Efficiency of socially responsible investments in the context of portfolio management

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Abstract

In this paper, we expand the literature on multi-criteria portfolio modeling for socially responsible investments using multi-directional efficiency analysis (MEA). We apply a positive screening based on MEA efficiency scores, and also directly exploit the information contained in the efficiency score in order to compute portfolio weights. We conduct a broad empirical analysis testing multiple portfolio strategies based on public equity market data of socially responsible investments from the US and Europe going back to 2005. We show that the explicit consideration of a social responsibility variable in the MEA portfolio models has a positive effect on the financial and social performance of all asset allocations strategies. Furthermore, we find that portfolios constructed using the proposed efficiency analysis in their asset allocation outperform the strategies which merely employ a positive efficiency screening. These portfolios also provide superior results compared to a naive or value-weighted strategy with respect to either the financial or social performance, implying a small tradeoff depending on the considered region, and outperform a mean-variance strategy in both the financial and social dimension. These results clearly outline the benefits of MEA portfolio modeling, not only for socially responsible investors, but also traditional investors.

Keywords: Portfolio Optimization, Socially Responsible Investments, Efficiency Analysis, International Financial Markets, Multi-directional Efficiency Analysis, Sustainable Finance, ESG

JEL classification: G11, G15, A13

1 Introduction

In recent years, an increasing number of both institutional and individual investors have started to change their view of their investment targets. They no longer care solely about financial returns and risk, but also about the social responsibility of their investment activities, appealing to the already popular sentiment of "doing well while doing good" (see e.g. Hamilton et al., 1993). As a result, roughly USD 12 trillion and EUR 11 trillion were invested in socially responsible assets in 2018 in the US and Europe respectively (The Forum for Sustainable and Responsible investment 2018; European Sustainable Investment Forum 2018).

Consequently, socially responsible investing has become a focus of research, where a diverse range of subtopics is covered. One of the largest associated areas of interest is the subject of constructing socially responsible investment portfolios. Numerous papers have been published in this field developing models that allow for the incorporation of multiple preferences regarding return, risk and social responsibility in the portfolio decision-making process. This article expands the literature on socially responsible investments (SRI) and multi-criteria portfolio modeling by relying on multi-directional efficiency analysis (MEA) to develop SRI strategies.

In the context of asset pricing and management, efficiency analysis has proven to be a valuable stock-selection tool. Usually, this follows a two-stage process. First, the efficiency analysis is applied in order to identify "highly efficient stocks", this is usually referred to as stock screening.[1] Second, a portfolio optimization, such as a mean-variance optimization (see Markowitz, 1952) is applied to compute the portfolio weights. This second step typically aims to maximize financial performance only, which implies that this optimization is potentially in conflict with step one if a multi-objective orientation – also including non-financial variables – is considered during the efficiency analysis. With the analysis

[1]Data envelopment analysis has mainly been used for efficiency-based stock selection in the literature.

proposed in this article, we overcome this problem by preserving the overall preferences defined via the MEA input and output variables and incorporating them directly into the asset allocation of the portfolio.

This paper explores how the proposed efficiency analysis performs for a variety of asset allocation strategies compared to selected, well-established benchmarks such as mean-variance, naive and value-weighted portfolios. The empirical analysis is based on a data set of US and European public equities, with an observation period of 2005 to 2016. We use quarterly stock prices from Thomson Reuters Datastream and ESG scores provided by Thomson Reuters ASSET4 as social responsibility measure. Furthermore, all stocks are grouped into sectors according to the Global Industry Classification Standard (GICS).

We find that the incorporation of a social responsibility variable in the multi-directional efficiency analysis improves the financial and social performance of the resulting portfolios when the efficiency information is directly used to determine the asset allocation of the portfolio. Strategies which employ a positive efficiency-based screening alone show clear financial and social underperformance. We further show that these efficiency-based asset allocation strategies provide superior results compared to a naive or value-weighted strategy with respect to either financial or social performance, implying a small tradeoff depending on the region under consideration and that they clearly outperform the mean-variance portfolio in both the financial and social dimension. These results clearly outline the benefits of MEA portfolio modeling and also provide validation to argue that not only socially responsible investors but also conventional investors, who focus solely on risk and return, should be interested in social responsibility measures when constructing their portfolios.

The structure of his article is as follows. In Section 2, we describe the existing literature, both on building portfolios with a view to social responsibility considerations as well as the related applications of efficiency analysis. Section 3 describes the general MEA methodology, while section 4 lays out the data set and provides a descriptive data analysis. Section 5 presents the results of our empirical analysis before the conclusion in section 6.

2 Literature Review

The study conducted in this paper is connected to two major strands of literature. The first relates to the fairly large number of papers that have been published on the subject of socially responsible investing over the last 20 years, aiming to investigate the empirical relationship between financial performance and social responsibility. More recently it has been observed that investors, institutions and foundations wish to incorporate this dimension into their investment decision making process actively. In light of this development, an increasing number of papers have been published focusing on formulating and introducing theoretical models that allow for an asset allocation that incorporates measures for return, risk and social responsibility at the same time.

Bilbao-Terol et al. (2012), for example, introduce a goal-programming model for SRI portfolio selection that aims to enable investors to combine ethical and financial preferences. Using a UK mutual funds data set, they demonstrate that an investor's risk attitude tends to influence the loss of return as a result of choosing SRIs. Ballestero et al. (2012) and Bilbao-Terol et al. (2013) also focus on SRIs and propose different models to incorporate investor preferences into the portfolio optimization process. Using their financial-ethical bi-criteria model, Ballestero et al. find that ethical investments are accompanied by risk exposure increases, while the results of Bilbao-Terol et al., based on their hedonic price method and a data set of 160 investment funds, suggest that the financial penalties associated with SRIs are relatively minor for highly risk-averse investors. More recently, Hirschberger et al. (2013) developed a multiparametric algorithm for the computation of the non-dominated set of portfolios in a tri-criterion optimization, and Gasser et al. (2017)

have proposed a Markowitz model modification to set up a three-dimensional capital allocation plane illustrating the complete set of feasible optimal portfolios on the basis of optimizing return, risk and social responsibility. Lee et al. (2021) show that the integration of environmental, social and governance analyses does not reduce risk-adjusted returns in Australia but argue that a "simple ESG integration strategy may provide a natural hedge against the … ESG risks".

The second strand of literature relates to efficiency analysis, which has already been used in the context of performance measurement and as a tool for asset selection in general, but has not yet been employed as a portfolio management and asset allocation model for socially responsible investing. The comparison of companies and industries according to their DEA efficiencies has a long history in several different areas of research. An excellent overview of the use of stochastic frontier analysis can be found in Lovell (1993). Data envelopment analysis, a special form of frontier analysis, can be traced back to Charnes et al. (1978) and combines operations research, econometrics and management science within one single efficiency measure. In the financial sector the fields of application of DEA are numerous, from measuring the performance of specific assets like funds or stocks, to portfolio selection on the basis of DEA efficiency scores. In their article on DEA for the performance assessment of mutual funds, Basso and Funari (2016) provide an overview of most of the recent applications of DEA for asset pricing purposes.

Powers and McMullen (2000) use DEA for stock selection based on multiple financial criteria, where the DEA efficiency scores of individual assets are determined via eight variables, of which 1-, 3-, 5-, and 10-year returns as well as earnings per share are treated as outputs, and price-to-earnings ratio, beta, and sigma as inputs. Most interestingly, they find that highly efficient stocks can be classified as quite robust in the face of unfavorable changes to the variables under consideration. For the group of inefficient firms the authors also analyze how much certain variables need to change in order for an inefficient company to become efficient. They conclude that DEA is helpful in distinguishing between strong performers and others and thus is a good companion for common selection models. In 2008, Chen used DEA for stock selection on the Taiwan stock market and obtained similar results, and confirmed the superior performance of firms that were selected using DEA.

Edirisinghe and Zhang (2008) use financial statement data and develop a relative financial strength (RFS) indicator on the basis of a DEA approach that visualizes a firm's fundamental strength. They also show that the RFS indicator can be used for stock selection within a mean-variance optimization. Dia (2009) proposes a four-step methodology for the portfolio selection of assets, in which portfolios are formed using a model that optimizes the weighted sum of all the assets' efficiency scores with respect to investor preferences.

Pätäri et al. (2010) compose portfolios using DEA scale efficiency for Finnish non-financial stocks. The performance of the portfolios is evaluated on the basis of average return and risk-performance metrics. They find that DEA efficiency scores have a positive effect on the value of the resulting portfolio and that this effect is most evident for shorter investment horizons. They also conclude that the use of DEA is useful if several variables need to be taken into consideration or if the number of stocks in the sample is large. In 2012, Pätäri et al. again examined the applicability of data envelopment analysis as a selection tool for equity portfolios. They combined value investing and momentum investing in constructing portfolios for the sample period of 1994 to 2010. The performance was measured on the basis of returns and several risk-adjusted performance metrics. They demonstrated that the DEA approach improves portfolio performance in a statistically significant way.

For the Malaysian stock market, Ismail et al. (2012) investigate the effectiveness of a DEA model on portfolio selection for investors over long horizons and use efficiency scores to select only efficient firms. Their technical efficiency portfolio seems to produce significantly higher cumulative abnormal returns over a 36-month holding period than other portfolios. As in the earlier studies, they conclude that DEA is an appropriate method for asset selection as it leads to superior portfolio performance.

Bahrani and Khedri (2013) create a portfolio of efficient companies by using DEA on a data set from the Teheran stock exchange. They find that it is not possible to generate a return beyond the average return of the market by using constant returns to scale of Charnes et al. (1978). However, using the variable returns-to-scale model of Banker et al. (1984) improves the performance of the resulting portfolio.

Lim et al. (2014) use DEA cross-efficiency evaluation (i.e. cross efficiencies between stocks) for portfolio selection. With a data set from the Korean stock market, the resulting portfolios yield higher risk-adjusted returns than various benchmark portfolios.

More recently, Rotela Junior et al. (2017) have presented a model for portfolio optimization based on DEA and entropy functions. The selection of the assets is based on DEA and only focuses on fully efficient assets. Second, the entropy function was used on the portfolio optimization model based on Sharpe. For their portfolios, they found a significant improvement in portfolio performance, measured by the Sharpe ratio, compared to other well established methods.

Tarnaud and Leleu (2018) adjust the input and output factors used and add various risk factors like the mean return, variance of returns, and moments of higher order. They call this specification the financial technology set, which allowed a further adjustment of DEA portfolio modelling with respect to an investor's appetite for risk.

All in all, the articles mentioned above show that efficiency analysis provides a useful tool for portfolio management. Its flexibility in the selection of relevant parameters with respect to investors' individual preferences makes this method a perfect fit for socially responsible investing. Previous studies use efficiency analysis in combination with financial data only and focus solely on the optimization of financial performance or the risk preferences of a certain investor. We introduce a novel approach suited for socially responsible investing and explicitly incorporate a social responsibility variable in the efficiency analysis. We apply multi-directional efficiency analysis (MEA), in which the social responsibility measure enters as a non-financial variable, in addition to well-known return and risk measures, for determining overall efficiency of a firm. Moreover, we contribute to the literature by proposing and investigating a so-called efficiency weighting approach – the direct transformation of efficiency scores into portfolio weights – as an asset allocation strategy, since previous studies use efficiency scores purely for asset screening based on the highest level of efficiency, while disregarding transaction cost and potential diversification benefits from including less efficient firms in the portfolio.

3 Methodology

The analysis of firm efficiency originates from the seminal work of Koopmans (1951) and Debreu (1951) on linear programming. Farrell (1957) developed a procedure based on these studies to analyse the efficiency of different operating units with respect to several input and output variables. He divided the overall efficiency of a certain operating unit into an efficiency coming from the technical part (technical efficiency) and a second part – the so called allocative efficiency – which describes the efficient allocation of resources for a certain output value (or maximization of output given a certain amount of input). This so called data envelopment analysis is a nonparametric approach to measuring the relative efficiency of different decision making units or firms. This methodology implies a radial scaling for the input factors (input orientation), output factors (output orientation), or both (input- and output orientation), and efficiency is measured by a weighted ratio of outputs over inputs.

In this article we disentangle the improvement potential for input and output variables separately without assuming a specific relationship between the factors included or making any assumptions about the tradeoff between the improvement (potential) of these factors. We rely on multi-directional efficiency analysis (MEA) as a fairly recent approach, which was first introduced by Bogetoft and Hougaard (1999) and further developed by Tone (2001) and Asmild et al. (2003). In contrast to DEA, multi-directional efficiency allows the analysis of the improvement potential for each of the factors included in the analysis separately. Since we are interested in the improvement potential of both inputs and outputs, we use a MEA model specification with mixed orientation in the following.

