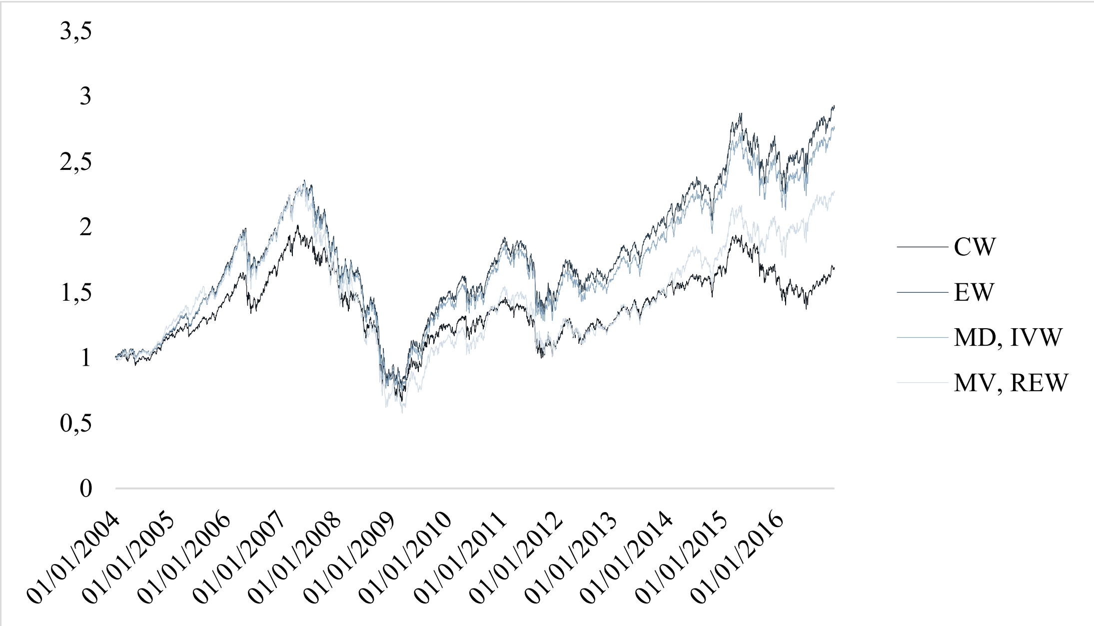
The evolution of portfolio values for the “Sustainable” sample of stocks, shown in figure 5.2, presents a similar shape to the other two figures. However, in this case all the strategies present a decline from 2015 towards the end of the period. The EW is the strategy with the highest portfolio value (2,9 million SEK) in the end of 2016. Additionally, the MD and IVW, both with a value of 2,8 million SEK outperform the rest of the strategies. Again, the CW underperforms, showing a value of 1,7 million SEK.

Figure 5.1 "Whole" Portfolio Value 2004-2016



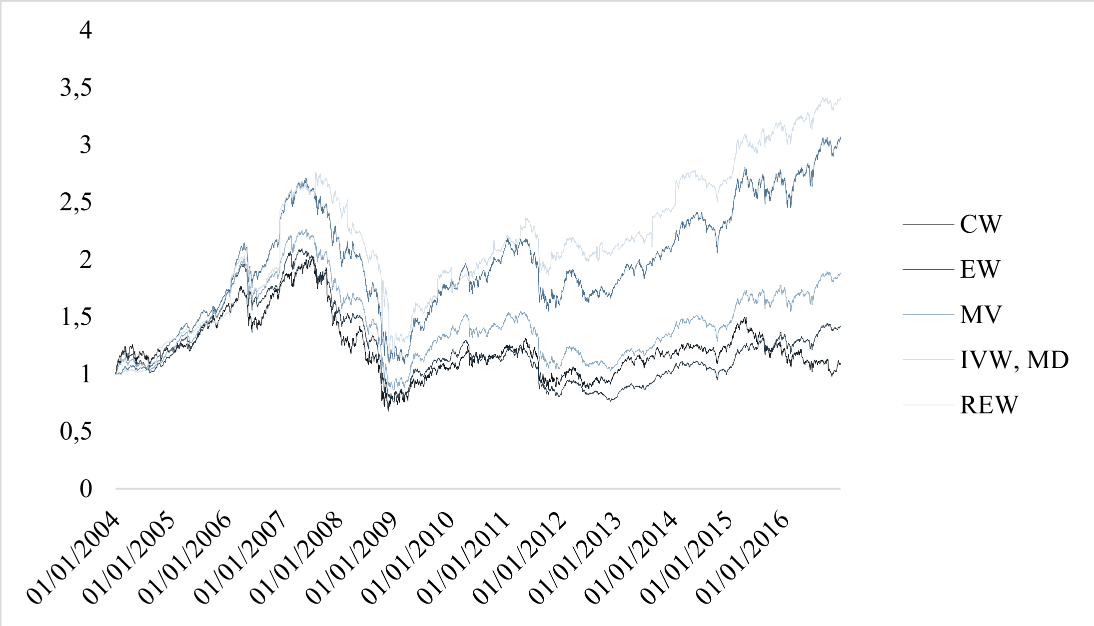
Portfolio values in Millions SEK, for an investment of 1M SEK

Figure 5.2 "Sustainable" Portfolio Value 2004-2016



Portfolio values in Millions SEK, for an investment of 1M SEK

Figure 5.3 ”Complement” Portfolio Value 2004-2016



Portfolio values in Millions SEK, for an investment of 1M SEK

5.2 Average Annual Return

Table 5.1 Average Annual Return 2004-2016

AVERAGE ANNUAL RETURN	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	5,27%	6,50%	0,70%
Equal Weight	5,17%	**10,25%**	3,67%
Inverse Volatility Weighting	7,01%	9,87%	5,81%
RISK-BASED TECHNIQUES			
Minimum Variance	10,02%	8,90%	9,79%
Maximum Diversification	6,84%	9,87%	5,81%
Risk Efficient Weighting	**11,79%**	8,90%	**11,65%**

From table 5.1, it can be observed that the CW strategy is the worst performer in the “Sustainable” (6,5%) and “Complement” (0,7%) portfolios and the second worst in the “Whole” (5,27%) portfolio.

The EW strategy performs best for the “Sustainable” portfolio, delivering a return of 10,25%. However, for the “Whole” portfolio this strategy is the worst performer, and the second worst in “Complement”.

REW and MV appear to deliver the lowest returns in the “Sustainable” portfolio (after the CW), while these two strategies are by far the best performers for the other two portfolios, with

11,79% and 10,02% returns for “Whole”, and 11,65% and 9,79% returns for “Complement”, respectively. These two are the only strategies that do not improve their raw performance when applied to the sustainable universe with respect to the broad universe.

Therefore, in general, the risk-based strategies lead to higher average returns for those two portfolios. However, for the “Sustainable” portfolio all the strategies deliver very similar returns, with the exception of the CW, which presents a significantly lower performance.

Moreover, it can be seen that the average annual returns for the IVW and MD strategies are very similar, especially in the “Sustainable” and “Complement” portfolios.

5.3 Annual Standard Deviation

Table 5.2 Annual Standard Deviation 2004-2016

ANNUAL STANDARD DEVIATION	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	21,82%	22,59%	24,71%
Equal Weight	**14,95%**	**20,24%**	14,02%
Inverse Volatility Weighting	15,44%	20,47%	**13,88%**
RISK-BASED TECHNIQUES			
Minimum Variance	17,10%	22,71%	15,42%
Maximum Diversification	15,84%	20,47%	**13,88%**
Risk Efficient Weighting	23,59%	22,74%	21,00%

Table 5.2 shows that, in terms of standard deviation, the CW is one of the worst performers. Both in the “Whole” and “Complement” portfolios, the standard deviation for this strategy, together with the REW, is significantly higher than for the remaining strategies.

For the “Whole” portfolio, the EW strategy presents the lowest risk (14,95%) while the REW shows the highest volatility (23,59%). The same pattern can also be observed in the “Sustainable” portfolio, for which the EW delivers 20,24% and the REW 22,74%. On the other hand, for the “Complement” portfolio the IVW and the MD lead to the lowest standard deviation (13,88%).

Compared to the broad universe, the sustainable universe presents higher annual standard deviation in all cases except for the REW strategy, which means that the volatility associated to this portfolio is higher, implying higher risks.

In the “Sustainable” portfolio, the volatility is relatively high and similar between all the strategies.

5.4 Sharpe Ratio

Table 5.3 Sharpe Ratio 2004-2016

SHARPE RATIO	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	-0,0712	-0,0144	-0,2480
Equal Weight	-0,1109	**0,1693**	-0,2253
Inverse Volatility Weighting	0,0119	0,1488	-0,0731
RISK-BASED TECHNIQUES			
Minimum Variance	0,1865	0,0911	0,1919
Maximum Diversification	0,0006	0,1488	-0,0731
Risk Efficient Weighting	**0,2104**	0,0909	**0,2298**

Comparing the risk adjusted returns, table 5.3 shows the Sharpe ratios for all the constructed portfolios. Some strategies present negative Sharpe ratios, which means that investors do not get any return in excess of the risk-free rate. The negative excess returns[18] can be explained by the fact that the evaluation period entails observations of very high STIBOR rates (three-month STIBOR around 5% in 2008), in contrast to the recent years, when those rates turned even negative. Therefore, an evaluation period starting after the financial crisis would lead to a lower average risk-free rate, what would result in higher excess returns.

Concretely, the CW strategy delivers the lowest Sharpe ratio in the "Sustainable" and "Complement" portfolios and the second lowest in "Whole". Additionally, the EW strategy presents a negative Sharpe ratio in the "Whole" portfolio and the EW, IVW and MD in "Complement".

Furthermore, from the table 5.3 it can be observed that the REW strategy performs best in the "Whole" and "Complement" portfolios, with Sharpe ratios of 0,21 and 0,23, respectively. In the "Sustainable" portfolio, the best performing strategy is the EW, with a Sharpe ratio of 0,17. However, this is still substantially lower than the Sharpe ratio for the REW strategies in the other two portfolios.

Except for the MV and REW strategies, the Sharpe ratio for the sustainable portfolios show higher risk adjusted returns in comparison to the broad universe. This means that only those two strategies are penalized from their application to the sustainable universe.

[18] The table A.3 in the Appendix compiles the excess returns.

5.5 Sortino Ratio

Table 5.4 Sortino Ratio 2004-2016

SORTINO RATIO	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	-0,0401	-0,0080	-0,1464
Equal Weight	-0,0578	**0,0923**	-0,1164
Inverse Volatility Weighting	0,0063	0,0811	-0,0381
RISK-BASED TECHNIQUES			
Minimum Variance	0,1022	0,0498	0,1038
Maximum Diversification	0,0003	0,0811	-0,0381
Risk Efficient Weighting	**0,1233**	0,0497	**0,1342**

Since the Sortino ratios are based on the downside deviations,[19] which are higher than the sample standard deviations, the Sortino ratios, as seen in table 5.4, are lower than the Sharpe ratios in absolute terms. Furthermore, similarly to the previous results, some strategies present negative Sortino ratios. The reasoning is the same as outlined for the Sharpe ratios.

The CW strategy is one of the worst performers in the three samples. Moreover, the highest ratio for "Whole" and "Complement" corresponds to the REW strategy (0,12 and 0,13, respectively), while for the "Sustainable" portfolio it corresponds to the EW (0,09).

Similarly to previous performance measures, the results for IVW and MD are very similar, especially for the "Sustainable" and "Complement" portfolios. In addition, the MV and REW are very similar for the "Sustainable" portfolio.

In accordance with the conclusions obtained from the Sharpe ratio, MV and REW are the only two strategies that are penalized when applied to the sustainable universe of stocks.

[19] The table A.4 in the Appendix compiles the downside deviations.