Let N be the number of DMUs analysed within a certain sector or country in each period $t = 1, \dots, T$.[2] Let DMU_j with $j \in \mathbb{N}$ at time t produce outputs $y^t_{r,j}$, with $r = 1, \dots, m$ by using inputs $x^t_{i,j}$ with $i = 1, ..., n$. A certain DMU_j under analysis is designated as DMU_o with $o = 1, \dots, N$ and the production plan (x^t_o, y^t_o). In order to analyze the improvement potential for DMU_o, an ideal reference point $(x^{t\star}_o, y^{t\star}_o)$ is detected for each point t by solving a system of linear programs for each variable included. The ideal reference point for each input variable $x^t_{i,j}$ is given by:

$$
\begin{aligned}
&\text{minimize} && d^t_{i,o}, && \\
&\text{subject to} && \sum_{j=1}^{N} \lambda_j x^t_{i,j} \leq d^t_{i,o}, && \\
& && \sum_{j=1}^{N} \lambda_j x^t_{-i,j} \leq x^t_{-i,o}, && -i = 1, \dots, i-1, i+1, \dots, n, \\
& && \sum_{j=1}^{N} \lambda_j y^t_{r,j} \geq y^t_{r,o}, && r = 1, \dots, m, \\
& && \lambda_j \geq 0, && j = 1, \dots, N,
\end{aligned}
\tag{1}
$$

and for each output variable $y^t_{r,j}$ by:

[2] In this analysis we use quarterly observations as explained in section 4.

$$
\begin{aligned}
\text{maximize} \quad & \delta^t_{r,o}, \\
\text{subject to} \quad & \sum_{j=1}^{N} \lambda_j x^t_{i,j} \leq x^t_{i,o}, \qquad && i = 1, \ldots, n, \\
& \sum_{j=1}^{N} \lambda_j y^t_{r,j} \geq \delta^t_{r,o}, && \\
& \sum_{j=1}^{N} \lambda_j y^t_{-r,j} \geq y^t_{-r,o}, && -r = 1, \ldots, r-1, r+1, \ldots, m, \\
& \lambda_j \geq 0, && j = 1, \ldots, N.
\end{aligned}
\tag{2}
$$

The ideal reference point corresponds to the maximum improvement potential inherent in each input and output variable separately.[3] The solution to this system of linear programs is generally outside the production set P and is given by $(\mathbf{d}^{t\star}_o, \boldsymbol{\delta}^{t\star}_o) \notin P$. This implies that it is not possible to implement the ideal production plan due to technological boundaries, which are given by the set of DMUs. The technological constraints are represented by the efficient frontier, which serves as a benchmark for measuring the relative efficiency of all DMUs. However, movement in the direction of this ideal is still possible. The distance between the current production plan and the efficient frontier represents the potential improvement direction β^t_o, which is given by:

$$
\begin{aligned}
\text{maximize} \quad & \beta^t_o, \\
\text{subject to} \quad & \sum_{j=1}^{N} \lambda_j x^t_{i,j} \leq x^t_{i,o} - \beta^t_o (x^t_{i,o} - d^{t\star}_{i,o}), \qquad && i = 1, \ldots, n, \\
& \sum_{j=1}^{N} \lambda_j y^t_{r,j} \geq y^t_{r,o} + \beta^t_o (\delta^{t\star}_{r,o} - y^t_{r,o}), && r = 1, \ldots, m, \\
& \lambda_j \geq 0, && j = 1, \ldots, N.
\end{aligned}
\tag{3}
$$

The solution $(\lambda*, \beta*)$ gives the realizable improvement potential compared to the benchmarks spanning the efficient frontier with $\beta^{t\star}_o = [0, 1]$. A value of 0 implies that

[3] The higher the distance to the optimal reference point, the larger is the improvement potential.

no further improvement is possible and this DMU is situated on the efficient frontier and even helps define it. In order have a straightforward interpretation of our results, we transform the MEA scores into Farrell efficiency scores η_j^t with 1 representing the most efficient firms.

In order to use MEA for portfolio management, we select common input and output variables which have been introduced in the existing literature on portfolio selection and performance evaluation (see e.g. Branda and Kopa, 2014; Chen and Lin, 2006; Gregoriou, 2006; Lin, 2009; Pendaraki, 2012; Zhao and Shi, 2010). Therefore, we use various risk measures as input factors and expected return as well a social responsibility measure on the output side. The factors used in the different MEA model specifications are summarized in Table 1.

Model 1 represents the base scenario and only considers volatility and expected return. Model 2 is extended by considering the ESG Score as a social responsibility measure (see section 4), whereas further risk measures are included for model 3.

For each model we implement three asset allocation strategies, which differ from each other in how the information gathered from the MEA models is used. In strategy 1, efficiency-weighted portfolios are constructed by directly transforming efficiency scores η_j^t into portfolio weights w_j^t:

$$w_j^t = \frac{\eta_j^t}{\sum_{j=1}^{N} \eta_j^t} \tag{4}$$

For strategy 2, we use the efficiency scores as a basis for screening, in which only the fully efficient firms are taken into consideration (efficiency-screening) and an efficiency-weighted portfolio is implemented.[4]

[4]A screening according to certain efficiency levels would also be possible but since the decision about the efficiency cut-off level would be arbitrary, we only focus on fully efficient firms (i.e. firms with an efficiency score of 1 in our MEA model, which results in an equally-weighted portfolio with $w_j = \frac{1}{N}$, if efficiency-weighting is applied).

In strategy 3, an efficiency-screening is again applied and followed by a mean-variance optimization as a second step, which is the standard approach proposed in the literature on DEA portfolio management (see Section 1).[5]

4 Data

For the empirical analysis, we rely on a comprehensive data set of public equities from the US and Europe. Since an unbiased and independent social responsibility measure is a prerequisite, we use the constituent lists of the Thomson Reuters ASSET4 database for these two regions to construct the initial data set.[6] This database provides ESG scores (see Section 1) for the largest publicly traded stocks in both regions. The ESG score is an aggregate score indicating a company's social responsibility on a scale between 0 (lowest possible ESG rating) and 100 (best-rated company) and makes companies comparable across markets.

ESG scores are updated on a quarterly basis and the observation period spans June 2005 to May 2016 (45 quarters) for the US, and October 2005 to December 2016 for Europe (46 quarters).[7] The sample comprises 388 firms for the US and 532 firms for Europe.[8] In total, the data set is composed of 17,460 and 24,472 firm observations for the US and Europe, respectively. For the efficiency analysis and portfolio modelling, we compute stock returns based on quarterly and daily stock prices from Thomson Reuters Datastream, respectively. All stocks are grouped into sectors according to their GICS (Global Industry

[5]Since strategies 2 and 3 both rely on screening techniques, the application of these strategies might be more restricted compared to strategy 1, since the reduction of the asset universe could lead to adverse diversification effects.

[6]The ASSET4 database covers public equities from major equity indices worldwide. It consists of 250 key performance indicators from four category pillars related to economic, environmental, social and governance performance (Thomson Reuters, 2012).

[7]The final observation period for each region is a result of an algorithm maximizing the number of available data points for each region.

[8]Only sectors for which more than 10 firms per quarter are available are included in the final data set. According to Golany and Roll (1989), is is a necessary restriction that the number of comparable units in DEA data sets is twice the number of in- and outputs, in order to ensure proper behavior of the efficiency model.

Classification Standard) industry codes. We use the US 3 Month Treasury Bill Rate as a risk-free rate. Tables 2 and 3 provides descriptive statistics for the data sets of the US and EU firms.

It can be seen that European firms exhibit on average higher ESG scores in each sector.[9] This is in line with previous studies, such as Amon et al. (2021), and implies that European firms maintain on average a higher level of social responsibility even before the adoption of the latest sustainable finance disclosure regulation, which was initiated in 2014.

5 Results

In this section we present the results of our analysis. First, we investigate the results of the multi-directional efficiency analysis. Second, we analyze the results of the strategies and compare them with the benchmarks. We further examine whether the proposed efficiency-based strategies are indeed successful in promoting a positive relationship between financial and social performance at the portfolio level. Finally, we investigate the rebalancing costs of all the portfolios to draw a final conclusion regarding the viability of the strategies.

5.1 MEA Results

The firm-level efficiency is evaluated on a quarterly basis, which results in a time series of efficiency scores for each firm and model.[10] We investigate the consistency of the efficiency analysis over time by grouping the quarterly firm-level efficiency scores into percentiles. We then track the percentile changes over time and compute the cumulative sum of positive and negative quarterly percentile changes as well as the absolute sum of changes. This allows us to investigate how far a company's efficiency level has departed from its first

[9]except Consumer Staples (30).

[10]The first half of the observation period is used as loading period to compute the input and output variables for the efficiency analysis.

efficiency measurement at the beginning of the observation period. This provides insights into the robustness of the multi-directional efficiency analysis over time. The results of this exercise are shown in tables 4 and 5.

For both the US and Europe, approximately one third of firms end up at the same percentile as at the beginning of the observation period, whereas overall two thirds of the firms end up, at most, one percentile up or down from their starting position. This implies that the relative efficiency scores are very stable over time for the majority of firms. It can further be shown that firms which have departed the most from their starting efficiency also exhibit the strongest variation, as well as the minimum, maximum and absolute sum of percentile changes. This implies that companies which are subject to a major change in efficiency experience this adjustment through multiple changes in their efficiency scores over the duration of the observation period.

When investigating the differences between models, the number of firms in the center of the distribution with no or one percentile change, drops from 77% to 66% for the US and from 82% to 70% for Europe between models 1 and 2. There is only a minor change from model 2 to model 3 in the US, while there is a further smaller decrease to 66% for model 3 in Europe. This implies that adding ESG information to the efficiency evaluation leads to an updated relative efficiency score for a number of firms, which either causes an increase or decrease. In the US, it seems that an equal number of firms exhibit a lower/higher efficiency score after including the ESG information. The number of firms with two or more positive or negative percentile changes increases from 11% to 17% in model 2. In Europe, a slightly larger fraction of firms experience a positive percentile change already in the base model 1. This gap further widens when including ESG information. While the number of firms receiving a penalty in their efficiency score increases from 8% to 14%, the number of firms benefiting from the updated efficiency evaluation increases more strongly from 10% to 16% and 20% in models 2 and 3. This tendency towards positive changes can also be observed in model 3 for the US.

Overall, these results indicate that the multi-directional efficiency analysis seems to capture changes in a firm's efficiency reasonably well, i.e. firms do not move from being least to fully efficient over a short period of time. The ESG information leads to more frequent positive or negative updates for a number of firms, and therefore, adds additional informational value to the efficiency evaluation, as it allows for a clearer distinction between firms, and consequently to the strategies constructed using the efficiency information.

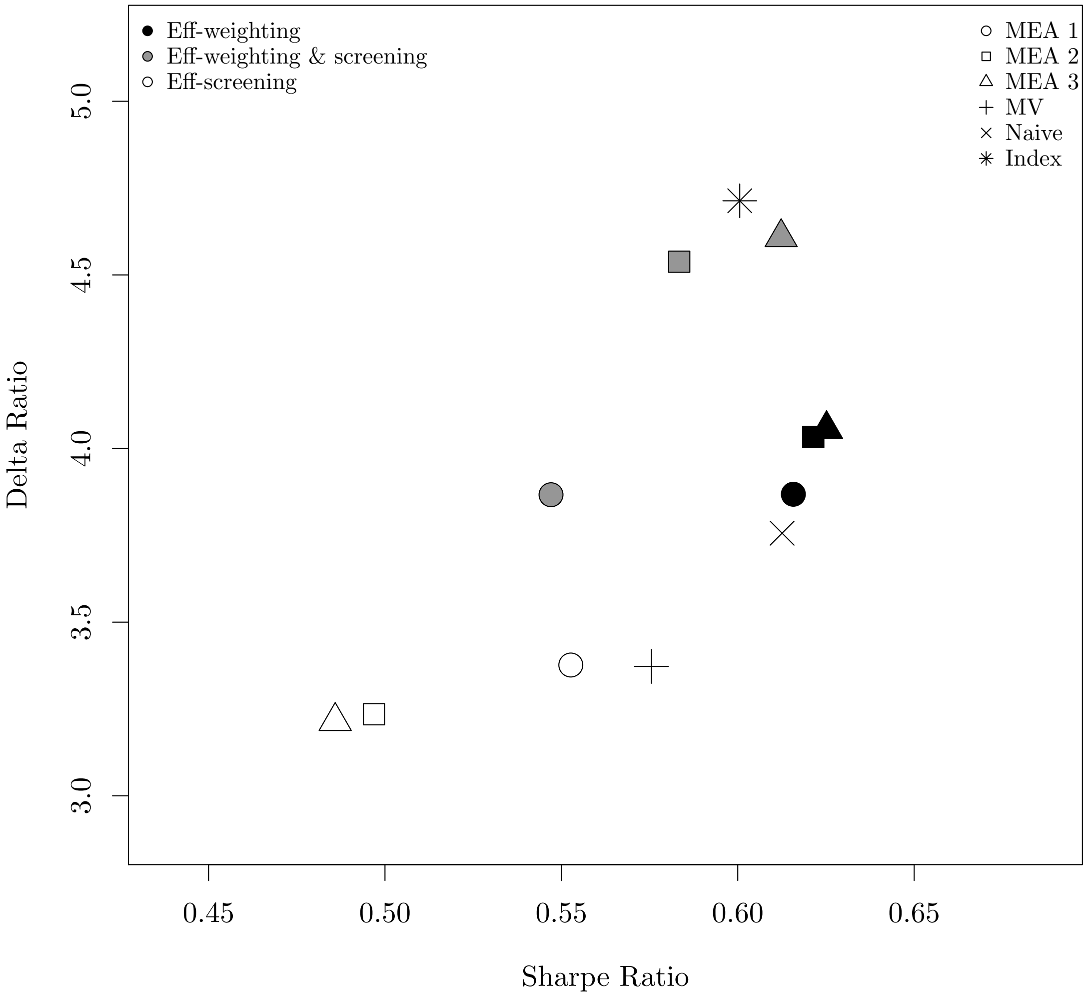
5.2 Strategy Results - Portfolio Comparison

This subsection investigates the results of the asset allocation strategies based on their respective MEA models. We compute daily portfolio returns with quarterly rebalancing in line with the ESG score updating frequency. The comparison of the strategies will mainly be conducted based on their mean financial and social performance.[11] The detailed portfolio results for each sector, strategy and MEA model are provided in the appendix in tables 9–16. Figures 1 and 2 illustrate the average results for all asset allocation strategies including the benchmarks for the US and Europe.

For the US, the efficiency-weighting strategy reports on average the highest financial performance, which also exceeds the benchmark portfolios (mean variance, naive and index portfolios). Furthermore, it can be seen that the consideration of ESG information in MEA model 2 leads on average to a significantly higher social, but also financial performance for the efficiency-weighting strategy and the combined strategy of efficiency-weighting and screening. The efficiency-screening strategy shows the worst financial and social perfor-

[11]While the results are discussed based on the mean results of each strategy and model, the conclusions hold true more generally at the sector level for both regions. The significance testing has been performed based on log returns using on the Sharpe ratio equality test by Wright et al. (2014), T-test for returns and ESG scores and F-test for variances. While the differences in returns are mostly insignificant, we find significant differences between the portfolio results for Sharpe ratios, variances and ESG scores.

Figure 1: Overview of Portfolio Results - US



Notes: This figure shows the average portfolio results of all asset allocation strategies and model specifications over all sectors for the US. The portfolio returns are annualized and based on daily observations with quarterly rebalancing. ○, □ and △ refer to the three MEA models, while black, gray and white filling indicates strategy 1 (Efficiency-weighting), strategy 2 (Efficiency-weighting & Efficiency screening) or strategy 3 (Efficiency screening). The symbols +, x and $*$ refer to the benchmark portfolios, i.e. the mean-variance and naive portfolio as well as the index.

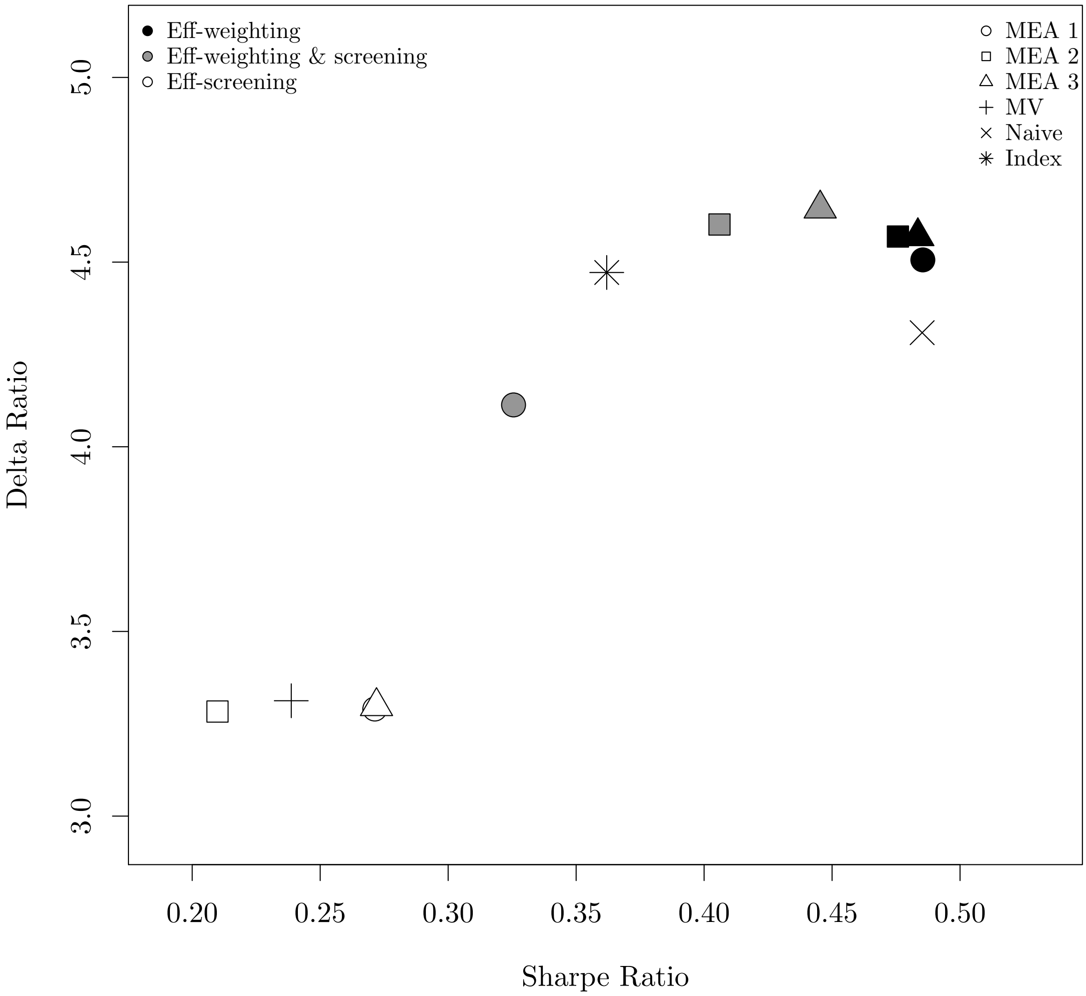
mance and the inclusion of ESG scores further widens the gap. The combined strategy shows the largest improvement in social performance after including ESG information in the MEA model. This strategy produces the highest social performance of all asset allocation strategies, which is almost on par with the index benchmark. The index reports on average the highest Delta Ratio,[12] but with a slightly lower average Sharpe ratio compared to the efficiency-screened portfolio under MEA model 3. The consideration of additional risk measures in the MEA model 3 shows an additional, smaller improvement in financial performance, which is again more pronounced for the combination strategy than for the efficiency-weighting strategy.

For Europe, the results are similar. The efficiency-weighting strategy also reports the highest financial performance, which is, in this case, on par with the naive benchmark. The financial outperformance is more pronounced compared to the index benchmark and the combined strategy than it was for the US. The positive effect of including ESG information in MEA model 2 is also observable (although to a much lesser extent). This increase in social performance is again most notable for the combined strategy. In case of the efficiency-weighting strategy, this effect is only very small and also no increase in financial performance can be documented. The combination strategy shows the highest social performance, which is slightly higher than the results from the index benchmark and also much closer to the social performance of the efficiency-weighting strategy. As for the US, the efficiency-screening strategy shows the worst financial and social performance. The lower positive impact of the MEA 2 model could be explained by the higher overall social performance of European firms, which implies that lower improvement potential is available if firms already operate at a rather high level.

These results overall suggest that efficiency-based asset allocation strategies seem to provide benefits for investors in terms of financial and social performance. In contrast to these findings, the efficiency-screening strategies seem to show on average the worst financial and social performance for both the US and Europe, irrespective of the MEA model. This is an interesting finding considering that asset screening based on efficiency information followed by a mean-variance optimization is the most popular strategy in this context.

[12] The Delta Ratio was first introduced by Gasser et al. (2017) and is a measure that relates the social performance to the risk of a firm. It is given by $\frac{\bar{\theta}}{\sigma}$

Figure 2: Overview of Portfolio Results - EU



Notes: This figure shows the average portfolio results of all asset allocation strategies and model specifications over all sectors for the EU. The portfolio returns are annualized and based on daily observations with quarterly rebalancing. ○, □ and △ refer to the three MEA models, while black, gray and white filling indicates strategy 1 (Efficiency-weighting), strategy 2 (Efficiency-weighting & Efficiency screening) or strategy 3 (Efficiency screening). The symbols +, x and ∗ refer to the benchmark portfolios, i.e. the mean-variance and naive portfolio as well as the index.

The inclusion of ESG information in the calculation of firm efficiency provides positive effects for the financial and social performance for the efficiency-weighting and combined strategies. Moreover, including additional risk measures leads to a further improvement in both strategies. In the US, a tradeoff between financial and social performance has to be accepted when deciding on an asset allocation strategy. The most favorable choices seem to be the value-weighted index for social performance and the efficiency-weighting strategy for financial performance.[13] However, the combined strategy deserves a mention, since it comes close to the index with a slightly better financial performance on average. This tradeoff is much less obvious in Europe, where the efficiency-weighting strategy offers only slightly lower social performance compared to the combination strategy, while reporting on average a higher financial performance. While the final decision has to be made according to individual investor preferences, these strategies seem to offer suitable alternatives compared to the benchmark strategies.

5.3 Strategy Results - Analysis of Social and Financial Performance

In the next step, we analyze the strategies and MEA model specifications with respect to their financial and social performance specifically. In doing so, we gain an understanding of the effectiveness of the strategies and MEA models when ESG information is actively considered alongside financial information in the estimation of efficiency. This is with the intention of addressing both dimensions at the same time in the asset allocation process, providing insights into a specific strategy's ability to establish a positive dependence between the financial and social performance in the resulting portfolios.

We conduct this investigation in two ways. First, we investigate the strategy results with respect to a specific MEA model in figures 3 and 4. This will tell us how effective each MEA model is in aligning the financial and social dimensions. Second, we focus on a specific asset allocation strategy and include the results from all MEA models for expository convenience in figures 5 and 6. This will provide insights into the effectiveness of each asset allocation strategy in pursuing both dimensions. For both approaches, we estimate the linear dependence between the financial and social performance using the

[13] At this point transaction cost are purposefully ignored. Their effect on these conclusions in relation to the naive benchmark will be explored in subsection 5.4.

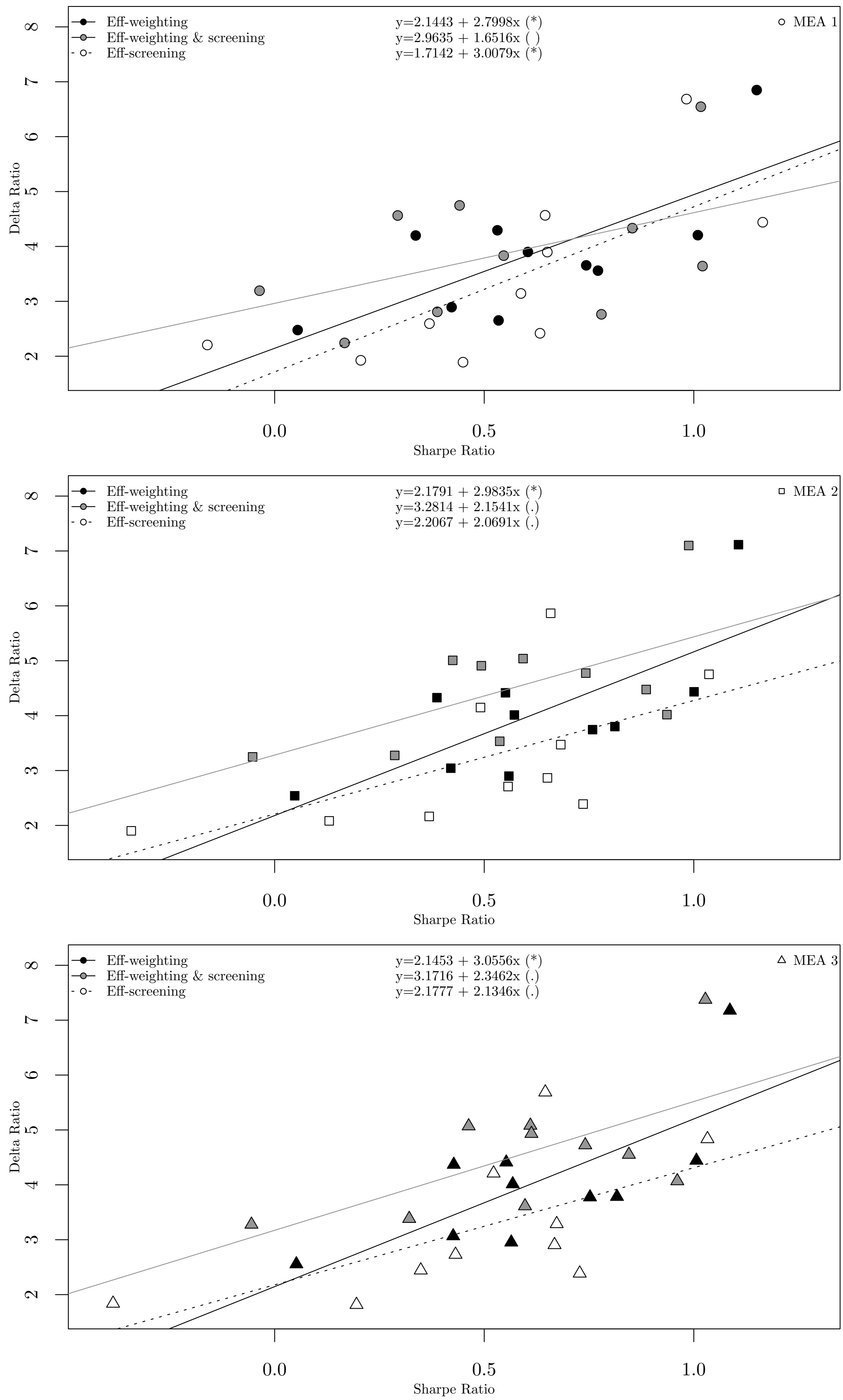
Sharpe and Delta ratios of the respective portfolios. We plot the regression lines and report the regression equations in order to obtain the intercept, slope and significance levels. We conduct this analysis for both the US and Europe.

Figure 3 shows the results of this exercise for the three MEA models for the US. It can be seen that the intercepts of the strategies in MEA model 2 are higher than for MEA model 1. This is in line with our expectations and implies that the overall level of social performance has increased for all portfolios. For MEA model 3 the intercepts are slightly reduced compared to MEA model 2. For the efficiency-weighting and combined strategies it can also be observed that the slope increases from MEA model 1 to model 2 and model 3, while still remaining significant at 5% and 10%, respectively. This implies that the inclusion of ESG information and risk measures leads to a stronger relationship between financial and social performance in these portfolio strategies. The slope decreases between the MEA models only for the efficiency screening. This is in line with our previous findings and supports the suspicion that efficiency-screening alone might not be sufficient, as, after the initial screening, assets are allocated using standard mean-variance optimization, in which the social dimension is ignored.