5.6 Maximum Drawdown

Table 5.5 Maximum Drawdown 2004-2016

MAXIMUM DRAWDOWN	**Whole**	**Sustainable**	**Complement**
HEURISTIC BASED TECHNIQUES			
Cap Weight	64,64%	**67,03%**	66,61%
Equal Weight	63,53%	67,06%	64,09%
Inverse Volatility Weighting	63,22%	68,44%	61,91%
RISK-BASED TECHNIQUES			
Minimum Variance	63,39%	75,34%	**59,89%**
Maximum Diversification	64,04%	68,44%	61,91%
Risk Efficient Weighting	**62,95%**	75,37%	60,05%

MAXIMUM DRAWDOWN 2004-2010	**Whole**	**Sustainable**	**Complement**
HEURISTIC BASED TECHNIQUES			
Cap Weight	64,64%	**67,03%**	66,61%
Equal Weight	63,53%	67,06%	64,09%
Inverse Volatility Weighting	63,22%	68,44%	61,91%
RISK-BASED TECHNIQUES			
Minimum Variance	63,39%	75,34%	**59,89%**
Maximum Diversification	64,04%	68,44%	61,91%
Risk Efficient Weighting	**62,95%**	75,37%	60,05%

MAXIMUM DRAWDOWN 2011-2014	**Whole**	**Sustainable**	**Complement**
HEURISTIC BASED TECHNIQUES			
Cap Weight	30,22%	31,92%	34,34%
Equal Weight	34,00%	**30,72%**	38,21%
Inverse Volatility Weighting	31,76%	31,37%	33,65%
RISK-BASED TECHNIQUES			
Minimum Variance	27,76%	34,85%	**29,31%**
Maximum Diversification	32,85%	31,37%	33,62%
Risk Efficient Weighting	**19,29%**	34,85%	21,37%

MAXIMUM DRAWDOWN 2015-2016	**Whole**	**Sustainable**	**Complement**
HEURISTIC BASED TECHNIQUES			
Cap Weight	37,24%	29,33%	34,63%
Equal Weight	-	21,45%	-
Inverse Volatility Weighting	-	21,88%	-
RISK-BASED TECHNIQUES			
Minimum Variance	-	**21,34%**	**-**
Maximum Diversification	-	21,88%	-
Risk Efficient Weighting	**-**	21,40%	-

In table 5.5, the Maximum Drawdowns are analyzed for three separate periods. The first table compiles the Maximum Drawdowns for the entire evaluation period, which is later divided in three subperiods that are analyzed separately, given that a distinct decline in portfolio values is observed in each of those periods.[20] The Maximum Drawdown for the entire period corresponds to the Maximum Drawdown in the subperiod ranging from 2004-2010 due to the financial crisis of 2008. The observed drawdowns are twice as high as for the next subperiod.

Concretely, for the first subperiod, the “Whole” portfolio presents the lowest Maximum Drawdown for the REW technique (62,95%). This means that, when using the REW strategy for the “Whole” portfolio, the maximum decline from a peak to a trough represents 62,95% relative to the portfolio value at the peak. The “Sustainable” portfolio exhibits the lowest Maximum Drawdown for CW (67,03%) and EW (67,06%) and “Complement” does for MV (59,89%) and REW (60,05%). It can also be observed that the Maximum Drawdowns are larger for the “Sustainable” portfolio than for “Whole”, what means that none of the strategies benefit when applied to the sustainable universe. Furthermore, the MV and REW strategies are especially penalized, with a difference of around twelve percentage points in both cases.

For the subperiod ranging from 2011-2014, similarly to the previous conclusion, the REW performs best in “Whole”, with a Maximum Drawdown of 19,29% and the MV performs best in “Complement”, with a Maximum Drawdown of 29,31%. In this case, the lowest value for the “Sustainable” portfolio corresponds to the EW (30,72%). Furthermore, it can be observed that, in general, the risk-based techniques perform better for the “Whole” and “Complement” portfolios, whereas the heuristic based strategies perform better for the “Sustainable” portfolio.

For the last subperiod, from 2015 to 2016, for the “Whole” and “Complement” portfolios, only the CW strategy presents a drawdown, which means that this strategy is the riskiest. For “Sustainable”, all the strategies experience a value decline, where the MV strategy leads to the smallest drawdown.

[20] This can be seen from figures 5.1, 5.2 and 5.3 introduced in Section 5.1.

5.7 Value at Risk

Table 5.6 Value at Risk 2004-2016

VALUE AT RISK	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	4,01%	4,16%	3,98%
Equal Weight	2,92%	**3,77%**	2,81%
Inverse Volatility Weighting	2,92%	3,84%	2,69%
RISK-BASED TECHNIQUES			
Minimum Variance	3,21%	4,34%	2,83%
Maximum Diversification	2,99%	3,84%	2,69%
Risk Efficient Weighting	**1,86%**	4,35%	**1,97%**

From table 5.6 it can be seen that, in terms of Value at Risk, the CW is the worst performer in "Whole" and "Complement" and one of the worst in "Sustainable".

The "Whole" and the "Complement" portfolios present the lowest Value at Risk for REW (1,86% and 1,97%, respectively). This means that, for this strategy, there is a 99% probability that the losses are smaller than 1,86% for "Whole" and 1,97% for "Complement". For instance, if one would invest 1 million SEK, there would be a 1% chance of losing more than 18,6 thousand SEK in the "Whole" portfolio and more than 19,7 thousand SEK in "Complement". For the "Sustainable" portfolio, the lowest Value at Risk is given by the EW strategy (3,77%).

Generally speaking, the values are slightly higher in the "Sustainable" portfolio than in the other two, meaning that all the strategies are penalized in the sustainable universe.

It can also be seen that the range of Value at Risk in the "Sustainable" portfolio is relatively small, with all the values fluctuating around 4%, while for the broad universe the range is larger, between 1,9% and 4%. This means that the choice of the portfolio construction strategy is of greater importance when investing in a broad universe of stocks compared to the sustainable universe.

5.8 Expected Shortfall

Table 5.7 Expected Shortfall 2004-2016

EXPECTED SHORTFALL	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	5,29%	5,45%	5,51%
Equal Weight	**4,08%**	**5,08%**	3,91%
Inverse Volatility Weighting	4,10%	5,14%	**3,82%**
RISK-BASED TECHNIQUES			
Minimum Variance	4,31%	5,70%	3,97%
Maximum Diversification	4,23%	5,14%	**3,82%**
Risk Efficient Weighting	5,63%	5,71%	5,15%

Table 5.7 presents the calculated Expected Shortfalls for all the constructed portfolios.

The CW technique presents one of the highest Expected Shortfalls for the three portfolios. In "Whole", it represents 5,29%, which means that the 1% losses that are above the Value at Risk are on average 5,29% (or 52,9 thousand SEK for an investment of 1 million SEK).

In this case, EW leads to the lowest Expected Shortfall in the "Whole" and "Sustainable" portfolios (4,08% and 5,08%, respectively). IVW and MD exhibit the smallest average loss above the Value at Risk in the "Complement" portfolio (3,82%). On the other hand, the maximum Expected Shortfall is given by the REW for the two first portfolios (5,63% and 5,71%) and by the CW for the last one (5,51%), what makes these strategies be the least effective.

In general, the sustainable firms seem to exhibit larger losses and thus perform worse under this performance measure. This is in accordance with the conclusions for the Sharpe ratio.

In this case, the range of values in the sustainable universe is also smaller than in the broad universe, what means that the choice matters less. However, the difference is not as substantial as in the previous performance measure.

6 Discussion

In order to answer the previously stated research question, this section addresses four of the subquestions individually, based on the results that are presented above. The last subquestion concerns the application of different time horizons, so it is analyzed in the robustness section.

1. *How do portfolio allocation strategies perform when they are applied to a broad stock universe in comparison to the CW strategy?*

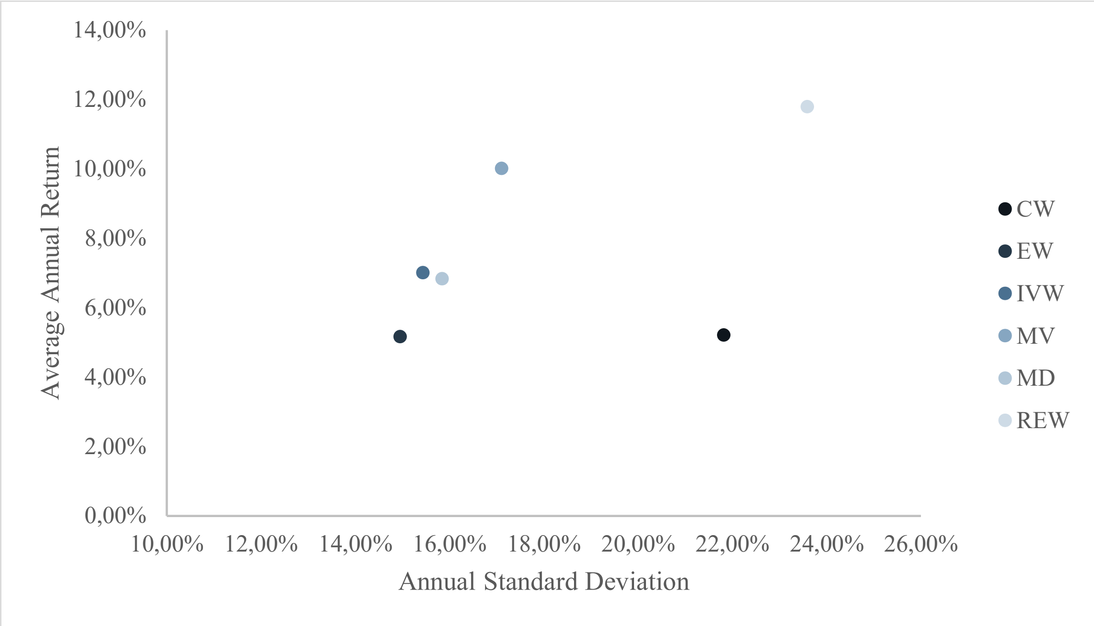
The results show that the recent popularity of risk-based strategies is not without reason. Based on the conclusions obtained in the previous section, it can be seen that the CW strategy consistently underperforms the rest of the applied strategies in the broad universe. Specifically, it is the worst performer when looking at the Value at Risk and the Maximum Drawdown, and the second worst considering the Average Annual Return, Annual Standard Deviation, Sharpe and Sortino ratios and Expected Shortfall. In the case when the CW presents the second lowest performance, the EW is the strategy that occupies the last position, i.e. worst performer. The only exception is the Annual Standard Deviation, where EW has the lowest value, and therefore represents the most favorable technique.

On the other hand, the REW and MV strategies are the two best performers in terms of Average Annual Return, Sharpe and Sortino ratios, and the REW is also the most effective technique with respect to Maximum Drawdown and Value at Risk.

These results are in line with the findings from previous studies, which argue that the Cap Weight technique is usually outperformed by other strategies. For instance, the results support the conclusions obtained by Finnerman and Kirchmann (2015), i.e. the EW and CW strategies are the worst. They also find that the REW and MV are the best performers.

Figure 6.1 displays the relation Annual Standard Deviation-Average Annual Return of the different strategies in the “Whole” sample.

Figure 6.1 Return-Standard Deviation "Whole" 2004-2016



The main takeaways from the figure are that the CW, as already elaborated on, is the worst performing since it is located in the lower right quadrant of the graph. The MV is apparently the best since it presents a balance between risk and return. The EW is the safest since it provides low returns but also the lowest standard deviation. Contrarily, the REW presents the highest return but at the same time the highest risk.

2. *How do portfolio allocation strategies perform when they are applied to a sustainable stock universe in comparison to the CW strategy?*

Risk-based portfolio allocation strategies, together with the IVW, outperform the CW technique in terms of Average Annual Return, Sharpe and Sortino ratio. Bertrand and Lapointe (2014) also arrive at the same conclusion.

In contrast, this study concludes that the MV and REW strategies underperform the CW according to the Standard Deviation, Maximum Drawdown, Value at Risk and Expected Shortfall. This seems counterintuitive since both strategies aim at minimizing the inherent risk. However, it can be explained by the fact that the weight allocation is based on the estimated VCV matrix from the first two years, i.e. the estimation period, which is not long enough to include different economic states, concretely a financial crisis. After applying the calculated weights to an evaluation period that includes the financial crisis from 2008, it results in an underestimation of risk by both strategies, which makes them inefficient.