The results for Europe are shown in figure 4. The comparison of the intercepts between MEA models shows similar results as presented for the US. It can further be observed that the intercepts are much higher than in the US, indicating once more the overall higher level of social performance. At the same time, the slopes of the strategies seem to decrease when including ESG information in the MEA model. Only the efficiency-weighting strategy always reports a significantly positive relationship at the 5% level between the financial and social dimension for all MEA models.[14] A possible explanation for the smaller slope could be that ESG scores are capped at a level of 100. If the general ESG score level is already rather high for the portfolios, then a high intercept can be observed and it is not

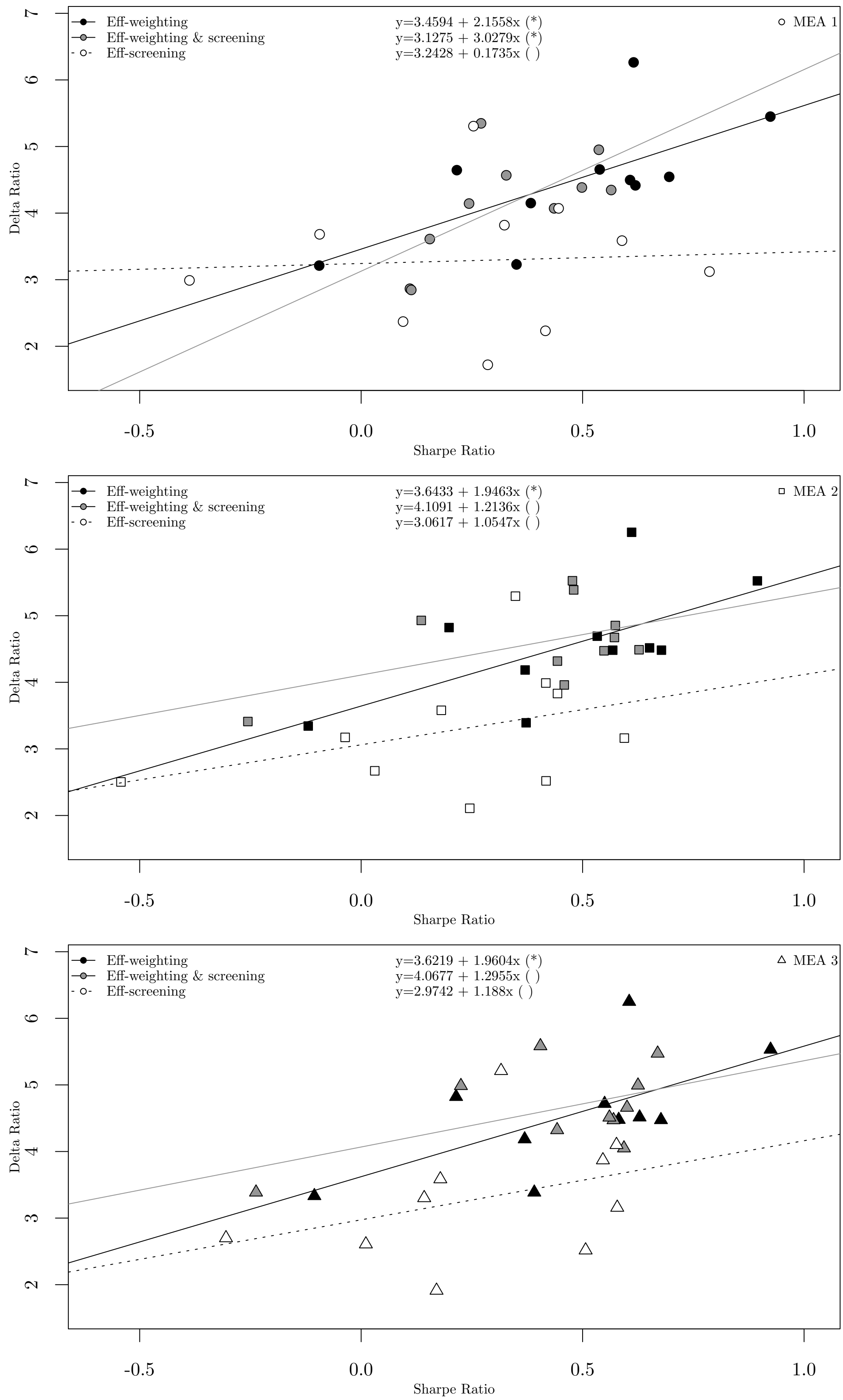
[14]This is indicated by the significance (*) of the beta values presented in the regression equations shown in figure 4.

Figure 3: Relationship between Sharpe and Delta ratio for each MEA model - US



Notes: These figures illustrate the average portfolio results for the Sharpe (y-axis) and Delta Ratio (x-axis) for each strategy and sector for the US. The portfolio returns are annualized and based on daily observations with quarterly rebalancing. ○, □ and △ refer to the three MEA models, while black, gray and white filling indicate strategy 1 (Efficiency-weighting), strategy 2 (Efficiency-weighting & Efficiency screening) or strategy 3 (Efficiency screening). Regression lines are plotted using all sector results for each asset allocation strategy within a specific MEA model. Regression equations are provided at the top aligned to the respective strategy. The significance of the beta values is given in brackets. Herein, (***) $p < 0.001$, (**) $p < 0.01$, (*) $p < 0.05$, (.) $p < 0.1$.

Figure 4: Relationship between Sharpe and Delta ratio for each MEA model - EU



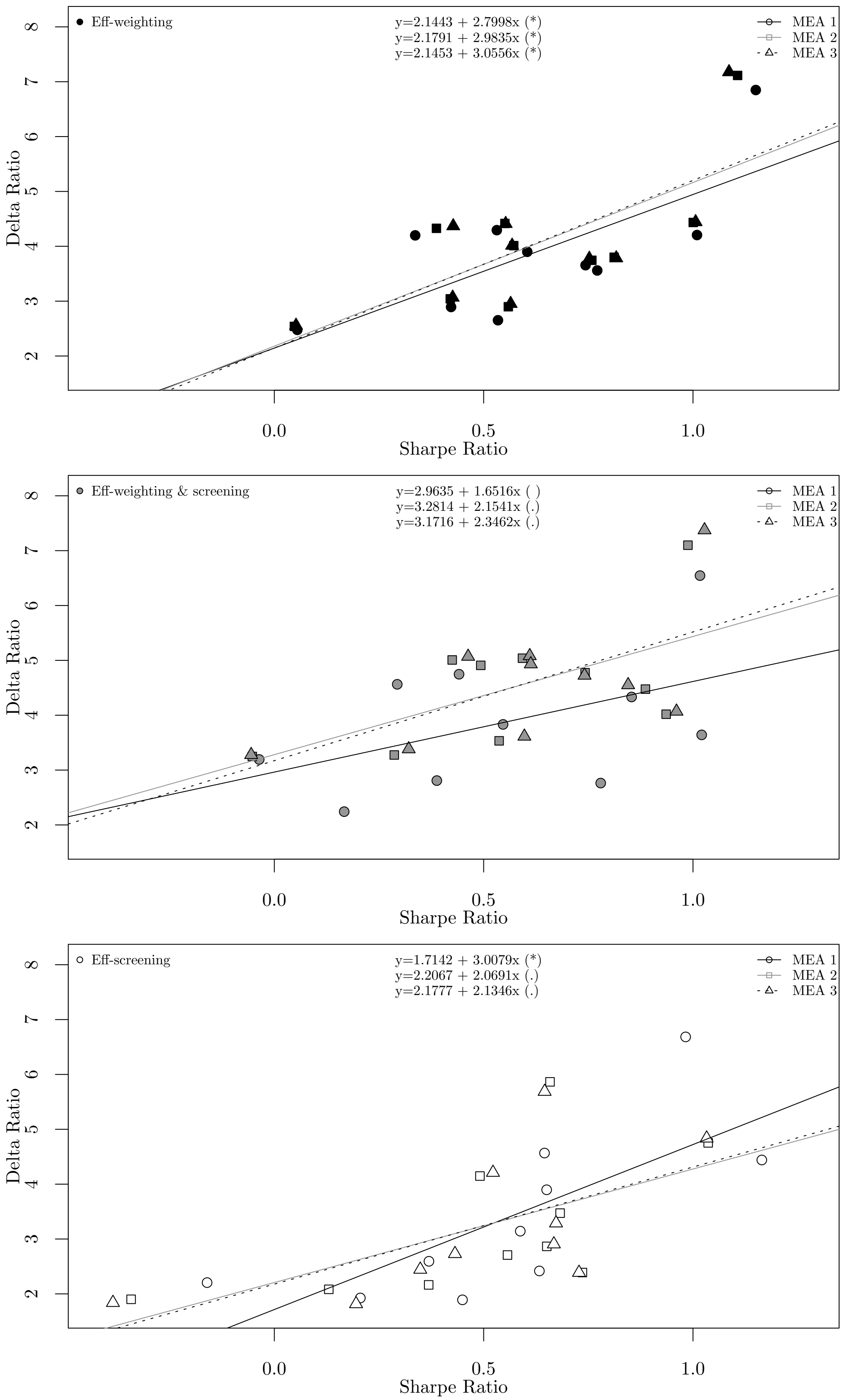
Notes: These figures illustrate the average portfolio results for the Sharpe (y-axis) and Delta Ratio (x-axis) for each strategy and sector for the EU. The portfolio returns are annualized and based on daily observations with quarterly rebalancing. ○, □ and △ refer to the three MEA models, while black, gray and white filling indicate strategy 1 (Efficiency-weighting), strategy 2 (Efficiency-weighting & Efficiency screening) or strategy 3 (Efficiency screening). Regression lines are plotted using all sector results for each asset allocation strategy within a specific MEA model. Regression equations are provided at the top aligned to the respective strategy. The significance of the beta values is given in brackets. Herein, (***) $p < 0.001$, (**) $p < 0.01$, (*) $p < 0.05$, (.) $p < 0.1$.

possible to establish a positive relationship between financial and social performance, since the corresponding increase in social performance is not achievable. The combined strategy always provides the highest intercept in all MEA models and for both regions, and the efficiency-weighting strategy consistently reports the highest slope after ESG information is included. Also in line with the results for the US, it can be seen that the efficiency-screening strategy offers the lowest effectiveness when comparing the intercepts and slopes of the MEA models.

Figure 5 reports the results of the relationship between the financial and social performance for the US when focusing on specific asset allocation strategies. It can be seen that the efficiency-weighting strategy is able to establish a significantly positive relationship between these two variables consistently for all the MEA models, to an increasing extent with similar intercepts. In the efficiency-weighting and combination strategies, MEA model 1 always reports the lowest and MEA model 3 the highest slope, which is in line with the previous results. The results for Europe are shown in figure 6. Similar findings can be observed for the efficiency-weighting strategy. For the combined strategy, the largest increase in the intercept between MEA models 1 and 2 can be observed for Europe, while the slope decreases and becomes insignificant. The efficiency-screening strategy reports insignificant results for all the MEA models suggesting that the attempt to establish a positive relationship between these variables has failed.

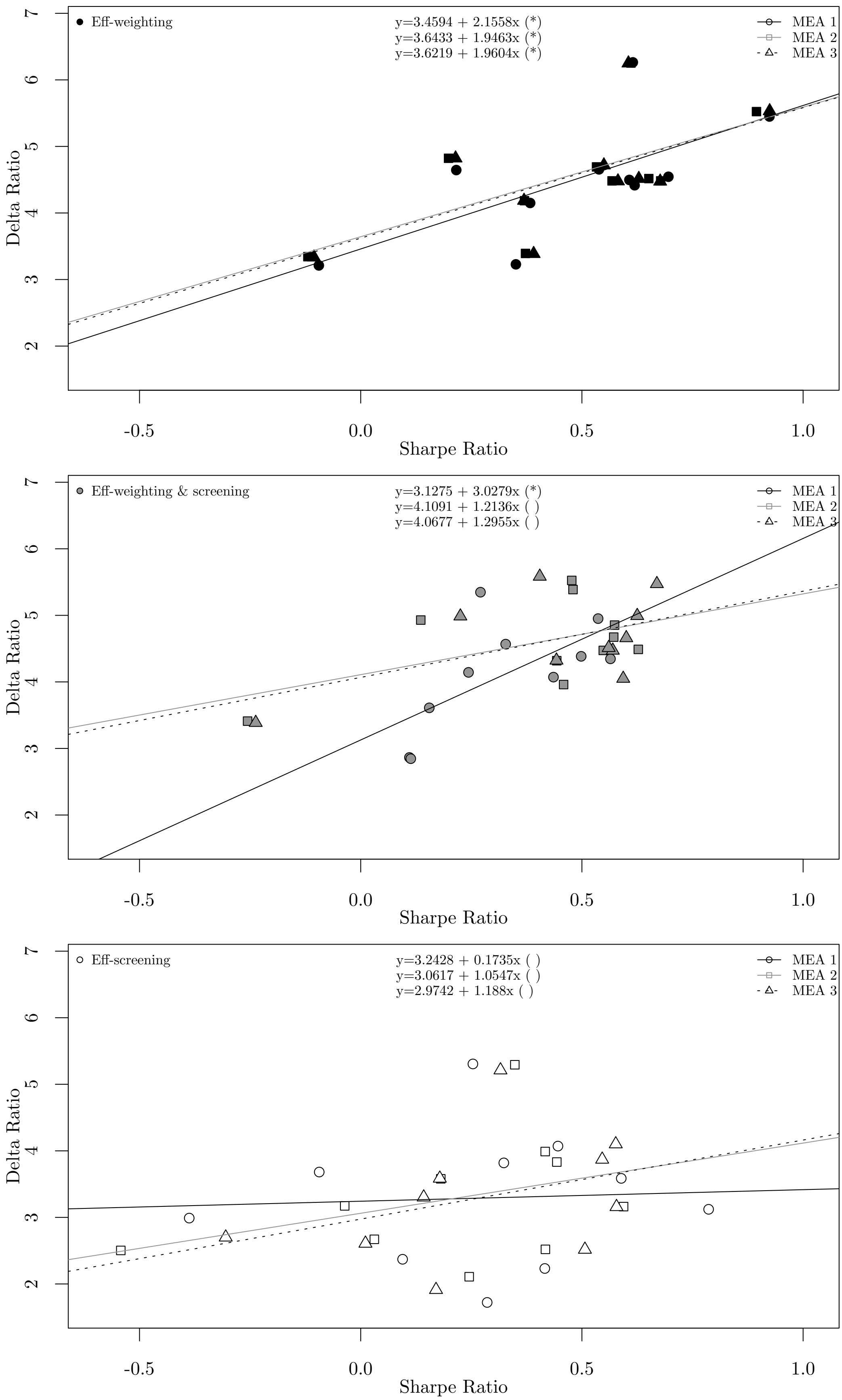
Overall, it can be concluded that efficiency-weighting seems to affect the relationship between financial and social performance positively once ESG information is added to the MEA models. The combined strategy offers the highest intercept suggesting an overall highest social performance. The efficiency-screening strategy does not seem to manage to effectively influence the Sharpe and Delta ratio making it the least useful alternative despite its popularity.

Figure 5: Relationship between Sharpe and Delta ratio for each strategy - US



Notes: These figures illustrate the average portfolio results for the Sharpe (y-axis) and Delta Ratio (x-axis) for each MEA model and sector for the US. The portfolio returns are annualized and based on daily observations with quarterly rebalancing. ○, □ and △ refer to the three MEA models, while black, gray and white filling indicate strategy 1 (Efficiency-weighting), strategy 2 (Efficiency-weighting & Efficiency screening) or strategy 3 (Efficiency screening). Regression lines are plotted using all sector results for each MEA model within a specific asset allocation strategy. Regression equations are provided at the top aligned to the respective MEA model. The significance of the beta values is given in brackets. Herein, (***) $p < 0.001$, (**) $p < 0.01$, (*) $p < 0.05$, (.) $p < 0.1$.

Figure 6: Relationship between Sharpe and Delta Ratio for each strategy - EU



Notes: These figures illustrate the average portfolio results for the Sharpe (y-axis) and Delta Ratio (x-axis) for each MEA model and sector for the EU. The portfolio returns are annualized and based on daily observations with quarterly rebalancing. ○, □ and △ refer to the three MEA models, while black, gray and white filling indicate strategy 1 (Efficiency-weighting), strategy 2 (Efficiency-weighting & Efficiency screening) or strategy 3 (Efficiency screening). Regression lines are plotted using all sector results for each MEA model within a specific asset allocation strategy. Regression equations are provided at the top aligned to the respective MEA model. The significance of the beta values is given in brackets. Herein, (***) $p < 0.001$, (**) $p < 0.01$, (*) $p < 0.05$, (.) $p < 0.1$.

5.4 Turnover

In the last part of the results, we turn our attention towards the role of transaction costs. The turnover rates of the benchmarks are reported in table 6, while the results for the strategies are presented in table 7 for the US and table 8 for Europe.

When comparing the turnover rates between the strategies, similar results can be observed for both regions. The efficiency-weighting strategy always reports on average the lowest turnover rates for the MEA models, while between 316% to 331% higher rates can be observed for the combination strategy for the US and between 342% to 376% higher rates for Europe. Turnover rates of the efficiency-screening strategy are on average even higher with up to 873% for the US and 993% for Europe. These results further increase the previously documented financial outperformance of the efficiency-weighting strategy. The index reports slightly lower turnover rates than the efficiency-weighting strategies, which reduces the tradeoff mentioned above compared to the efficiency-weighting and combination strategies in the US. In Europe, the naive strategy seems to gain an advantage over the efficiency-weighting strategy after consideration of transaction cost due to its zero-transaction-cost characteristic. However, it still reports lower social performance thereby creating a potential tradeoff between these two strategies, in which higher social performance can be achieved at the expense of transaction costs.

6 Conclusion

In this paper we analyse the application of multi-directional efficiency analysis for portfolio management for socially responsible investments. Its flexibility in the selection of parameters makes this method a perfect fit for analyzing investors' preferences that are driven by more than just risk and return.

We compare three different MEA models which include up to five variables, both financial and social, to compute the relative efficiency scores. We also implement three asset allocation strategies, compare and evaluate their financial and social performance against each other and selected, well-established benchmark portfolios.

Our study documents the relevance of a firm's social responsibility in evaluating stock efficiency and also shows the benefits of multi-directional efficiency analysis for socially responsible portfolio management. We find that a superior financial and social performance can be achieved for all the MEA models compared to a traditional mean-variance portfolio. Explicitly considering a social responsibility variable in the MEA model has a positive effect on all asset allocation strategies. The combined strategy offers overall the best social performance. For the US, the efficiency-weighting strategy provides the highest financial performance, while the index reports the highest social performance, indicating a tradeoff between these two variables. For Europe, it seems that increased social performance is achievable with the efficiency-weighting strategy, but at the expense of transcation costs compared to the naive strategy. Efficiency-based screening of assets results in inferior social and financial performance suggesting that this strategy is not favorable.

In general, it can be concluded that MEA offers a useful complement for investors who wish to achieve a mapping of their preferences for financial and social performance in the portfolio management decision. This method also offers a possible application and consideration of portfolio modelling for private equity, something which is left for further research.

Table 1: Overview of input and output variables

MEA model	Inputs	Outputs
Model 1	Volatility (σ)	Expected return ($\bar{\mu}$)
Model 2	Volatility (σ)	Expected return ($\bar{\mu}$), ESG Score (θ)
Model 3	Volatility (σ), Value at Risk (VaR, 95%), Expected Shortfall (ES, 95%)	Expected return ($\bar{\mu}$), ESG Score (θ)

Notes: This table provides a list of all input and output variables used in the three models of the multi-directional efficiency analysis.

Table 2: Descriptive statistics - US

Sector	# of Firms		μ (%)	σ (%)	θ	Market Cap
10	27	Mean	2.47	18.27	62.52	40410.76
		Median	2.93	18.94	63.25	39961.29
		Min	-42.31	10.49	42.02	23527.31
		Max	44.42	23.67	80.08	63525.13
15	28	Mean	2.99	17.52	77.97	8855.09
		Median	2.60	18.82	81.15	7990.60
		Min	-40.73	6.91	55.19	3409.68
		Max	57.24	23.66	91.98	17884.72
20	50	Mean	2.69	13.99	73.83	24229.62
		Median	3.16	15.14	75.12	22919.51
		Min	-32.08	6.03	49.38	11241.54
		Max	37.13	18.79	89.33	39911.26
25	62	Mean	2.94	17.72	60.50	15167.27
		Median	2.26	18.58	59.23	13901.74
		Min	-38.73	8.11	38.22	5283.64
		Max	55.85	23.96	82.05	31359.06
30	28	Mean	2.16	10.02	83.97	42163.92
		Median	2.17	10.51	87.45	40354.37
		Min	-23.83	5.22	55.32	26603.46
		Max	25.92	12.57	94.37	63853.35
35	40	Mean	3.11	13.64	65.95	29914.11
		Median	3.82	14.18	66.47	27316.64
		Min	-34.53	6.08	44.56	14573.42
		Max	35.59	17.69	85.49	53282.45
40	58	Mean	1.65	16.53	57.94	27891.10
		Median	2.04	18.68	58.19	26806.39
		Min	-44.62	4.65	38.01	10216.59
		Max	55.84	23.54	76.34	45941.35
45	49	Mean	2.82	16.85	70.75	35805.42
		Median	2.81	17.47	71.75	34313.42
		Min	-35.32	8.58	50.89	16641.58
		Max	45.29	21.97	87.80	62365.37
50	18	Mean	2.36	14.71	49.99	40603.75
		Median	2.15	16.00	48.53	37221.78
		Min	-36.82	4.99	33.13	17090.33
		Max	44.54	19.82	72.08	75991.46
60	28	Mean	2.86	17.80	41.02	9923.38
		Median	3.18	19.24	37.15	9077.49
		Min	-47.40	6.37	20.63	2799.53
		Max	61.36	25.71	72.18	18513.56

Notes: This table shows the descriptive statistics of the data set for the US, sorted according to the General Industry Classification Standard (GICS). In column 2 the number of stocks contained in each sector are given, while the columns 4 - 7 show the sector-specific mean, median, maximum and minimum values for return (μ), volatility (σ), ESG Score (θ) and the market capitalization (given in Mio. USD)

Table 3: Descriptive statistics - EU

Sector	# of Firms		μ (%)	σ (%)	θ	Market Cap
10	33	Mean	1.57	19.30	67.21	161646.29
		Median	1.11	19.31	70.49	140689.51
		Min	-46.05	13.07	39.74	96237.38
		Max	52.88	28.02	83.49	290523.75
15	47	Mean	2.79	17.62	79.15	15075.35
		Median	2.71	18.56	81.95	13465.15
		Min	-40.66	7.70	55.80	5553.62
		Max	50.45	22.73	90.34	31490.47
20	128	Mean	2.63	17.06	72.16	11797.24
		Median	2.52	17.73	74.62	11168.82
		Min	-36.32	7.34	47.05	5057.21
		Max	47.99	22.33	86.84	20818.11
25	66	Mean	2.67	16.74	70.45	12670.50
		Median	2.54	17.68	71.99	12118.74
		Min	-38.20	6.65	46.56	5834.09
		Max	47.83	22.32	86.60	22357.58
30	39	Mean	2.29	12.03	77.78	24338.99
		Median	2.03	12.39	81.71	22721.85
		Min	-27.87	4.94	52.10	13164.02
		Max	34.09	15.72	90.70	39641.99
35	28	Mean	2.36	13.18	67.13	40683.99
		Median	2.28	13.76	70.18	38135.40
		Min	-28.71	5.75	42.85	19403.17
		Max	34.90	16.93	82.18	74634.27
40	95	Mean	0.98	17.29	65.43	22580.47
		Median	0.59	18.58	66.18	20924.65
		Min	-41.46	5.26	45.27	8974.11
		Max	55.39	23.39	80.80	39389.42
45	23	Mean	2.92	16.54	74.80	20983.67
		Median	2.27	17.43	76.59	18310.54
		Min	-38.56	6.39	51.29	10289.35
		Max	52.85	21.61	88.50	40933.62
50	43	Mean	0.32	15.19	70.31	21065.71
		Median	-0.40	16.42	73.09	20426.28
		Min	-36.90	5.19	46.67	11634.39
		Max	54.06	20.62	86.13	33111.36
60	30	Mean	1.91	18.42	61.85	3696.39
		Median	2.21	19.07	64.22	3496.19
		Min	-41.48	5.69	35.82	1499.20
		Max	54.60	25.38	82.08	6732.20

Notes: This table shows the descriptive statistics of the data set for the EU, sorted according to the General Industry Classification Standard (GICS). In column 2 the number of stocks contained in each sector are given, while the columns 4 - 7 show the sector-specific mean, median, maximum and minimum values for return (μ), volatility (σ), ESG Score (θ) and the market capitalization (given in Mio. USD)