In addition, we find that the EW outperforms the CW, which is supported by our findings, where this strategy is the best performing for most of the performance measures.

Figure 6.2 plots the return-standard deviations for the "Sustainable" portfolio.

Figure 6.2 Return-Standard Deviation "Sustainable" 2004-2016

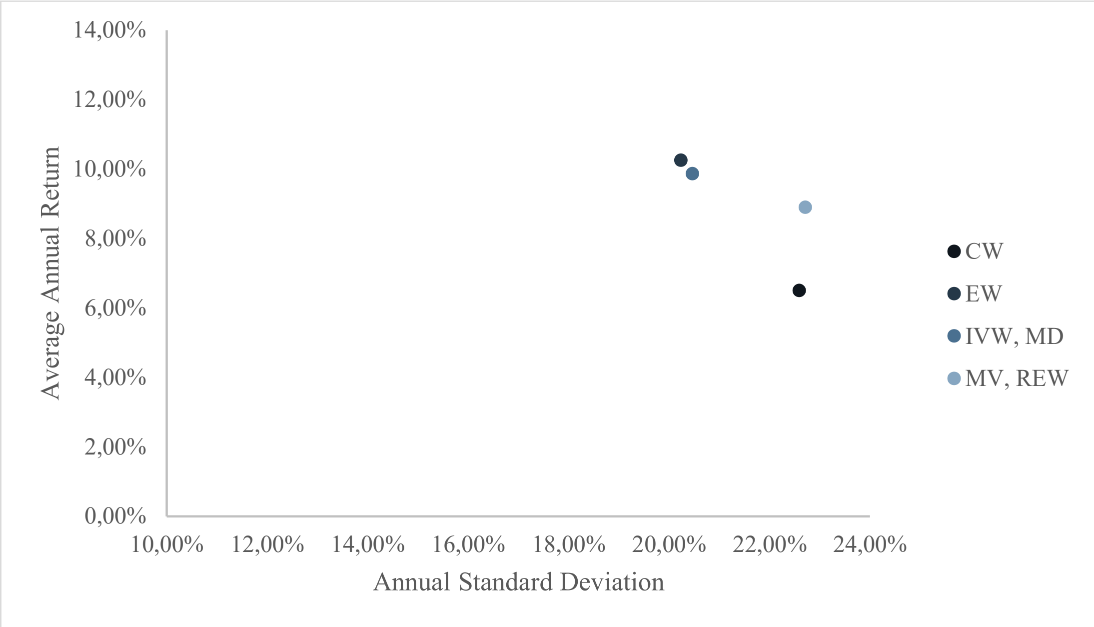
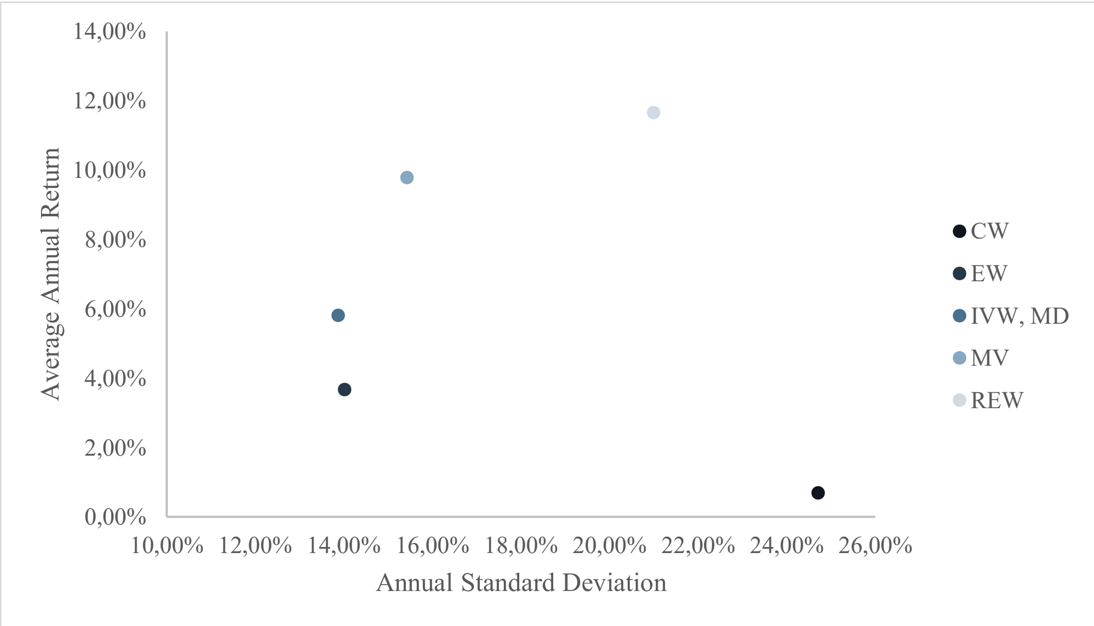


Figure 6.3 Return-Standard Deviation "Complement" 2004-2016



In this case, it can be seen that all the strategies are situated in the upper right quadrant, indicating that the strategies are quite risky, which is in general compensated by high returns. The worst strategy is the CW and the best the EW. Similarly, figure 6.3 presents the scatterplot for the "Complement" portfolio.

3. *How does each of the risk-based portfolio allocation strategies perform when they are applied to a sustainable stock universe in comparison to a broad stock universe?*

Intuitively, as stated earlier, applying an optimization problem to a constrained universe leads to a suboptimal solution. Hence, the risk-based techniques are expected to perform worse when applied to the "Sustainable" portfolio compared to the broad universe. This holds true when looking at the Maximum Drawdown, Value at Risk and Expected Shortfall, which present higher values for the "Sustainable" portfolio than for "Whole". Specifically, the fact that the "Sustainable" portfolio is the only one presenting a drawdown for all the strategies in the subperiod 2015-2016 indicates that this portfolio carries more risk.

In terms of Average Annual Return, Sharpe and Sortino ratios, the MV and REW are penalized from their application to the sustainable universe but the MD performs better. This shows that the combination of the financial and non-financial criteria provides superior performance for the MD, i.e. the choice of investing in sustainable firms is advantageous for the MD strategy.

Additionally, the EW technique, despite being heuristic based, gains the most from its implementation to the "Sustainable" portfolio, as for example the Average Annual Return is twice as high as for "Whole". This finding is in line with Bertrand and Lapointe (2014).

Another result from the tables that should be highlighted is that the IVW and MD techniques present very similar results for all the three portfolios. It can also be observed that the difference in the values is the largest in the "Whole" portfolio, followed by "Complement" and very insignificant in the "Sustainable" portfolio. Both strategies are based on the sample standard deviations of the stocks and aim to minimize it. Therefore, in both cases the weights are allocated in a similar way, so that the daily portfolio returns are almost the same and hence the performance results are similar. As previously stated, the fact that the strategies are applied to a constrained universe makes them perform inefficiently, and the values are more similar among them the more constrained the portfolio is. Note that "Sustainable" contains 44 stocks, so it is considered more constrained than "Complement", which contains 149.

4. *How differently do the strategies behave under different economic conditions for each of the portfolios?*

For a more visual analysis, the yearly average portfolio returns are plotted in figures 6.4, 6.5 and 6.6 for the "Whole", "Sustainable" and "Complement" portfolios.