Table 4: MEA Results US: Distribution of percentile changes over time

MEA model	$\sum \Delta P(F_{i,t})$	#	μ	σ	Min	Max	$\sum \Delta \lvert P(F_{i,t}) \rvert$
	2.00	-9.00	-0.41	4.02	-9.00	8.50	46.00
	3.00	-8.00	-0.36	2.31	-7.67	5.00	20.00
	3.00	-7.00	-0.32	2.11	-7.00	3.67	17.67
	2.00	-6.00	-0.27	1.50	-4.50	2.50	17.00
	7.00	-5.00	-0.23	1.74	-6.00	3.00	15.29
	5.00	-4.00	-0.18	1.17	-3.00	1.60	16.00
	7.00	-3.00	-0.14	0.59	-1.57	1.00	6.71
	15.00	-2.00	-0.09	0.66	-1.53	1.40	7.73
Model 1	89.00	-1.00	-0.05	0.62	-1.31	1.21	7.11
	162.00	0.00	0.00	0.55	-1.23	1.19	6.00
	67.00	1.00	0.05	0.69	-1.39	1.52	8.07
	20.00	2.00	0.09	0.72	-1.50	1.95	7.90
	4.00	3.00	0.14	0.64	-0.75	1.75	8.00
	7.00	4.00	0.18	1.75	-3.29	5.00	18.57
	9.00	5.00	0.23	1.31	-2.33	3.89	13.00
	7.00	6.00	0.27	1.99	-4.43	6.43	19.43
	2.00	9.00	0.41	3.95	-9.00	9.00	43.00
	2.00	-9.00	-0.41	3.88	-9.00	8.50	46.00
	2.00	-8.00	-0.36	2.11	-6.50	5.00	20.00
	1.00	-7.00	-0.32	2.64	-7.00	5.00	27.00
	9.00	-6.00	-0.27	1.71	-5.22	3.22	19.78
	6.00	-5.00	-0.23	1.48	-5.17	2.17	13.67
	11.00	-4.00	-0.18	1.61	-4.64	3.09	17.45
	10.00	-3.00	-0.14	0.91	-2.10	1.90	10.40
	29.00	-2.00	-0.09	0.73	-1.62	1.38	8.83
Model 2	66.00	-1.00	-0.05	0.63	-1.41	1.20	7.03
	139.00	0.00	0.00	0.64	-1.53	1.57	6.43
	66.00	1.00	0.05	0.67	-1.42	1.58	7.67
	14.00	2.00	0.09	0.86	-1.79	2.21	10.00
	7.00	3.00	0.14	1.43	-3.14	3.86	15.86
	16.00	4.00	0.18	1.65	-3.50	5.12	17.00
	16.00	5.00	0.23	1.62	-2.81	5.38	15.62
	10.00	6.00	0.27	1.59	-2.80	5.10	16.00
	4.00	7.00	0.32	1.72	-3.25	5.75	15.50
	2.00	8.00	0.36	2.35	-4.00	6.50	26.00
	1.00	9.00	0.41	4.39	-9.00	9.00	55.00
	2.00	-8.00	-0.36	2.09	-6.50	5.00	22.00
	2.00	-7.00	-0.32	2.07	-6.00	3.50	22.00
	6.00	-6.00	-0.27	1.71	-5.83	2.83	17.33
	5.00	-5.00	-0.23	1.69	-5.60	3.00	15.80
	12.00	-4.00	-0.18	1.62	-4.83	2.67	17.33
	14.00	-3.00	-0.14	0.86	-1.93	1.71	10.43
	21.00	-2.00	-0.09	0.70	-1.76	1.33	8.10
	61.00	-1.00	-0.05	0.51	-1.16	0.95	5.43
Model 3	141.00	0.00	0.00	0.60	-1.46	1.42	6.03
	75.00	1.00	0.05	0.73	-1.60	1.79	8.12
	17.00	2.00	0.09	0.71	-1.35	1.76	8.24
	9.00	3.00	0.14	1.32	-2.33	4.00	13.67
	17.00	4.00	0.18	1.45	-2.94	4.53	14.12
	13.00	5.00	0.23	1.51	-2.62	5.15	14.54
	11.00	6.00	0.27	1.86	-3.82	5.09	19.82
	3.00	7.00	0.32	2.09	-3.67	7.00	19.00
	1.00	8.00	0.36	4.49	-8.00	8.00	58.00
	1.00	9.00	0.41	4.41	-9.00	9.00	55.00

Notes: This table shows the MEA results with respect to the percentile changes over time for the US. MEA scores are grouped into percentiles $P(F_{i,t})$ and quarterly percentile changes are observed over time, ie. the MEA score of a particular firm moves up/down one or more percentiles from quarter $t-1$ to t. Column 2 shows the sum of total percentile changes over the whole observation period grouped from the most negative to most positive total percentile change observed. Column 3 reports the number of firms belonging to each group defined under Column 1. Columns 4 and 5 report the mean periodic percentile change and volatility. Columns 6 and 7 indicate the minimum and maximum percentile change over the whole observation period. Column 8 displays the firm-level average value of the sum of absolute percentile changes.

Table 5: MEA Results EU: Distribution of percentile changes over time

MEA model	$\sum \Delta P(F_{i,t})$	#	μ	σ	Min	Max	$\sum \Delta \lvert P(F_{i,t}) \rvert$
	2.00	-7.00	-0.32	2.57	-8.00	5.00	27.00
	4.00	-6.00	-0.27	1.67	-5.50	3.25	15.50
	6.00	-5.00	-0.23	1.43	-5.00	2.33	14.67
	4.00	-4.00	-0.18	2.32	-6.00	6.00	24.50
	2.00	-3.00	-0.14	0.51	-1.00	1.00	6.00
	25.00	-2.00	-0.09	0.75	-1.52	1.44	8.80
	108.00	-1.00	-0.05	0.56	-1.38	1.13	5.94
	242.00	0.00	0.00	0.59	-1.37	1.35	6.08
Model 1	104.00	1.00	0.05	0.56	-1.20	1.29	5.90
	28.00	2.00	0.09	0.52	-0.96	1.11	5.71
	3.00	3.00	0.14	1.70	-5.33	4.33	18.33
	6.00	4.00	0.18	1.59	-3.00	4.67	16.67
	8.00	5.00	0.23	1.73	-3.38	5.62	18.50
	5.00	6.00	0.27	2.87	-5.40	7.60	32.00
	1.00	7.00	0.32	1.76	-1.00	8.00	11.00
	4.00	8.00	0.36	1.94	-2.50	7.00	15.50
	2.00	-7.00	-0.32	2.20	-7.50	4.00	17.00
	6.00	-6.00	-0.27	1.40	-4.67	2.50	13.00
	12.00	-5.00	-0.23	1.49	-4.50	3.25	15.17
	12.00	-4.00	-0.18	1.39	-4.00	3.08	14.33
	17.00	-3.00	-0.14	1.21	-3.47	2.47	13.59
	27.00	-2.00	-0.09	0.71	-1.70	1.33	8.22
	97.00	-1.00	-0.05	0.60	-1.42	1.22	6.65
	200.00	0.00	0.00	0.70	-1.63	1.62	7.47
Model 2	88.00	1.00	0.05	0.65	-1.30	1.57	7.07
	32.00	2.00	0.09	0.79	-1.59	1.84	9.25
	14.00	3.00	0.14	1.28	-2.86	3.79	12.86
	19.00	4.00	0.18	1.51	-3.16	4.21	16.42
	12.00	5.00	0.23	1.62	-2.58	4.92	16.67
	4.00	6.00	0.27	1.88	-3.25	6.00	20.50
	8.00	7.00	0.32	1.84	-3.50	6.00	17.25
	1.00	8.00	0.36	2.13	-4.00	8.00	18.00
	1.00	9.00	0.41	1.22	-2.00	4.00	17.00
	2.00	-7.00	-0.32	2.20	-7.50	4.00	17.00
	6.00	-6.00	-0.27	1.39	-5.00	2.17	12.67
	15.00	-5.00	-0.23	1.47	-4.33	3.00	15.67
	11.00	-4.00	-0.18	1.32	-4.09	2.73	12.73
	14.00	-3.00	-0.14	1.22	-3.71	2.43	13.29
	28.00	-2.00	-0.09	0.82	-1.93	1.54	10.07
	98.00	-1.00	-0.05	0.59	-1.42	1.19	6.49
	186.00	0.00	0.00	0.68	-1.63	1.63	7.04
Model 3	82.00	1.00	0.05	0.66	-1.34	1.61	7.34
	35.00	2.00	0.09	0.74	-1.49	1.71	8.57
	13.00	3.00	0.14	1.23	-2.77	3.54	12.54
	29.00	4.00	0.18	1.41	-2.66	4.07	14.21
	16.00	5.00	0.23	1.39	-2.44	4.19	14.62
	7.00	6.00	0.27	1.66	-3.00	5.43	15.43
	7.00	7.00	0.32	1.51	-2.57	5.14	14.43
	2.00	8.00	0.36	1.65	-2.50	6.50	14.00
	1.00	9.00	0.41	1.40	-1.00	6.00	15.00

Notes: This table shows the MEA results with respect to the percentile changes over time for the EU. MEA scores are grouped into percentiles $P(F_{i,t})$ and quarterly percentile changes are observed over time, ie. the MEA score of a particular firm moves up/down one or more percentiles from quarter $t-1$ to t. Column 2 shows the sum of total percentile changes over the whole observation period grouped from the most negative to most positive total percentile change observed. Column 3 reports the number of firms belonging to each group defined under Column 1. Columns 4 and 5 report the mean periodic percentile change and volatility. Columns 6 and 7 indicate the minimum and maximum percentile change over the whole observation period. Column 8 displays the firm-level average value of the sum of absolute percentile changes.

Table 6: Overview of turnover rates for the Benchmarks

	US		EU	
Sector	MV	Index	MV	Index
10	15.74	1.31	14.11	0.67
15	14.28	1.84	17.50	1.71
20	17.94	1.25	15.47	1.49
25	14.62	1.77	12.77	1.54
30	11.09	0.95	14.32	1.16
35	13.33	1.38	9.01	1.26
40	12.89	1.24	10.65	1.61
45	24.19	1.66	10.52	1.45
50	7.37	1.64	13.58	1.26
60	8.73	1.42	8.04	1.06
Mean	14.02	1.42	12.60	1.32
Median	13.80	1.35	13.18	1.36

Notes: This table shows the turnover rates of the mean-variance optimized and value-weighted portfolios for each sector and each region as well as the mean and median values over all sectors based on quarterly rebalancing.

Table 7: Overview of turnover rates for efficiency-based strategies - US

Strategy 1: Efficiency-weighting			
Sector	Model 1	Model 2	Model 3
10	2.08	2.00	1.98
15	3.21	2.95	2.69
20	1.83	1.87	1.97
25	1.15	1.76	1.88
30	3.39	3.80	3.04
35	1.92	1.68	1.64
40	2.00	1.96	1.63
45	0.62	1.63	1.40
50	2.22	2.16	1.80
60	2.70	1.69	1.08
Mean	2.11	2.15	1.91
Median	2.04	1.91	1.84
Strategy 2: Efficiency-weighting & Efficiency-screening			
Sector	Model 1	Model 2	Model 3
10	7.80	6.43	6.14
15	6.23	8.27	6.71
20	7.07	7.91	7.93
25	1.30	5.39	6.48
30	9.27	9.78	7.50
35	8.80	7.11	6.77
40	6.37	7.34	6.56
45	4.33	7.09	5.41
50	6.83	5.77	4.07
60	8.67	6.10	3.28
Mean	6.67	7.12	6.08
Median	6.95	7.10	6.52
Strategy 3: Efficiency-screening			
Sector	Model 1	Model 2	Model 3
10	15.44	22.89	21.02
15	7.29	13.46	13.90
20	23.90	32.41	32.65
25	1.46	4.91	5.58
30	11.07	20.04	22.16
35	16.72	16.08	16.35
40	10.42	19.11	21.06
45	8.24	21.35	18.16
50	7.57	8.40	7.64
60	10.39	8.80	8.23
Mean	11.25	16.75	16.67
Median	10.41	17.60	17.25

Notes: This table shows the turnover rates of all efficiency-based strategies and all MEA Models for each sector for the US as well as the mean and median values over all sectors based on quarterly rebalancing.

Table 8: Overview of turnover rates for efficiency-based strategies - EU

Strategy 1: Efficiency-weighting			
Sector	Model 1	Model 2	Model 3
10	1.31	1.89	1.90
15	1.05	1.58	1.61
20	1.25	1.56	1.53
25	2.24	2.43	2.51
30	2.41	2.69	2.66
35	1.38	1.75	1.72
40	1.96	1.95	1.86
45	2.25	1.78	1.87
50	1.71	2.07	1.79
60	2.96	1.89	1.74
Mean	1.85	1.96	1.92
Median	1.83	1.89	1.82
Strategy 2: Efficiency-weighting & Efficiency-screening			
Sector	Model 1	Model 2	Model 3
10	3.67	6.70	6.95
15	2.50	6.64	6.79
20	8.09	8.80	7.45
25	9.93	8.72	8.93
30	8.83	7.36	7.50
35	4.67	7.03	6.27
40	10.95	8.49	7.40
45	5.80	4.42	4.70
50	8.23	7.11	5.37
60	6.93	4.40	4.40
Mean	6.96	6.97	6.57
Median	7.51	7.07	6.87
Strategy 3: Efficiency-screening			
Sector	Model 1	Model 2	Model 3
10	6.41	19.34	22.55
15	6.73	19.21	18.92
20	13.31	28.28	24.75
25	11.27	17.43	18.41
30	8.99	9.42	10.51
35	5.98	8.61	7.87
40	25.22	38.34	35.56
45	9.43	14.36	15.43
50	16.01	25.59	24.38
60	14.67	14.16	13.17
Mean	11.80	19.47	19.15
Median	10.35	18.32	18.67

Notes: This table shows the turnover rates of all efficiency-based strategies and all MEA Models for each sector for the EU as well as the mean and median values over all sectors based on quarterly rebalancing.

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7 Appendix

Table 9: Portfolio Results for Benchmarks - US

Mean-variance portfolio							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	2.44	35.67	0.07	75.35	2.11	-53.36	-78.48
15	-1.46	22.66	-0.06	95.89	4.23	-35.85	-52.66
20	16.33	21.07	0.77	78.03	3.70	-33.56	-46.78
25	16.83	22.41	0.75	61.96	2.76	-37.87	-50.75
30	16.49	15.99	1.03	92.89	5.81	-23.87	-35.09
35	23.29	23.01	1.01	83.39	3.62	-35.49	-51.52
40	3.84	14.70	0.26	32.78	2.23	-22.81	-33.39
45	-4.98	26.59	-0.19	76.10	2.86	-42.75	-62.15
50	21.83	19.52	1.12	79.54	4.07	-30.78	-43.40
60	17.26	17.43	0.99	40.40	2.32	-25.13	-35.79
Mean	11.19	21.91	0.58	71.63	3.37	-34.14	-49.00
Median	16.41	21.74	0.76	77.06	3.24	-34.52	-48.77
Naive portfolio							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	2.36	29.48	0.08	67.38	2.29	-46.66	-69.75
15	8.60	21.06	0.41	82.29	3.91	-33.90	-49.72
20	10.30	18.99	0.54	78.49	4.13	-29.75	-44.69
25	13.14	18.27	0.72	65.28	3.57	-28.73	-43.40
30	13.06	12.77	1.02	87.64	6.86	-20.10	-29.20
35	16.27	16.31	1.00	71.11	4.36	-27.01	-38.78
40	9.66	21.66	0.45	60.87	2.81	-33.69	-51.66
45	11.22	20.08	0.56	74.63	3.72	-32.81	-45.75
50	13.27	16.68	0.80	54.45	3.26	-25.70	-39.73
60	10.32	18.59	0.56	49.29	2.65	-28.65	-44.21
Mean	10.82	19.39	0.61	69.14	3.76	-30.70	-45.69
Median	10.77	18.79	0.56	69.24	3.65	-29.24	-44.45
Value-weigthed index portfolio							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	2.32	21.89	0.11	84.10	3.84	-34.34	-52.27
15	4.27	20.28	0.21	88.66	4.37	-32.73	-47.84
20	9.89	17.47	0.57	88.05	5.04	-27.46	-41.24
25	14.96	17.04	0.88	72.73	4.27	-27.53	-40.20
30	9.44	11.61	0.81	91.17	7.85	-18.13	-26.57
35	16.76	15.55	1.08	79.79	5.13	-25.77	-35.91
40	8.37	23.09	0.36	78.30	3.39	-36.98	-54.84
45	9.57	17.66	0.54	87.20	4.94	-27.95	-41.32
50	12.57	14.51	0.87	78.40	5.40	-22.23	-32.84
60	10.38	17.77	0.58	51.50	2.90	-28.40	-42.31
Mean	9.85	17.69	0.60	79.99	4.52	-28.15	-41.54
Median	9.73	17.56	0.58	81.93	4.66	-27.74	-41.28

Notes: This table shows the results of the benchmark portfolios for the US. $\bar{\mu}$ represents the annualized average return, σ annualized portfolio volatility, SR denotes the Sharpe Ratio and $\bar{\theta}$ stands for the average ESG Score. The Delta Ratio (DR) is computed by $\frac{\bar{\theta}}{\sigma}$. VaR and ES represent the annualized Value-at-Risk and Expected Shortfall of the 95% quantile, respectively. The portfolio returns are based on daily observations with quarterly rebalancing.

Table 10: Portfolio Results for Benchmarks - EU

Mean-variance portfolio							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\overline{\theta}$	DR	VaR (%)	ES (%)
10	3.42	39.72	0.09	78.63	1.98	-58.93	-94.63
15	5.65	73.94	0.08	72.76	0.98	-47-24	-97.98
20	4.17	21.05	0.20	88.28	4.19	-34.83	-45.50
25	11.45	20.14	0.57	78.34	3.89	-32.39	-44.80
30	7.25	18.65	0.39	85.96	4.61	-29.75	-40.84
35	7.09	20.83	0.34	88.25	4.24	-35.04	-46.04
40	17.24	19.53	0.88	70.95	3.63	-30.27	-42.79
45	-0.75	23.94	-0.03	84.98	3.55	-39.17	-52.98
50	-9.68	20.91	-0.46	79.18	3,79	-34.98	-45.89
60	6.50	19.08	0.34	43.18	2.26	-30.28	-41.16
Mean	5.23	27.78	0.24	77.05	3.31	-37.29	-55.26
Median	6.07	20.87	0.27	78.91	3.71	-34.91	-45.69
Naive portfolio							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\overline{\theta}$	DR	VaR (%)	ES (%)
10	-2.49	23.61	-0.11	74.09	3.14	-38.63	-54.62
15	7.75	21.41	0.36	83.47	3.90	-34.45	-49.35
20	10.10	17.49	0.58	78.70	4.50	-28.03	-42.18
25	12.31	17.31	0.71	76.33	4.41	-27.40	-41.59
30	8.87	13.56	0.65	84.55	6.23	-22.05	-30.94
35	14.00	14.82	0.95	72.84	4.92	-25.36	-35.93
40	6.26	23.23	0.27	69.11	2.97	-37.40	-54.72
45	12.81	18.60	0.69	81.27	4.37	-29.07	-43.11
50	2.93	17.58	0.17	76.75	4.37	-29.11	-41.91
60	9.55	16.37	0.58	70.10	4.28	-24.89	-38.51
Mean	8.21	18.40	0.49	76.72	4.31	-29.64	-43.28
Median	9.21	17.53	0.58	76.54	4.37	-28.55	-42.04
Value-weigthed index portfolio							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\overline{\theta}$	DR	VaR (%)	ES (%)
10	-0.61	22.94	-0.03	67.43	2.94	-34.93	-50.09
15	5.73	20.61	0.28	89.54	4.34	-33.48	-49.53
20	9.01	20.63	0.44	86.87	4.21	-33.52	-49.48
25	8.08	19.31	0.42	82.30	4.26	-30.50	-46.22
30	8.61	13.92	0.62	90.80	6.52	-22.44	-31.33
35	11.07	16.82	0.66	87.23	5.19	-27.69	-39.74
40	8.68	22.95	0.38	82.68	3.60	-36.51	-54.92
45	5.19	22.05	0.24	87.16	3.95	-34.69	-53.29
50	3.05	16.65	0.18	89.03	5.35	-25.42	-37.82
60	7.93	18.07	0.44	78.66	4.35	-27.76	-42.19
Mean	6.68	19.40	0.36	84.17	4.47	-30.69	-45.46
Median	8.01	19.96	0.40	87.02	4.30	-31.99	-47.85

Notes: This table shows the results of the benchmark portfolios for the EU. $\bar{\mu}$ represents the annualized average return, σ annualized portfolio volatility, SR denotes the Sharpe Ratio and $\bar{\theta}$ stands for the average ESG Score. The Delta Ratio (DR) is computed by $\frac{\bar{\theta}}{\sigma}$. VaR and ES represent the annualized Value-at-Risk and Expected Shortfall of the 95% quantile, respectively. The portfolio returns are based on daily observations with quarterly rebalancing.

Table 11: Portfolio Results for MEA Model 1 - US

Strategy 1: Efficiency-weighting

Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	1.54	28.01	0.05	69.37	2.48	-43.77	-66.26
15	6.86	20.37	0.34	85.56	4.20	-33.20	-48.68
20	9.85	18.54	0.53	79.62	4.29	-28.63	-43.52
25	13.24	17.81	0.74	65.11	3.66	-28.45	-42.16
30	14.67	12.75	1.15	87.34	6.85	-19.65	-28.60
35	16.85	16.69	1.01	70.20	4.21	-27.05	-39.34
40	8.80	20.84	0.42	60.31	2.89	-34.05	-49.78
45	11.68	19.33	0.60	75.39	3.90	-30.93	-44.25
50	12.50	16.20	0.77	57.66	3.56	-25.56	-38.36
60	9.87	18.48	0.53	49.01	2.65	-29.59	-44.23
Mean	10.59	18.90	0.62	69.96	3.87	-30.09	-44.52
Median	10.78	18.51	0.57	69.79	3.78	-29.11	-43.88

Strategy 2: Efficiency-weighting & Efficiency-screening

Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	-0.86	23.76	-0.04	75.87	3.19	-37.30	-55.72
15	8.69	19.69	0.44	93.49	4.75	-30.00	-47.59
20	5.43	18.48	0.29	84.35	4.56	-28.59	-42.50
25	18.20	17.82	1.02	64.91	3.64	-28.19	-40.40
30	14.02	13.79	1.02	90.25	6.55	-20.86	-30.05
35	17.88	22.94	0.78	63.38	2.76	-35.62	-49.33
40	3.71	22.25	0.17	49.89	2.24	-34.86	-51.11
45	15.32	17.96	0.85	77.81	4.33	-29.25	-41.84
50	9.36	17.12	0.55	65.62	3.83	-26.97	-38.85
60	7.83	20.18	0.39	56.68	2.81	-31.56	-48.59
Mean	9.96	19.40	0.55	72.23	3.87	-30.32	-44.60
Median	9.02	19.09	0.49	70.74	3.74	-29.62	-45.04

Strategy 3: Efficiency-screening

Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	-4.80	29.86	-0.16	65.86	2.21	-47.61	-69.15
15	13.25	20.54	0.65	93.79	4.57	-31.55	-49.53
20	16.61	26.24	0.63	63.45	2.42	-40.98	-57.27
25	17.22	14.79	1.16	65.66	4.44	-23.16	-33.20
30	13.38	13.62	0.98	91.04	6.68	-21.62	-30.44
35	11.95	26.60	0.45	50.30	1.89	-41.00	-62.66
40	4.71	22.94	0.21	44.16	1.93	-35.88	-56.51
45	13.49	20.74	0.65	80.85	3.90	-31.71	-49.33
50	11.46	19.51	0.59	61.31	3.14	-29.86	-45.20
60	7.67	20.78	0.37	53.90	2.59	-32.72	-50.37
Mean	10.50	21.56	0.55	67.03	3.38	-33.61	-50.37
Median	12.60	20.76	0.61	64.55	2.87	-32.22	-49.95

Notes: This table shows the results for the MEA Model 1 for the US, which uses volatility as input and expected return as output. $\bar{\mu}$ represents the average return, σ portfolio volatility, SR denotes the Sharpe Ratio and $\bar{\theta}$ stands for the average ESG Score. The Delta Ratio (DR) is computed by $\frac{\bar{\theta}}{\sigma}$. VaR and ES represent the Value-at-Risk and Expected Shortfall of the 95% quantile, respectively. The portfolio returns are based on daily observations with quarterly rebalancing.

Table 12: Portfolio Results for MEA Model 1 - EU

Strategy 1: Efficiency-weighting							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	-2.20	23.22	-0.09	74.58	3.21	-39.06	-53.90
15	7.79	20.35	0.38	84.45	4.15	-32.99	-48.24
20	9.25	17.17	0.54	79.94	4.66	-27.80	-41.27
25	11.80	16.97	0.70	77.12	4.54	-26.91	-40.70
30	8.33	13.53	0.62	84.77	6.26	-22.15	-31.19
35	13.24	14.33	0.92	78.09	5.45	-23.68	-33.87
40	7.39	21.07	0.35	68.01	3.23	-34.40	-50.56
45	10.89	17.94	0.61	80.67	4.50	-27.56	-41.15
50	3.56	16.49	0.22	76.60	4.64	-27.39	-38.96
60	9.74	15.73	0.62	69.46	4.42	-22.90	-36.80
Mean	7.98	17.68	0.49	77.37	4.51	-28.48	-41.66
Median	8.79	17.07	0.57	77.61	4.52	-27.47	-40.93
Strategy 2: Efficiency-weighting & Efficiency-screening							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	2.79	25.30	0.11	72.46	2.86	-41.03	-59.46
15	9.78	22.44	0.44	91.37	4.07	-35.97	-52.88
20	6.04	18.42	0.33	84.15	4.57	-30.37	-42.56
25	8.80	17.65	0.50	77.39	4.38	-28.97	-40.77
30	4.68	17.30	0.27	92.51	5.35	-27.96	-39.00
35	9.65	17.98	0.54	89.00	4.95	-28.61	-41.19
40	2.02	17.84	0.11	50.78	2.85	-27.19	-43.78
45	4.60	18.88	0.24	78.22	4.14	-29.98	-43.51
50	2.61	16.85	0.15	60.83	3.61	-27.34	-39.54
60	8.60	15.24	0.56	66.22	4.35	-23.38	-35.35
Mean	5.96	18.79	0.33	76.29	4.11	-30.08	-43.80
Median	5.36	17.91	0.30	77.81	4.24	-28.79	-41.88
Strategy 3: Efficiency-screening							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	2.89	30.54	0.09	72.40	2.37	-49.16	-74.73
15	7.63	23.60	0.32	90.13	3.82	-38.16	-55.49
20	-2.08	22.18	-0.09	81.64	3.68	-34.08	-51.12
25	12.19	20.69	0.59	74.21	3.59	-30.34	-46.31
30	4.43	17.47	0.25	92.68	5.31	-27.63	-40.00
35	9.54	21.39	0.45	87.09	4.07	-32.83	-48.96
40	-9.50	24.51	-0.39	73.26	2.99	-35.23	-60.02
45	18.36	23.35	0.79	72.87	3.12	-34.32	-50.37
50	6.77	23.69	0.29	40.80	1.72	-38.88	-56.88
60	7.69	18.48	0.42	41.24	2.23	-29.16	-43.11
Mean	5.79	22.59	0.27	72.63	3.29	-34.98	-52.7
Median	7.20	22.76	0.30	73.74	3.35	-34.20	-50.75

Notes: This table shows the results for the MEA Model 1 for the EU, which uses volatility as input and expected return as output. $\bar{\mu}$ represents the average return, σ portfolio volatility, SR denotes the Sharpe Ratio and $\bar{\theta}$ stands for the average ESG Score. The Delta Ratio (DR) is computed by $\frac{\bar{\theta}}{\sigma}$. VaR and ES represent the Value-at-Risk and Expected Shortfall of the 95% quantile, respectively. The portfolio returns are based on daily observations with quarterly rebalancing.