Figure 6.4 "Whole" Yearly Average Portfolio Return 2004-2016

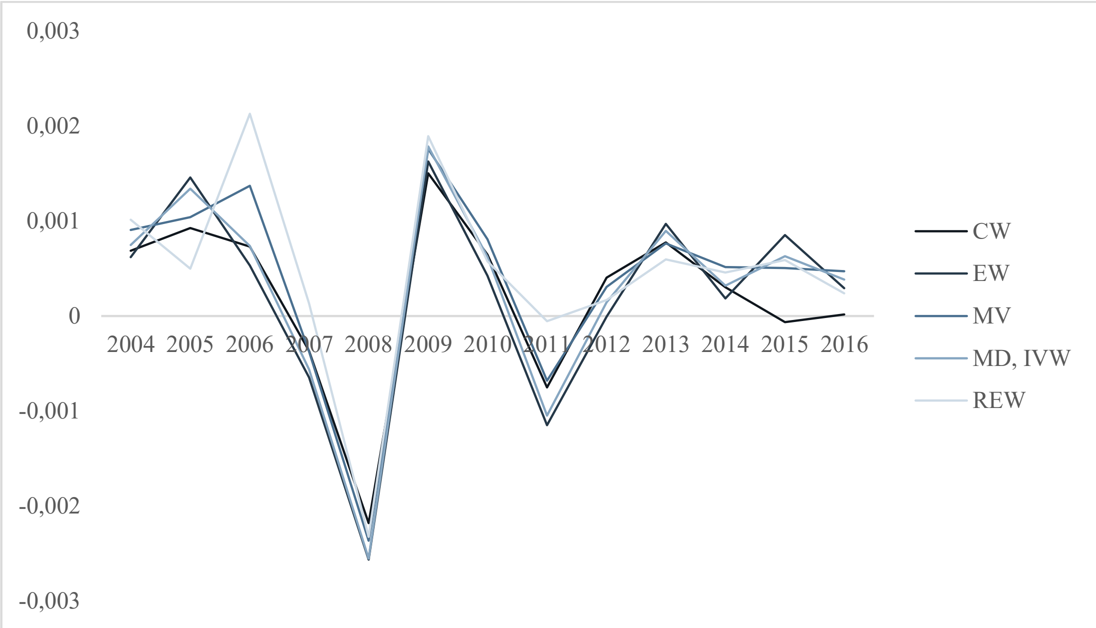


Figure 6.5 "Sustainable" Yearly Average Portfolio Return 2004-2016

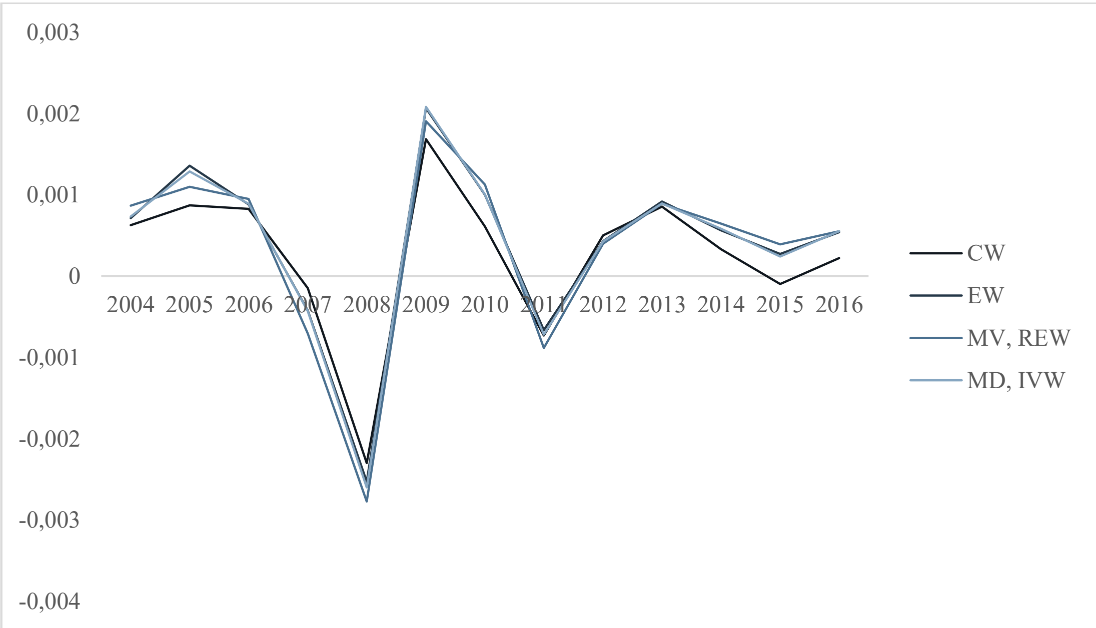
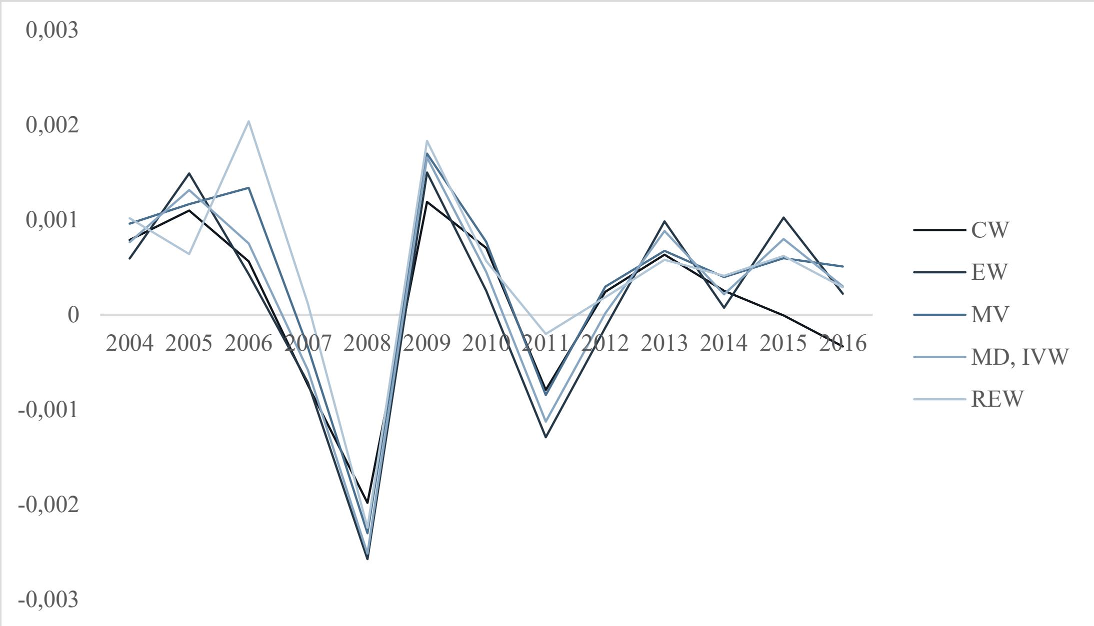


Figure 6.6 "Complement" Yearly Average Portfolio Return 2004-2016



For the broad universe, it can be observed that the performance of all strategies is very similar during the 2008 financial crisis. While the development of the average yearly returns follows a similar pattern, during non-crisis periods the difference in the performance between the different strategies is larger. The same is observed for the "Complement" portfolio. Additionally, on average, the REW strategy shows the highest return. Compared to 2008, in 2006 this strategy performs much better than the rest. On the other hand, the EW, MD and IVW strategies seem to be more sensitive to the economic conditions, as they not only present the worst performance in 2008, but also in 2011. At the same time, they are above the rest in most of the peaks. Therefore, to conclude, during crisis periods, the choice of the weight allocation strategy matters less compared to non-crisis periods.

The "Sustainable" portfolio also presents a similar development to the other two portfolios, given that the returns are mainly affected by the general economic conditions. In this case, in contrast to the other two portfolios, all the strategies behave similarly during the whole period, regardless of the economic state. Given that "Complement" contains a larger proportion of the stocks in "Whole", the shapes of the graphs of these two portfolios look very much alike. However, the proportion of firms in the "Sustainable" sample is smaller, so the shape of the graph differs slightly from the other two.

To sum up, the conclusions derived from our results are different from previous literature, which suggests that the outperformance of the risk-based strategies over the CW strategy is higher during crises. In this study, the risk-based techniques outperform the CW, but the difference is not larger during crisis periods. This contradiction might be due to the fact that the sample of companies used is different.

7 Robustness Check

In order to test the robustness of the results, the strategies are applied to different estimation horizons. The estimation period ranges from 01.01.2002 to 31.12.2008, and the evaluation period from 01.01.2009 to 31.12.2016. In order to answer the last subquestion, this section compares the results from the application of the above utilized performance measures within the new time horizons to the previous results.

The methodology used to estimate the VCV matrix, derive portfolio weights, construct the portfolios and apply the performance measures is identical to the procedure used for the previous analysis.

Table A.5 presents the descriptive statistics of the constructed portfolios, and tables A.6 to A.14 show the results of the application of the performance measures. Figures A.1 to A.9 display the time evolution of portfolio values, the return-standard deviation relationship and yearly average returns.

Starting with the Portfolio Values, from figures A.1 to A.3 it can be observed that all the strategies present a general increase over time, with the exception of a slight decline in 2011 until 2012. In addition, in “Whole” and “Complement”, the CW also shows a value decline in 2015. For these two portfolios, the values for the MV and REW strategies lie above the rest over the whole period. For the “Sustainable” sample, however, portfolio values decline for all the strategies in the last year and the EW, MD and IVW outperform the other strategies.

For the Average Annual Return, it can be observed that the MV and REW strategies are the best performers in the “Whole” portfolio and the latter one also in “Complement”. In the “Sustainable” portfolio, the EW presents the highest raw performance. The CW strategy clearly underperforms the rest of the strategies in the three portfolios.

In terms of Standard Deviation, the EW is the least risky strategy for “Whole” and “Complement”, whereas the REW has the lowest Standard Deviation for “Sustainable”. The CW is the riskiest strategy in the three samples. Furthermore, the risk related to the “Sustainable” portfolio is higher than in the other two.

Regarding the risk adjusted returns, from both the Sharpe and Sortino ratios one can conclude that the REW performs the best in the “Whole” and “Complement” portfolios, while the “EW” does in the “Sustainable”. In this case, and in contrast to the conclusions from the previous analysis, the downside deviations are lower than the standard deviations, resulting in higher Sortino ratios than Sharpe ratios. This could be explained by the fact that the evaluation period in the robustness analysis does not contain a crisis, what implies that there are not as many negative excess returns as in our previous analysis, resulting in a lower downside deviation and lower average risk-free rates.

The Maximum Drawdown can be found in the period 2011-2012, and the largest decline corresponds to the "REW" strategy for all portfolios.

The Value at Risk is the lowest for the EW technique in "Whole" and "Complement" and for "REW" in Sustainable. This result is in accordance with the conclusions obtained from the Annual Standard Deviation.

Expected Shortfall is the lowest for the REW in the "Whole" and "Sustainable" and for EW in "Complement".

In order to compare the conclusions to the previous findings of this study, the last subquestion is addressed:

5. *How different are the results when the strategies are applied based on a different estimation horizon?*

The Portfolio Values, Average Annual Return and risk adjusted returns measures derive the very same conclusions for the two different estimation horizons. The REW technique performs the best when investing in a broad universe of stocks and the EW strategy delivers higher returns when the investor is interested only in sustainable stocks. In addition, Sharpe and Sortino ratios are much higher in the new horizon and do not present any negative values, given that none of the strategies deliver any negative excess return. Comparing the sustainable portfolio to the other two, the conclusions are the same as in the previous analysis, i.e. the heuristic based techniques and MD provide higher returns in the "Sustainable" portfolio than in the "Whole" and "Complement" portfolios. Thus, the combination of the financial and non-financial strategies is also beneficial for the heuristic based and MD techniques. Therefore, the robustness check does not alter the results in this respect.

Since the estimation period in the robustness analysis is longer and therefore entails different economic states, it is expected that the volatility is estimated in a more accurate way. Given that the evaluation period in the previous analysis contained the 2008 financial crisis, the Maximum Drawdown in that analysis is higher than in the robustness check. Comparing the 2011-2014 subperiod, the risk-based strategies lead to lower Maximum Drawdowns for all the three portfolios in the robustness analysis. In the previous analysis, however, the "Sustainable" portfolio presents slightly lower Maximum Drawdowns for the heuristic based strategies. Regarding the last subperiod, in both analysis the CW is the only strategy that presents a decline in "Whole" and "Complement" while all the strategies do in "Sustainable", where the risk-based strategies perform better than the heuristic in both cases and are lower in the robustness analysis.

Similarly, the heuristic based strategies have a lower Value at Risk only in the case of the Sustainable portfolio in the original analysis, whereas the risk-based always present a lower risk for the robustness horizons.

Figures A.4 to A.6 display the Return-Standard Deviations scatterplots for the three portfolios. From the first graph, it is obvious that the CW strategy is the worst performer. The remaining strategies are situated in the upper left, delivering high returns and low standard deviations. In comparison with the prior analysis, all the strategies provide a better performance, especially the EW and REW, which were more extreme before, situated in the lower left and upper right quadrants, respectively. Similarly, the "Sustainable" portfolios also present more favorable results in the robustness check, even though they are still situated in the upper right quadrant.

From the yearly average portfolio returns plots (figures A.7 to A.9), it can be observed that, for all the three portfolios, the EW strategy delivers the lowest return during the 2011 recession. However, the MV and REW, while also delivering negative returns, perform much better compared to the previous strategy. The explanation to this fact is that in the robustness analysis risk is predicted better, so that the risk-based strategies improve their performance, i.e. the decline in return is not as severe as in the previous analysis. On the other hand, since the EW does not incorporate any measure of risk, this strategy does not improve its performance during crisis periods. This conclusion is in line with the findings of Bertrand and Lapointe (2014). Since the Market Capitalization values are taken from 31.12.2008, when stock prices where low, the CW technique reflects in some way the risk during crisis. Thus, the performance of this strategy is similar to the MV and REW in 2011.

To conclude, even though the takeaways are very similar for the two analysis, we consider that the inclusion of a longer estimation horizon containing periods of both high and low volatility leads to a lower underestimation of risk.

8 Limitations and Further Research

We are aware that the scope of this study is limited and therefore simplistic to some extent. Nevertheless, the results allow to have an indication about the performance of the different weight allocation strategies. In the following, a summary of the main limitations and some suggestions for potential further research are provided.

Concerning the data, this study only considers the firms with available stock prices and market value information over the whole period. Therefore, many firms are excluded from the analysis, what might bias the results. Additionally, since the sample is composed of only Swedish stocks, the results might not be completely representative when the strategies are applied to international portfolios or portfolios of companies not based in Sweden. We are aware that some investors are interested in geographically diversified portfolios to avoid exposure to a single national economy. A suggestion for further research is an expansion of the geographical scope, also taking into account other countries and continents.

Regarding the selection of the firms in the sustainable sample, the data file provided by Resility contains static observations from 2016 and for this study it is assumed that the information already held true at the beginning of the estimation period, i.e. 2002. This means that it is assumed that the sustainable firms in 2016 were the same as in 2002 and that they were already considered sustainable 15 years ago.

Furthermore, the market values used for the estimation of the CW and the REW strategies are static observations from the last day in the estimation period, which is not an accurate reflection of the actual recent market capitalization of the firms.

The portfolios are not rebalanced. This means that the sample of companies is fixed for the whole period and the weights do not change over the whole evaluation window. A more accurate methodology would include the use of rolling windows to adjust the portfolio composition. Consequently, transaction costs would need to be taken into account. This would imply that the firms are added to or removed from the rolling sample at the time when they are founded or delisted during the analyzed period.

Similarly, the components of the sustainable sample and the market values of all the firms in the sample would be updated at each rebalancing date.

In this study, a short-selling constraint is imposed. Additionally, there is no reinvestment of dividends which prevents the portfolio values from increasing exponentially over time. Both limitations could be considered a potential extension for a more holistic study.

As previously outlined, different VCV matrix estimation methods exist. The constant correlation model has been found to provide accurate results, but other methods, such as the single index or shrinkage models, could also be used for the performance evaluation of the strategies.

The fact that the sustainable sample is a fraction of all the total available firms implies the existence of idiosyncratic risk in the sample. This contradicts the CAPM theory, which assumes that idiosyncratic risk can be diversified away. In line with this argumentation, the Jensen's alpha is not employed as a performance measure in this study since it also requires the assumption that investors diversify all firm-specific risk. This is amplified by the exclusion of stocks with missing data, as it further restricts the sample.

Finally, this paper assesses the performance of six portfolio weight allocation strategies, which are perceived to be the most commonly used. However, there are several other techniques that could be analyzed, such as the Equal Risk Contribution, Risk-Weighted Alpha or Autoregressive Integrated Moving Average Weighting (Finnerman and Kirchmann, 2015).

9 Conclusion

In the following, the main takeaways from the study are summarized and an answer to the previously formulated research question is provided.

The first aspect worth noticing is that all risk and return performance measures lead to exactly the same findings. Furthermore, the “Complement” portfolio behaves similarly to “Whole”, while the “Sustainable” portfolio tends to show an opposite behavior.

Concerning the performance of the strategies, the IVW and MD and the MV and REW techniques provide very similar results.

Overall, the CW is the least effective strategy. Apart from this strategy, in the broad universe of stocks, the EW is the worst performer. In this universe, the most favorable strategies are the MV and REW. In the sustainable universe the conclusions are the opposite way, with the EW being the best performing strategy and the MV and REW being the worst. To conclude, the combination of the financial and non-financial criteria present in the sustainable sample benefit the MD and EW but penalize the MV and REW strategies.

Generally, the risk-based strategies outperform the heuristic based in the broad universe, whereas the opposite holds true in the sustainable universe. In addition, the values are similar among the different strategies for the “Sustainable” portfolio, while they are more dispersed for the other two portfolios.

In terms of risk, the sustainable portfolio shows a higher volatility compared to the broad portfolio. In both of them, the EW, IVW and MD seem to be more sensitive to the economic conditions, lying below the rest of the strategies in recession periods and above in economic upswings. In crisis periods, all the strategies perform equally poor.

The results from the robustness analysis support the conclusions derived above. The CW underperforms the rest of the strategies. The REW is the best performer in the broad universe, while the EW is the best in the sustainable universe. Additionally, the combination of the financial and non-financial criteria is beneficial for MD.

While in the previous analysis all the strategies perform similarly bad during crisis periods, in the robustness check risk-based techniques improve their performance in crises. This is due to a better prediction of risk in the second analysis. Such conclusion is supported by lower Maximum Drawdowns in the robustness analysis.

To sum up, in order to answer the research question, risk-based strategies perform differently among each other when they are applied to a sustainable stock universe. Concretely, the MD technique benefits but the MV and REW are penalized in comparison to the broad universe.

References

Benninga, S. and Czaczkes, B. (2008), Financial modelling using Excel, 3rd edition, Ch. 10. London, England: MIT Press.

Bertrand, P. and Lapointe, V. (2014), How performance of risk-based strategies is modified by socially responsible investment universe? International Review of Financial Analysis, vol. 38, pp. 175-190.

Bodie, Z., Kane, A. and Marcus, A.J., (2014), Investments, 10th edition, p. 48. New York, US: McGraw-Hill.

Capelle-Blancard, G. and Monjon, S. (2014), The performance of socially responsible funds: Does the screening process matter? European Financial Management, vol. 20, pp. 494–520.

Christiansen, C., Jansson, T., Kallestrup-Lamb, M. and Noren, V. (2018), Who are the socially responsible investors?

Clarke, R., De Silva, H. and Thorley, S. (2013), Risk Parity, maximum diversification and minimum variance: An analytic perspective, Journal of Portfolio Management, pp. 39-53.

Cortez, M.C. and Silva, F. (2016), The performance of US and European green funds in different market conditions, Journal of Cleaner Production, vol. 135 pp. 558-566.

DataStream International, [Accessed March 25th 2018]

DeMiguel, V., Garlappi, L., Uppal, R. (2009), Optimal versus naive diversification: How inefficient is the 1/N portfolio strategy? The Review of Financial Studies, vol. 22, no.5, pp.1915-1953.

Dhaliwal, D., Li, O. Z., Tsang, A and Yang, Y. G. (2011), Voluntary nonfinancial disclosure and the cost of equity capital: The initiation of corporate social responsibility reporting. The Accounting Review, vol. 86, pp. 59–100.

Feibel, B. J. (2003), Investment Performance Measurement, Ch. 2. Hoboken, New Jersey, US: Wiley.

Finnerman, E. and Kirchmann, C. (2015), Evaluation of alternative weighting techniques on the Swedish stock market.

Hull, J. C. (2015), Risk management and financial institutions, 4th edition, Ch. 12. Hoboken, New Jersey, US: Wiley.

Knutzen, S. and Retterholt, J. (2015), Performance of risk-based asset allocation strategies.

Learning for a Sustainable Future - Teacher Centre, UNESCO, as cited in Global Footprints, n.d. Available online: globalfootprints.org [Accessed April 18th 2018]

Ledoit, O. and Wolf, M. (2003), Honey, I shrunk the sample covariance matrix.

Ledoit, O. and Wolf, M. (2002), Improved estimation of the covariance matrix of stock returns with an application to portfolio selection, Journal of Empirical Finance, vol. 10, pp. 603-621.

Markowitz, H. M. (1952), Portfolio selection, Journal of Finance, vol. 7, no. 1, pp.77-91.

Markowitz, H. M. (1959), Portfolio selection: efficient diversification of investments. New York: Wiley.

Michaud, R.O. (1989), The Markowitz optimization enigma: Is "Optimized" optimal?, SSRN Electronic Journal.

Nofsinger, J. and Varma, A. (2013), Socially responsible funds and market crises, Journal of Banking and Finance, vol. 48, pp. 180-193.

Saphiro, A. (2008), Index Models Lecture Notes 8, Available Online: http://pages.stern.nyu.edu/~ashapiro/courses/B01.231103/FFL08.pdf [Accessed April 16th 2018]

Sharpe, W. F. (1964), Capital Asset Prices: A theory of market equilibrium under conditions of Risk, Journal of Finance, vol. 19, no.3.

Swedish House of Finance (sustainable companies' database) (n.d.), Available Online: data.houseoffinance.se [Accessed April 16th 2018]

Swedish National Bank (n.d.), Available online: riksbank.se [Accessed April 16th 2018]

Tobin, J. (1958), Liquidity preference as behavior towards risk, Review of Economic Studies Ltd., vol. 25 no. 2.

UBS (2015), Investment strategy insights, Available online: ubs.com [Accessed May 10h 2018]

United Nations General Assembly, Brundtland Report for the World Commission on Environment and Development (1987), Our Common Future, p. 43, Available online: http://www.un-documents.net [Accessed April 18th 2018]

Appendix

Table A.1 Sustainable Firms Selection

			Variables																					
Company Name	**Segment**	**Industry**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**Score[21]**
Svenska Handelsbanken	Large	Financials	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21
Hennes & Mauritz AB, H & M	Large	Consumer Services	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	20
Modern Times Group MTG AB	Large	Consumer Services	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	20
Trelleborg AB	Large	Industrials	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	20
Ericsson, Telefonab. L M	Large	Technology	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	20
Boliden AB	Large	Basic Materials	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	19
Axfood AB	Large	Consumer Services	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	19
NIBE Industrier AB	Large	Industrials	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	19
Sandvik AB	Large	Industrials	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	19
SKF, AB	Large	Industrials	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	19
Volvo, AB	Large	Industrials	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	19
Axis AB	Large	Technology	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	19
Telia Company AB	Large	Telecommunications	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	19
BillerudKorsnÃ¤s AB	Large	Basic Materials	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	18
Swedish Match AB	Large	Consumer Goods	1	1	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	18
Castellum AB	Large	Financials	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1	1	18
JM AB	Large	Financials	1	1	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	18
SAAB AB	Large	Industrials	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	18

[21] 1 indicates that the firm fulfils the respective variable (yes) and 0 indicates that it does not (no). The total score is the sum of all the 1 for each firm.

Table A.1 Sustainable Firms Selection (cont.)

Company Name	Segment	Industry	Variables																					Score
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Addtech AB	Mid	Industrials	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	18
Gunnebo AB	Mid	Industrials	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	18
Electrolux, AB	Large	Consumer Goods	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	1	1	1	1	1	0	17
Fabege AB	Large	Financials	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	0	1	17
ASSA ABLOY AB	Large	Industrials	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	17
Atlas Copco AB	Large	Industrials	1	1	1	1	0	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	0	17
NCC AB	Large	Industrials	1	1	1	1	1	1	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	17
Peab AB	Large	Industrials	1	1	1	1	0	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	17
Securitas AB	Large	Industrials	1	1	0	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	17
Skanska AB	Large	Industrials	1	1	1	1	0	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	17
Lundin Petroleum AB	Large	Oil & Gas	1	1	1	1	1	1	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	17
Fagerhult, AB	Mid	Industrials	1	1	1	1	0	1	1	1	1	0	1	1	0	0	1	1	1	1	1	1	1	17
Holmen AB	Large	Basic Materials	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	0	0	16
SSAB AB	Large	Basic Materials	1	1	1	1	0	1	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	16
Swedbank AB	Large	Financials	1	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	1	1	1	0	0	16
AF AB	Large	Industrials	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	0	0	16
Clas Ohlson AB	Mid	Consumer Services	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	0	1	1	1	0	1	16
Vitrolife AB	Mid	Health Care	0	1	0	1	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	1	1	16
Nolato AB	Mid	Industrials	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	16
Investor AB	Large	Financials	1	1	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	15
Nordea Bank AB	Large	Financials	1	1	1	0	0	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	0	15
Skandinaviska Enskilda Banken	Large	Financials	1	1	1	1	0	0	0	1	1	1	1	1	0	1	0	1	1	1	1	0	1	15
Elekta AB	Large	Health Care	1	1	0	1	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	15
SWECO AB	Large	Industrials	1	1	0	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	15
Haldex AB	Mid	Consumer Goods	1	1	1	1	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	0	0	15
Mekonomen AB	Mid	Consumer Goods	1	1	0	1	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	15

Table A.1 Sustainable Firms Selection (cont.)

	List of Variables
1	CEO/Chair/Executive sustainability statement
2	Environmental policy and assessment
3	Targets associated with environmental performance
4	Steps taken to reduce negative environmental impact
5	Increased usage of renewable energy
6	Targets associated with efficient use of resources
7	Board of Directors responsible for ES performance
8	Senior Executives responsible for ES performance
9	External audit of ESG reporting
10	Female employees %
11	Training and education policy for employees
12	Supplier guidelines
13	Supplier assessment for labor practices
14	Supplier assessment for human rights
15	Supplier assessment for environmental impact
16	Whistle-blower mechanisms / hotlines
17	Anti-corruption policy, including extortion and bribery
18	Human rights policy or statement
19	Code of conduct / ethics policy
20	Social impact assessments on local communities
21	Local community development programs

Table A.2 Descriptive Statistics of Daily Portfolio Returns 2004-2016

CW WHOLE	
Mean	0,0002
Standard Error	0,00023
Median	0,00041
Mode	0
Standard Deviation	0,01353
Sample Variance	0,00018
Kurtosis	5,46889
Skewness	-0,0911
Range	0,17393
Minimum	-0,0847
Maximum	0,08919
Sum	0,68029
Count	3392

CW SUSTAINABLE	
Mean	0,00025
Standard Error	0,00024
Median	0,00015
Mode	0
Standard Deviation	0,01401
Sample Variance	0,0002
Kurtosis	5,97363
Skewness	0,01907
Range	0,18195
Minimum	-0,0865
Maximum	0,09545
Sum	0,84844
Count	3392

CW COMPLEMENT	
Mean	0,00012
Standard Error	0,00024
Median	0,00029
Mode	0
Standard Deviation	0,01392
Sample Variance	0,00019
Kurtosis	4,74679
Skewness	-0,3597
Range	0,16907
Minimum	-0,0905
Maximum	0,07857
Sum	0,41618
Count	3392

EW WHOLE	
Mean	0,0002
Standard Error	0,00016
Median	0,0008
Mode	0
Standard Deviation	0,00927
Sample Variance	8,6E-05
Kurtosis	7,20956
Skewness	-0,7202
Range	0,13027
Minimum	-0,0647
Maximum	0,06553
Sum	0,67453
Count	3392