Table 13: Portfolio Results for MEA Model 2 - US

Strategy 1: Efficiency-weighting							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	1.34	27.91	0.05	70.89	2.54	-43.41	-65.94
15	7.82	20.19	0.39	87.39	4.33	-32.90	-48.32
20	10.15	18.44	0.55	81.42	4.42	-28.28	-43.30
25	13.56	17.88	0.76	66.96	3.74	-28.73	-42.53
30	13.85	12.51	1.11	89.04	7.11	-19.68	-28.18
35	16.53	16.53	1.00	73.28	4.43	-26.72	-39.04
40	8.86	21.08	0.42	64.13	3.04	-34.68	-50.46
45	11.05	19.32	0.57	77.53	4.01	-31.10	-44.49
50	12.92	15.91	0.81	60.48	3.80	-25.37	-37.64
60	10.34	18.50	0.56	53.62	2.90	-29.14	-44.22
Mean	10.64	18.83	0.62	72.47	4.03	-30.00	-44.41
Median	10.70	18.47	0.57	72.09	3.91	-28.94	-43.76
Strategy 2: Efficiency-weighting & Efficiency-screening							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	-1.29	24.60	-0.05	79.90	3.25	-38.32	-57.99
15	9.44	19.15	0.49	94.02	4.91	-30.69	-46.42
20	7.54	17.74	0.42	88.85	5.01	-28.05	-40.85
25	15.16	17.11	0.89	76.57	4.48	-26.74	-39.86
30	12.83	12.99	0.99	92.20	7.10	-19.67	-28.36
35	18.25	19.50	0.94	78.34	4.02	-29.43	-44.20
40	6.17	21.52	0.29	70.49	3.28	-34.45	-51.33
45	10.41	17.56	0.59	88.47	5.04	-29.34	-41.18
50	11.60	15.63	0.74	74.63	4.77	-24.46	-35.00
60	10.77	20.05	0.54	70.82	3.53	-32.47	-47.91
Mean	10.09	18.58	0.58	81.43	4.54	-29.36	-43.31
Median	10.59	18.45	0.56	79.12	4.63	-29.38	-42.69
Strategy 3: Efficiency-screening							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	-10.79	31.54	-0.34	59.95	1.90	-50.80	-73.14
15	10.99	22.39	0.49	92.86	4.15	-33.34	-54.20
20	14.40	25.86	0.56	70.03	2.71	-41.43	-57.60
25	15.20	14.67	1.04	69.71	4.75	-22.30	-33.39
30	10.14	15.40	0.66	90.33	5.87	-23.35	-34.84
35	19.64	26.68	0.74	63.75	2.39	-42.51	-60.86
40	2.72	20.93	0.13	43.59	2.08	-33.53	-50.30
45	16.49	25.34	0.65	72.64	2.87	-39.42	-59.65
50	13.02	19.08	0.68	66.23	3.47	-30.25	-44.78
60	8.02	21.74	0.37	47.04	2.16	-33.71	-51.76
Mean	9.98	22.36	0.50	67.61	3.23	-35.07	-52.05
Median	12.01	22.06	0.60	67.97	2.79	-33.62	-52.98

Notes: This table shows the results for the MEA Model 2 for the US, which uses volatility as input and expected return and ESG Score θ as output. $\bar{\mu}$ represents the average return, σ portfolio volatility, SR denotes the Sharpe Ratio and $\bar{\theta}$ stands for the average ESG Score. The Delta Ratio (DR) is computed by $\frac{\bar{\theta}}{\sigma}$. VaR and ES represent the Value-at-Risk and Expected Shortfall of the 95% quantile, respectively. The portfolio returns are based on daily observations with quarterly rebalancing.

Table 14: Portfolio Results for MEA Model 2 - EU

Strategy 1: Efficiency-weighting							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	-2.75	23.01	-0.12	76.93	3.34	-38.91	-53.92
15	7.63	20.62	0.37	86.28	4.18	-33.32	-48.88
20	9.27	17.39	0.53	81.60	4.69	-28.37	-41.74
25	12.04	17.76	0.68	79.61	4.48	-28.11	-42.51
30	8.34	13.66	0.61	85.40	6.25	-22.46	-31.27
35	12.97	14.50	0.89	80.09	5.52	-23.35	-34.59
40	7.86	21.10	0.37	71.58	3.39	-34.76	-50.44
45	12.08	18.56	0.65	83.81	4.52	-29.73	-42.58
50	3.20	16.14	0.20	77.81	4.82	-26.42	-37.89
60	9.26	16.30	0.57	73.07	4.48	-23.90	-38.14
Mean	7.99	17.90	0.48	79.62	4.57	-28.93	-42.19
Median	8.80	17.57	0.55	79.85	4.50	-28.24	-42.12
Strategy 2: Efficiency-weighting & Efficiency-screening							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	-6.13	23.95	-0.26	81.69	3.41	-39.53	-57.69
15	9.55	21.55	0.44	93.07	4.32	-33.86	-51.04
20	10.66	18.57	0.57	90.11	4.85	-29.69	-42.73
25	10.61	19.35	0.55	86.58	4.47	-30.31	-45.66
30	8.09	16.95	0.48	93.67	5.52	-26.91	-37.41
35	8.02	16.72	0.48	90.06	5.39	-27.54	-38.59
40	8.51	18.56	0.46	73.52	3.96	-27.29	-43.38
45	12.15	19.37	0.63	86.92	4.49	-31.37	-43.44
50	2.11	15.54	0.14	76.59	4.93	-24.81	-36.02
60	9.38	16.40	0.57	76.64	4.67	-24.78	-37.72
Mean	7.30	18.70	0.41	84.89	4.60	-29.61	-43.37
Median	8.95	18.57	0.48	86.75	4.58	-28.62	-43.05
Strategy 3: Efficiency-screening							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	8.06	32.87	0.25	69.30	2.11	-51.26	-75.57
15	4.53	25.03	0.18	89.59	3.58	-40.01	-59.03
20	-0.90	24.81	-0.04	78.73	3.17	-38.35	-56.20
25	8.76	19.75	0.44	75.68	3.83	-31.41	-45.09
30	6.12	17.56	0.35	92.97	5.29	-28.06	-40.72
35	9.09	21.80	0.42	86.98	3.99	-33.92	-49.27
40	-13.41	24.72	-0.54	61.89	2.50	-36.04	-61.41
45	14.46	24.34	0.59	76.96	3.16	-37.18	-52.50
50	0.68	22.12	0.03	59.08	2.67	-36.05	-53.35
60	7.50	17.97	0.42	45.29	2.52	-27.35	-41.03
Mean	4.49	23.10	0.21	73.65	3.28	-35.96	-53.42
Median	6.81	23.23	0.30	76.32	3.17	-36.04	-52.92

Notes: This table shows the results for the MEA Model 2 for the EU, which uses volatility as input and expected return and ESG Score θ as output. $\bar{\mu}$ represents the average return, σ portfolio volatility, SR denotes the Sharpe Ratio and $\bar{\theta}$ stands for the average ESG Score. The Delta Ratio (DR) is computed by $\frac{\bar{\theta}}{\sigma}$. VaR and ES represent the Value-at-Risk and Expected Shortfall of the 95% quantile, respectively. The portfolio returns are based on daily observations with quarterly rebalancing.

Table 15: Portfolio Results for MEA Model 3 - US

Strategy 1: Efficiency-weighting							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	1.44	27.81	0.05	71.10	2.56	-43.22	-65.62
15	8.57	20.05	0.43	87.62	4.37	-32.14	-47.83
20	10.20	18.46	0.55	81.45	4.41	-27.83	-43.40
25	13.42	17.84	0.75	67.36	3.78	-28.95	-42.48
30	13.49	12.42	1.09	89.18	7.18	-19.60	-28.14
35	16.60	16.50	1.01	73.33	4.44	-26.67	-38.98
40	8.96	21.04	0.43	64.55	3.07	-34.80	-50.29
45	10.97	19.32	0.57	77.56	4.01	-31.10	-44.43
50	12.92	15.83	0.82	59.90	3.78	-25.31	-37.51
60	10.45	18.51	0.56	54.65	2.95	-29.35	-44.11
Mean	10.70	18.78	0.63	72.67	4.06	-29.90	-44.28
Median	10.71	18.49	0.57	72.21	3.90	-29.15	-43.75
Strategy 2: Efficiency-weighting & Efficiency-screening							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	-1.35	24.37	-0.06	79.90	3.28	-37.75	-56.81
15	11.60	18.93	0.61	93.38	4.93	-30.62	-45.36
20	8.04	17.36	0.46	88.00	5.07	-26.71	-39.94
25	14.32	16.94	0.85	77.12	4.55	-26.71	-39.88
30	12.80	12.46	1.03	91.90	7.38	-18.95	-27.54
35	18.54	19.31	0.96	78.57	4.07	-29.46	-43.73
40	6.77	21.08	0.32	71.33	3.38	-34.54	-50.44
45	10.65	17.46	0.61	88.72	5.08	-28.95	-40.80
50	11.35	15.32	0.74	72.38	4.73	-23.91	-34.49
60	11.71	19.60	0.60	70.85	3.61	-30.86	-46.63
Mean	10.44	18.28	0.61	81.22	4.61	-28.85	-42.56
Median	11.47	18.20	0.61	79.23	4.64	-29.21	-42.27
Strategy 3: Efficiency-screening							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	-12.33	31.98	-0.39	58.80	1.84	-51.80	-73.19
15	11.58	22.16	0.52	93.33	4.21	-36.02	-53.07
20	11.11	25.75	0.43	70.32	2.73	-40.99	-57.98
25	14.99	14.52	1.03	70.21	4.84	-22.24	-33.16
30	-10.04	15.54	0.65	88.41	5.69	-24.02	-34.98
35	19.45	26.73	0.73	63.82	2.39	-42.51	-61.17
40	4.02	20.57	0.20	37.37	1.82	-34.02	-47.98
45	16.76	25.11	0.67	72.98	2.91	-38.03	-59.62
50	12.65	18.80	0.67	61.84	3.29	-30.47	-44.30
60	7.36	21.10	0.35	51.58	2.44	-32.33	-50.69
Mean	9.56	22.23	0.49	66.87	3.21	-35.24	-51.61
Median	11.34	21.63	0.58	67.02	2.82	-35.02	-51.88

Notes: This table shows the results for the MEA Model 3 for the US, which uses volatility, VaR and ES as input and expected return and ESG Score θ as output. $\bar{\mu}$ represents the average return, σ portfolio volatility, SR denotes the Sharpe Ratio and $\bar{\theta}$ stands for the average ESG Score. The Delta Ratio (DR) is computed by $\frac{\bar{\theta}}{\sigma}$. VaR and ES represent the Value-at-Risk and Expected Shortfall of the 95% quantile, respectively. The portfolio returns are based on daily observations with quarterly rebalancing.

Table 16: Portfolio Results for MEA Model 3 - EU

Strategy 1: Efficiency-weighting							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	-2.41	22.87	-0.11	76.24	3.33	-38.61	-53.54
15	7.61	20.61	0.37	86.29	4.19	-33.41	-48.87
20	9.51	17.30	0.55	81.61	4.72	-28.27	-41.52
25	12.06	17.81	0.68	79.71	4.47	-28.09	-42.69
30	8.25	13.63	0.61	85.18	6.25	-22.29	-31.21
35	13.38	14.48	0.92	80.11	5.53	-23.28	-34.52
40	8.25	21.11	0.39	71.50	3.39	-34.83	-50.49
45	11.66	18.55	0.63	83.73	4.51	-29.69	-42.58
50	3.45	16.07	0.21	77.51	4.82	-26.05	-37.85
60	9.48	16.30	0.58	72.97	4.48	-23.98	-38.08
Mean	8.12	17.87	0.48	79.48	4.57	-28.85	-42.13
Median	8.86	17.55	0.57	79.91	4.50	-28.18	-42.05
Strategy 2: Efficiency-weighting & Efficiency-screening							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	-5.58	23.51	-0.24	79.65	3.39	-39.65	-56.57
15	9.52	21.53	0.44	93.08	4.32	-33.86	-50.89
20	11.09	17.75	0.63	88.63	4.99	-28.65	-41.25
25	11.01	19.32	0.57	86.43	4.47	-29.72	-45.70
30	6.79	16.77	0.40	93.66	5.58	-26.79	-45.70
35	10.86	16.22	0.67	88.79	5.47	-26.64	-37.67
40	10.79	18.18	0.59	73.64	4.05	-28.31	-42.75
45	10.81	19.29	0.56	87.08	4.51	-31.06	-43.40
50	3.39	15.03	0.23	74.97	4.99	-23.61	-35.09
60	9.83	16.37	0.60	76.30	4.66	-24.89	-37.63
Mean	7.85	18.40	0.45	84.22	4.64	-29.32	-42.83
Median	10.31	17.96	0.57	86.76	4.59	-28.48	-42.00
Strategy 3: Efficiency-screening							
Sector	$\bar{\mu}$ (%)	σ (%)	SR	$\bar{\theta}$	DR	VaR (%)	ES (%)
10	5.44	31.96	0.17	61.14	1.91	-51.33	-73.01
15	4.47	24.99	0.18	89.61	3.59	-40.10	-58.80
20	3.29	23.11	0.14	76.32	3.30	-37.16	-52.14
25	10.51	19.26	0.55	74.57	3.87	-28.83	-43.54
30	5.63	17.81	0.32	92.84	5.21	-28.58	-41.38
35	12.07	20.93	0.58	85.85	4.10	-32.17	-46.56
40	-6.97	22.84	-0.31	61.69	2.70	-34.41	-55.17
45	14.14	24.45	0.58	77.23	3.16	-36.92	-52.57
50	0.24	22.05	0.01	57.52	2.61	-34.57	-52.55
60	9.13	18.01	0.51	45.35	2.52	-27.22	-39.88
Mean	5.79	22.54	0.27	72.21	3.30	-35.13	-51.56
Median	5.53	22.44	0.25	75.45	3.23	-34.49	-52.35

Notes: This table shows the results for the MEA Model 3 for the EU, which uses volatility, VaR and ES as input and expected return and ESG Score θ as output. $\bar{\mu}$ represents the average return, σ portfolio volatility, SR denotes the Sharpe Ratio and $\bar{\theta}$ stands for the average ESG Score. The Delta Ratio (DR) is computed by $\frac{\bar{\theta}}{\sigma}$. VaR and ES represent the Value-at-Risk and Expected Shortfall of the 95% quantile, respectively. The portfolio returns are based on daily observations with quarterly rebalancing.