EW SUSTAINABLE	
Mean	0,00039
Standard Error	0,00022
Median	0,00069
Mode	0
Standard Deviation	0,01255
Sample Variance	0,00016
Kurtosis	5,79272
Skewness	-0,2534
Range	0,16257
Minimum	-0,0737
Maximum	0,08889
Sum	1,33763
Count	3392

EW COMPLEMENT	
Mean	0,00014
Standard Error	0,00015
Median	0,00065
Mode	0
Standard Deviation	0,00869
Sample Variance	7,6E-05
Kurtosis	7,57855
Skewness	-0,8327
Range	0,12379
Minimum	-0,0652
Maximum	0,05864
Sum	0,47872
Count	3392

IVW WHOLE	
Mean	0,00027
Standard Error	0,00016
Median	0,00075
Mode	0
Standard Deviation	0,00957
Sample Variance	9,2E-05
Kurtosis	6,66575
Skewness	-0,6098
Range	0,11813
Minimum	-0,0614
Maximum	0,05676
Sum	0,9147
Count	3392

IVW SUSTAINABLE	
Mean	0,00038
Standard Error	0,00022
Median	0,0007
Mode	0
Standard Deviation	0,01269
Sample Variance	0,00016
Kurtosis	5,87779
Skewness	-0,2511
Range	0,16746
Minimum	-0,0753
Maximum	0,09217
Sum	1,28814
Count	3392

IVW COMPLEMENT	
Mean	0,00022
Standard Error	0,00015
Median	0,00079
Mode	0
Standard Deviation	0,00861
Sample Variance	7,4E-05
Kurtosis	7,76139
Skewness	-0,7422
Range	0,12387
Minimum	-0,0598
Maximum	0,06403
Sum	0,75848
Count	3392

MV WHOLE		*MV SUSTAINABLE*		*MV COMPLEMENT*	
Mean	0,00039	Mean	0,00034	Mean	0,00038
Standard Error	0,00018	Standard Error	0,00024	Standard Error	0,00016
Median	0,00052	Median	0,00047	Median	0,00079
Mode	0	Mode	0	Mode	0
Standard Deviation	0,01061	Standard Deviation	0,01409	Standard Deviation	0,00957
Sample Variance	0,00011	Sample Variance	0,0002	Sample Variance	9,1E-05
Kurtosis	8,22783	Kurtosis	5,96517	Kurtosis	7,76431
Skewness	-0,1781	Skewness	-0,2092	Skewness	-0,3711
Range	0,18435	Range	0,1894	Range	0,15688
Minimum	-0,0809	Minimum	-0,0816	Minimum	-0,069
Maximum	0,10348	Maximum	0,10778	Maximum	0,08788
Sum	1,3068	Sum	1,16069	Sum	1,27698
Count	3392	Count	3392	Count	3392

MD WHOLE		*MD SUSTAINABLE*		*MD COMPLEMENT*	
Mean	0,00026	Mean	0,00038	Mean	0,00022
Standard Error	0,00017	Standard Error	0,00022	Standard Error	0,00015
Median	0,00075	Median	0,0007	Median	0,0008
Mode	0	Mode	0	Mode	0
Standard Deviation	0,00982	Standard Deviation	0,01269	Standard Deviation	0,00861
Sample Variance	9,7E-05	Sample Variance	0,00016	Sample Variance	7,4E-05
Kurtosis	7,05562	Kurtosis	5,87776	Kurtosis	7,75963
Skewness	-0,5895	Skewness	-0,2511	Skewness	-0,7404
Range	0,13604	Range	0,16746	Range	0,12404
Minimum	-0,0629	Minimum	-0,0753	Minimum	-0,0598
Maximum	0,07315	Maximum	0,09217	Maximum	0,0642
Sum	0,89205	Sum	1,28814	Sum	0,7584
Count	3392	Count	3392	Count	3392

REW WHOLE		*REW SUSTAINABLE*		*REW COMPLEMENT*	
Mean	0,00045	Mean	0,00034	Mean	0,00045
Standard Error	0,00025	Standard Error	0,00024	Standard Error	0,00022
Median	0,00025	Median	0,00046	Median	0,00041
Mode	0	Mode	0	Mode	0
Standard Deviation	0,01463	Standard Deviation	0,0141	Standard Deviation	0,01302
Sample Variance	0,00021	Sample Variance	0,0002	Sample Variance	0,00017
Kurtosis	298,034	Kurtosis	5,95451	Kurtosis	267,966
Skewness	0,47408	Skewness	-0,2082	Skewness	0,52291
Range	0,70543	Range	0,18937	Range	0,61727
Minimum	-0,362	Minimum	-0,0816	Minimum	-0,3171
Maximum	0,34342	Maximum	0,10777	Maximum	0,30019
Sum	1,53833	Sum	1,16049	Sum	1,52029
Count	3392	Count	3392	Count	3392

Table A.3 Excess Return 2004-2016

EXCESS RETURN	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	-1,55%	-0,32%	-6,13%
Equal Weight	-1,66%	3,43%	-3,16%
Inverse Volatility Weighting	0,18%	3,05%	-1,01%
RISK-BASED TECHNIQUES			
Minimum Variance	3,19%	2,07%	2,96%
Maximum Diversification	0,01%	3,05%	-1,01%
Risk Efficient Weighting	4,96%	2,07%	4,83%

Table A.4 Downside Deviation 2004-2016

DOWNSIDE DEVIATION	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	40,19%	40,73%	41,86%
Equal Weight	28,69%	37,11%	27,14%
Inverse Volatility Weighting	29,26%	37,57%	26,62%
RISK-BASED TECHNIQUES			
Minimum Variance	31,21%	41,59%	28,52%
Maximum Diversification	30,04%	37,57%	26,62%
Risk Efficient Weighting	40,25%	41,64%	35,94%

Table A.5 Descriptive Statistics of Daily Portfolio Returns 2009-2016

CW WHOLE		*CW SUSTAINABLE*		*CW COMPLEMENT*	
Mean	0,0003	Mean	0,0004	Mean	0,0003
Standard Error	0,0003	Standard Error	0,0003	Standard Error	0,0003
Median	0,0002	Median	7E-06	Median	0,0002
Mode	0	Mode	0	Mode	0
Standard Deviation	0,0127	Standard Deviation	0,0129	Standard Deviation	0,013
Sample Variance	0,0002	Sample Variance	0,0002	Sample Variance	0,0002
Kurtosis	3,4166	Kurtosis	3,5468	Kurtosis	2,9951
Skewness	-0,229	Skewness	-0,18	Skewness	-0,319
Range	0,1444	Range	0,1498	Range	0,1396
Minimum	-0,084	Minimum	-0,084	Minimum	-0,085
Maximum	0,0604	Maximum	0,0662	Maximum	0,0549
Sum	0,7291	Sum	0,7822	Sum	0,6442
Count	2087	Count	2087	Count	2087

EW WHOLE	
Mean	0,0004
Standard Error	0,0002
Median	0,0007
Mode	0
Standard Deviation	0,0087
Sample Variance	8E-05
Kurtosis	5,0716
Skewness	-0,507
Range	0,1063
Minimum	-0,052
Maximum	0,0539
Sum	0,8352
Count	2087

EW SUSTAINABLE	
Mean	0,0006
Standard Error	0,0003
Median	0,0005
Mode	0
Standard Deviation	0,0121
Sample Variance	0,0001
Kurtosis	3,7095
Skewness	-0,238
Range	0,1374
Minimum	-0,074
Maximum	0,0637
Sum	1,3403
Count	2087

EW COMPLEMENT	
Mean	0,0003
Standard Error	0,0002
Median	0,0006
Mode	0
Standard Deviation	0,0081
Sample Variance	7E-05
Kurtosis	5,5242
Skewness	-0,539
Range	0,106
Minimum	-0,051
Maximum	0,0548
Sum	0,686
Count	2087

IVW WHOLE	
Mean	0,0005
Standard Error	0,0002
Median	0,0006
Mode	0
Standard Deviation	0,009
Sample Variance	8E-05
Kurtosis	4,9295
Skewness	-0,479
Range	0,1109
Minimum	-0,055
Maximum	0,0556
Sum	0,9501
Count	2087

IVW SUSTAINABLE	
Mean	0,0006
Standard Error	0,0003
Median	0,0005
Mode	0
Standard Deviation	0,012
Sample Variance	0,0001
Kurtosis	3,706
Skewness	-0,24
Range	0,1364
Minimum	-0,074
Maximum	0,0627
Sum	1,3111
Count	2087

IVW COMPLEMENT	
Mean	0,0004
Standard Error	0,0002
Median	0,0007
Mode	0
Standard Deviation	0,0082
Sample Variance	7E-05
Kurtosis	5,7331
Skewness	-0,568
Range	0,1055
Minimum	-0,053
Maximum	0,0528
Sum	0,8094
Count	2087

MV WHOLE	
Mean	0,0005
Standard Error	0,0002
Median	0,0006
Mode	0
Standard Deviation	0,0093
Sample Variance	9E-05
Kurtosis	3,4857
Skewness	-0,355
Range	0,1054
Minimum	-0,058
Maximum	0,0477
Sum	1,1008
Count	2087

MV SUSTAINABLE	
Mean	0,0005
Standard Error	0,0002
Median	0,0004
Mode	0
Standard Deviation	0,0103
Sample Variance	0,0001
Kurtosis	3,421
Skewness	-0,249
Range	0,1177
Minimum	-0,068
Maximum	0,0493
Sum	1,0516
Count	2087

MV COMPLEMENT	
Mean	0,0005
Standard Error	0,0002
Median	0,0006
Mode	0
Standard Deviation	0,0091
Sample Variance	8E-05
Kurtosis	3,6428
Skewness	-0,42
Range	0,1039
Minimum	-0,055
Maximum	0,0488
Sum	1,0802
Count	2087

MD WHOLE	
Mean	0,0005
Standard Error	0,0002
Median	0,0006
Mode	0
Standard Deviation	0,009
Sample Variance	8E-05
Kurtosis	4,9312
Skewness	-0,479
Range	0,1109
Minimum	-0,055
Maximum	0,0556
Sum	0,9498
Count	2087

MD SUSTAINABLE	
Mean	0,0006
Standard Error	0,0003
Median	0,0005
Mode	0
Standard Deviation	0,012
Sample Variance	0,0001
Kurtosis	3,706
Skewness	-0,24
Range	0,1364
Minimum	-0,074
Maximum	0,0627
Sum	1,3111
Count	2087

MD COMPLEMENT	
Mean	0,0004
Standard Error	0,0002
Median	0,0007
Mode	0
Standard Deviation	0,0082
Sample Variance	7E-05
Kurtosis	5,7353
Skewness	-0,568
Range	0,1055
Minimum	-0,053
Maximum	0,0528
Sum	0,8092
Count	2087

REW WHOLE	
Mean	0,0005
Standard Error	0,0002
Median	0,0006
Mode	0
Standard Deviation	0,0093
Sample Variance	9E-05
Kurtosis	3,463
Skewness	-0,352
Range	0,1047
Minimum	-0,057
Maximum	0,0474
Sum	1,1005
Count	2087

REW SUSTAINABLE	
Mean	0,0005
Standard Error	0,0002
Median	0,0003
Mode	0
Standard Deviation	0,0103
Sample Variance	0,0001
Kurtosis	3,412
Skewness	-0,247
Range	0,1175
Minimum	-0,068
Maximum	0,0493
Sum	1,047
Count	2087

REW COMPLEMENT	
Mean	0,0005
Standard Error	0,0002
Median	0,0006
Mode	0
Standard Deviation	0,0091
Sample Variance	8E-05
Kurtosis	3,6355
Skewness	-0,418
Range	0,1038
Minimum	-0,055
Maximum	0,0487
Sum	1,0826
Count	2087

Table A.6 Average Annual Return 2009-2016

AVERAGE ANNUAL RETURN	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	9,08%	9,75%	8,03%
Equal Weight	10,40%	**16,70%**	8,55%
Inverse Volatility Weighting	11,84%	16,33%	10,08%
RISK-BASED TECHNIQUES			
Minimum Variance	**13,71%**	13,10%	13,46%
Maximum Diversification	11,83%	16,33%	10,08%
Risk Efficient Weighting	**13,71%**	13,04%	**13,49%**

Table A.7 Annual Standard Deviation 2009-2016

ANNUAL STANDARD DEVIATION	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	20,40%	20,88%	20,93%
Equal Weight	**14,01%**	19,56%	**13,04%**
Inverse Volatility Weighting	14,54%	19,31%	13,20%
RISK-BASED TECHNIQUES			
Minimum Variance	15,01%	16,58%	14,60%
Maximum Diversification	14,54%	19,31%	13,19%
Risk Efficient Weighting	14,96%	**16,56%**	14,60%

Table A.8 Excess Return 2009-2016

EXCESS RETURN	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	5,44%	6,10%	4,38%
Equal Weight	6,76%	13,05%	4,90%
Inverse Volatility Weighting	8,19%	12,69%	6,44%
RISK-BASED TECHNIQUES			
Minimum Variance	10,07%	9,46%	9,81%
Maximum Diversification	8,19%	12,69%	6,44%
Risk Efficient Weighting	10,06%	9,40%	9,84%

Table A.9 Sharpe Ratio 2009-2016

SHARPE RATIO	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	0,2666	0,2922	0,2092
Equal Weight	0,4825	**0,6675**	0,3759
Inverse Volatility Weighting	0,5634	0,6572	0,4879
RISK-BASED TECHNIQUES			
Minimum Variance	0,6710	0,5702	0,6721
Maximum Diversification	0,5632	0,6572	0,4878
Risk Efficient Weighting	**0,6730**	0,5675	**0,6742**

Table A.10 Downside Deviation 2009-2016

DOWNSIDE DEVIATION	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	15,73%	15,69%	16,07%
Equal Weight	10,84%	14,59%	10,16%
Inverse Volatility Weighting	11,17%	14,41%	10,26%
RISK-BASED TECHNIQUES			
Minimum Variance	11,29%	12,40%	11,07%
Maximum Diversification	11,17%	14,41%	10,26%
Risk Efficient Weighting	11,24%	12,38%	11,06%

Table A.11 Sortino Ratio 2009-2016

SORTINO RATIO	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	0,3457	0,3887	0,2726
Equal Weight	0,6238	**0,8947**	0,4823
Inverse Volatility Weighting	0,7333	0,8803	0,6276
RISK-BASED TECHNIQUES			
Minimum Variance	0,8921	0,7624	0,8867
Maximum Diversification	0,7330	0,8803	0,6275
Risk Efficient Weighting	**0,8952**	0,7589	**0,8898**

Table A.12 Maximum Drawdown 2009-2016

MAXIMUM DRAWDOWN	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	29,56%	29,81%	34,13%
Equal Weight	34,00%	30,72%	38,21%
Inverse Volatility Weighting	32,41%	30,30%	35,27%
RISK-BASED TECHNIQUES			
Minimum Variance	24,60%	21,55%	28,40%
Maximum Diversification	32,41%	30,30%	35,27%
Risk Efficient Weighting	**24,34%**	**21,42%**	**28,35%**

MAXIMUM DRAWDOWN 2011-2014	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	28,31%	29,33%	34,13%
Equal Weight	34,00%	30,72%	38,21%
Inverse Volatility Weighting	32,41%	30,30%	35,27%
RISK-BASED TECHNIQUES			
Minimum Variance	24,60%	21,55%	28,40%
Maximum Diversification	32,41%	30,30%	35,27%
Risk Efficient Weighting	**24,34%**	**21,42%**	**28,35%**

MAXIMUM DRAWDOWN 2015-2016	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	29,56%	29,81%	30,61%
Equal Weight	-	21,45%	-
Inverse Volatility Weighting	-	21,23%	-
RISK-BASED TECHNIQUES			
Minimum Variance	-	15,52%	-
Maximum Diversification	-	21,23%	-
Risk Efficient Weighting	-	**15,48%**	-

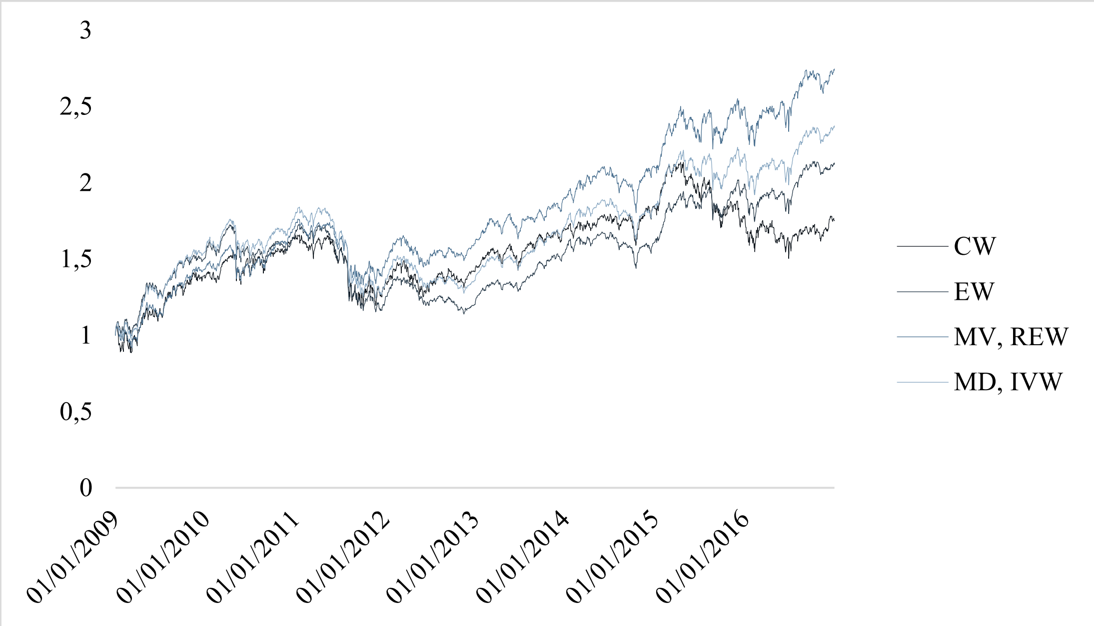
Table A.13 Value at Risk 2009-2016

VALUE AT RISK	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	3,64%	3,76%	3,66%
Equal Weight	**2,50%**	3,39%	**2,32%**
Inverse Volatility Weighting	2,55%	3,38%	2,33%
RISK-BASED TECHNIQUES			
Minimum Variance	2,60%	**2,83%**	2,56%
Maximum Diversification	2,55%	3,38%	**2,32%**
Risk Efficient Weighting	2,59%	**2,83%**	2,56%

Table A.14 Expected Shortfall 2009-2016

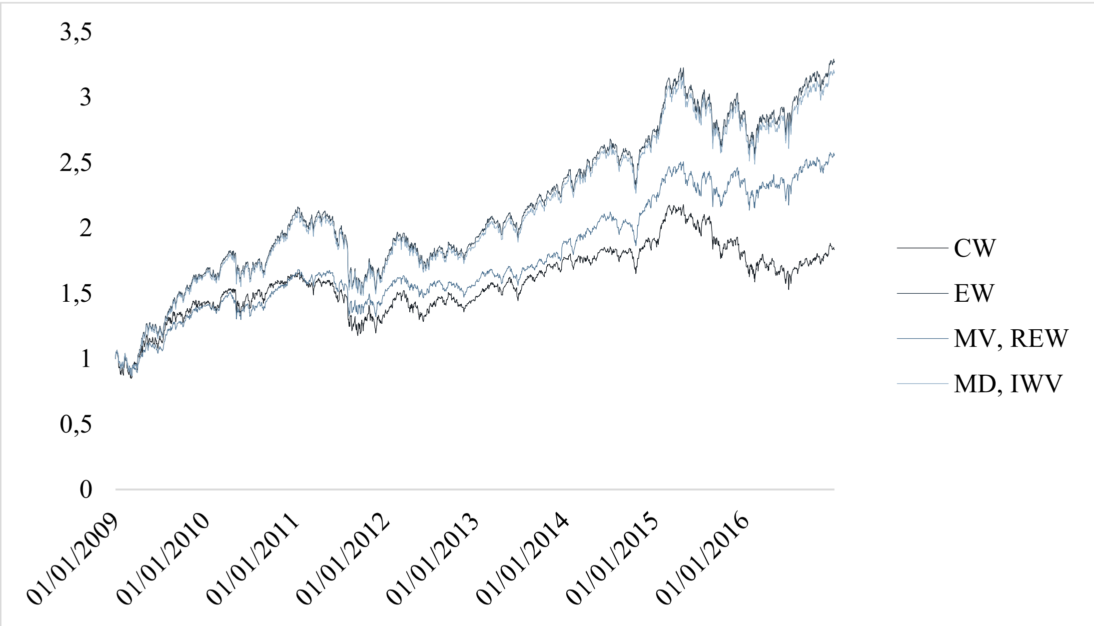
EXPECTED SHORTFALL	Whole	Sustainable	Complement
HEURISTIC BASED TECHNIQUES			
Cap Weight	4,65%	4,79%	4,70%
Equal Weight	3,48%	4,57%	**3,32%**
Inverse Volatility Weighting	3,60%	4,51%	3,36%
RISK-BASED TECHNIQUES			
Minimum Variance	3,47%	3,79%	3,43%
Maximum Diversification	3,60%	4,51%	3,36%
Risk Efficient Weighting	**3,45%**	**3,78%**	3,43%

Figure A.1 "Whole" Portfolio Value 2009-2016



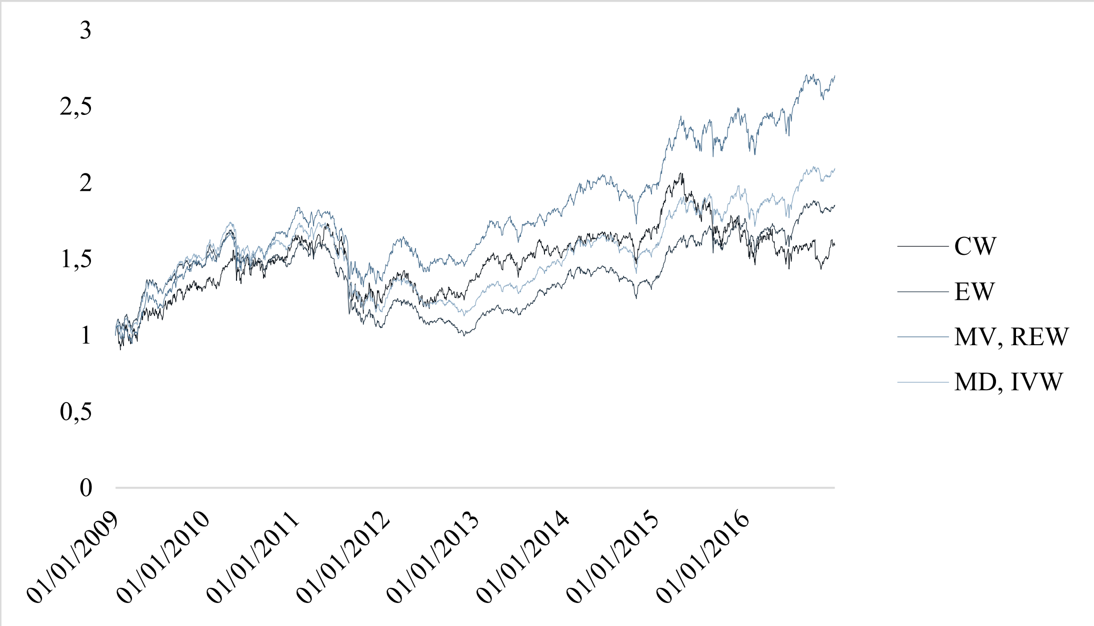
Portfolio values in Millions SEK, for an investment of 1M SEK

Figure A.2 "Sustainable" Portfolio Value 2009-2016



Portfolio values in Millions SEK, for an investment of 1M SEK

Figure A.3 "Complement" Portfolio Value 2009-2016



Portfolio values in Millions SEK, for an investment of 1M SEK

Figure A.4 Return-Standard Deviation "Whole" 2009-2016

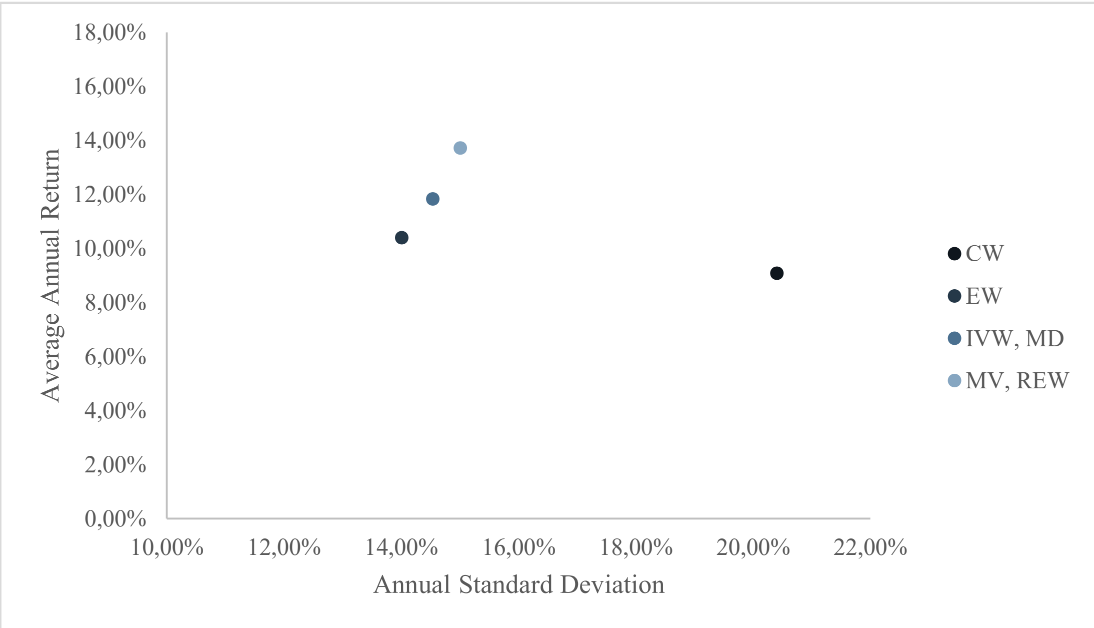


Figure A.5 Return-Standard Deviation "Sustainable" 2009-2016

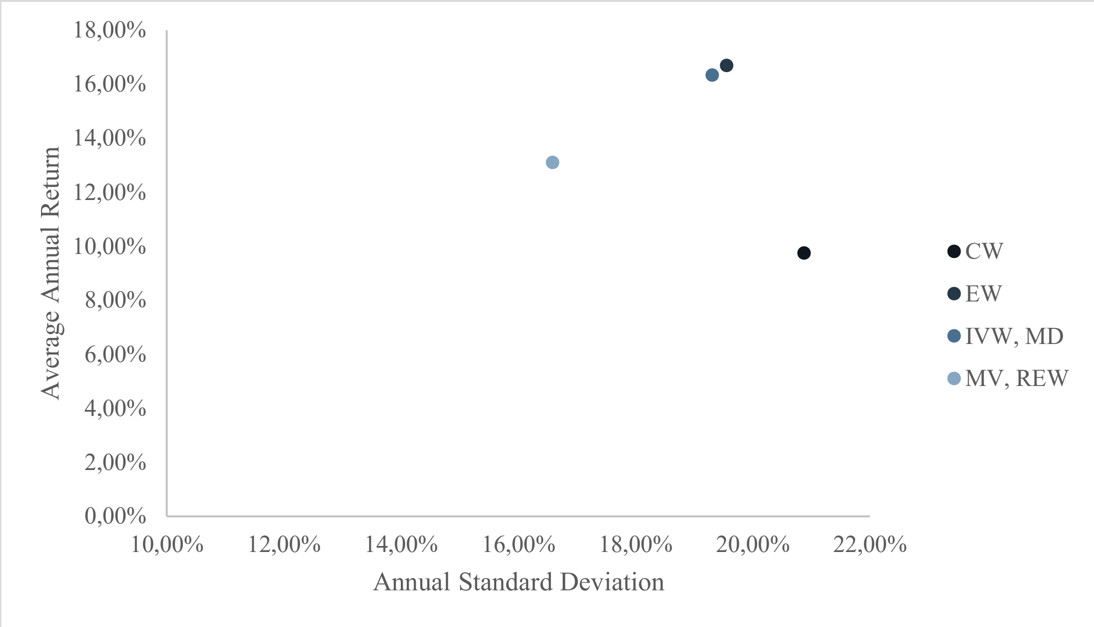


Figure A.6 Return-Standard Deviation "Complement" 2009-2016

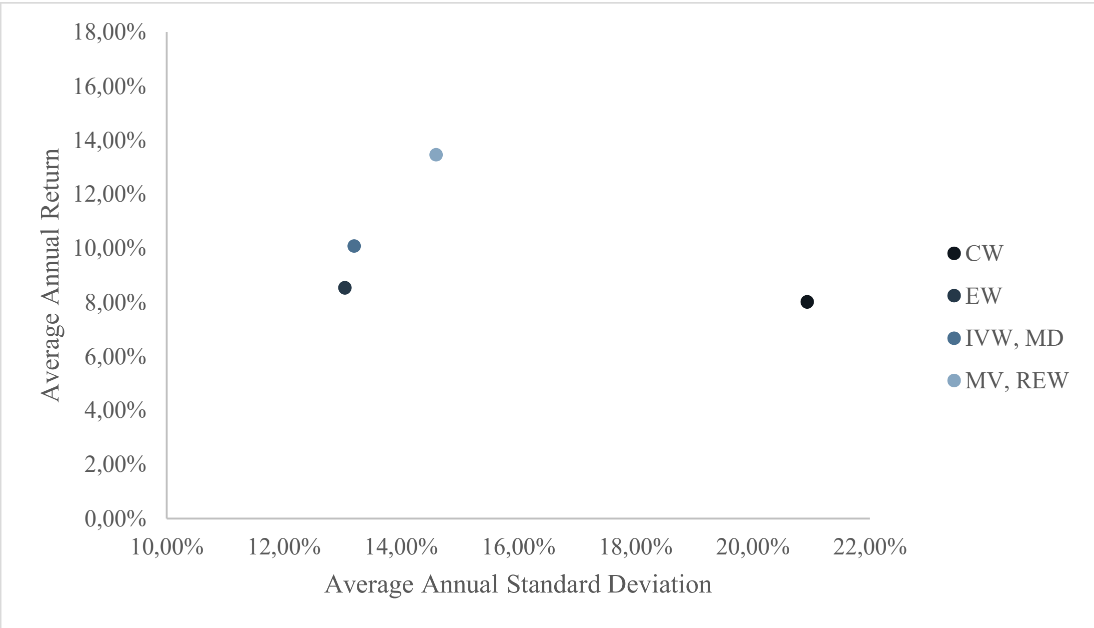


Figure A.7 "Whole" Yearly Average Portfolio Return 2009-2016

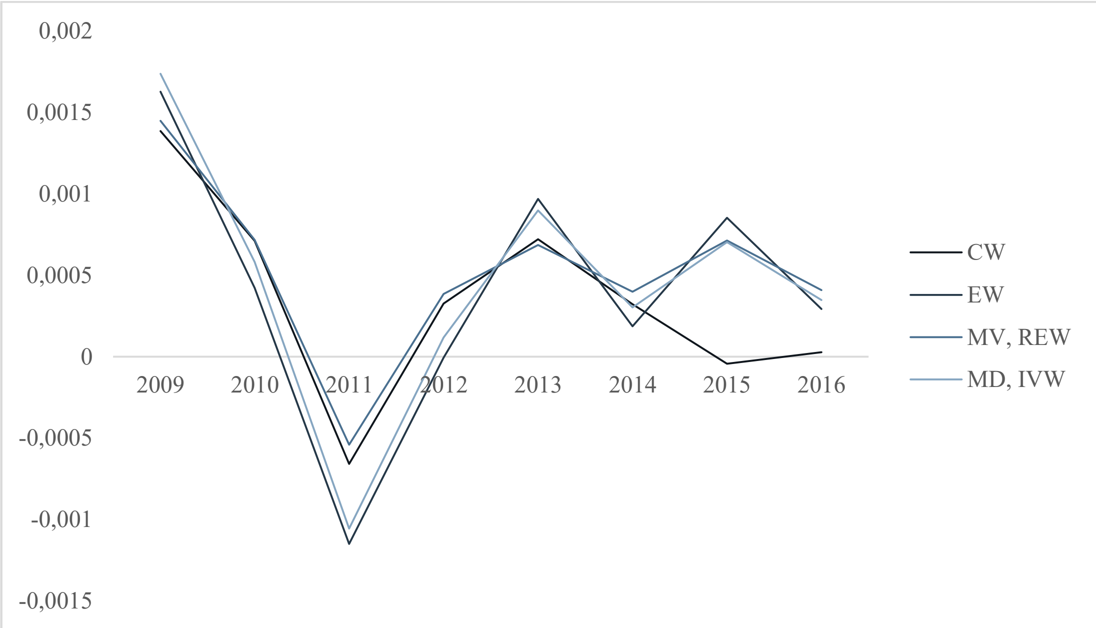


Figure A.8 "Sustainable" Yearly Average Portfolio Return 2009-2016

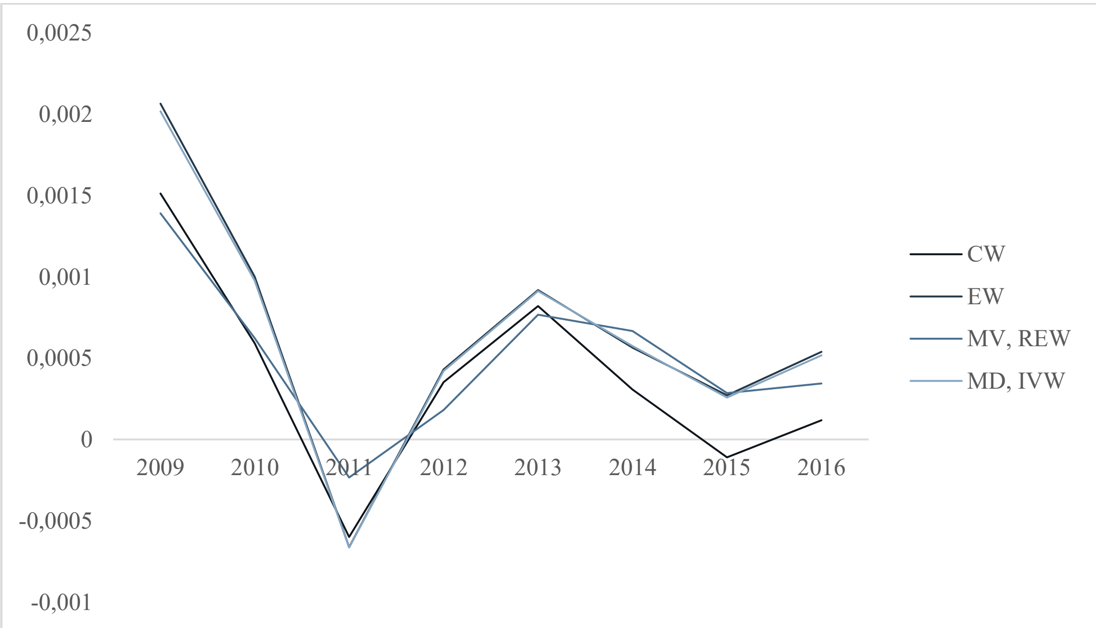


Figure A.9 "Complement" Yearly Average Portfolio Return 2009-2016