M.Sc in Finance

University of Gothenburg

Reducing the Carbon Footprint of Equity Portfolios

Authors:

Harpa Sif Jónsdóttir

890329-5247

Sheida Palmelind

840829-8605

Supervisor:

Evert Carlsson, Ph.D

UNIVERSITY OF GOTHENBURG

SCHOOL OF BUSINESS, ECONOMICS AND LAW

Abstract

This paper investigates the effect of reducing the carbon footprint of Swedish equity portfolios. In order to decrease CO_2e emission of investments, the constituents of the portfolios are re-weighted with regards to their carbon footprint, while minimizing the tracking error against a benchmark portfolio. The study provides insight to whether it is possible to construct portfolios with lower CO_2e in a limited investment environment. Our findings show that we can decrease carbon footprint by 25% without altering the portfolios' sector exposure or suffering loss of returns. The optimization incorporates a recently proposed Swedish national standard for calculating portfolio footprint as well as a calculation of how much an investor contributes to emission when investing 1000 SEK a month for ten years in each of the portfolios.

Keywords: *Portfolio Optimization, Carbon Footprint, Tracking Error, Sustainable Investments, Factor Analysis, Climate Risk, Green Finance, Swedish Equities.*

Acknowledgements

We would like to acknowledge the support we received from our supervisor Ph.D Evert Carlsson while writing our thesis. We are grateful not only for the supervision of this thesis, but for the hours he has spent teaching us during these past two years. With his guidance and encouragements our interest for finance has grown, which has prepared us for our future within this field. We would also like to thank Joseph Vecci for his advice and encouragement during the writing of our thesis. Finally we would like to thank both classmates and each other for support, friendship and invaluable advice.

Contents

List of Tables

List of Figures

1 Introduction

This study aims to investigate the possibility of decreasing the carbon footprint of Swedish equity portfolios while maintaining returns. We will incorporate a proposed Swedish national standard for calculating the carbon footprint in an optimization which aims to decrease carbon dioxide and equivalent gases (CO_2e) in the portfolio while minimizing tracking error.[1] This method of decarbonization could provide a way for environmentally conscious investors to reduce portfolio carbon footprint without suffering loss of returns.

Whether investors are trying to climate hedge against a transition towards a low-carbon economy or trying to invest according to their environmental concerns, a greater interest for emission metrics in portfolio decisions is emerging. In recent proceedings in Paris, where actions towards a low-carbon economy were presented (The European Commission, 2015), with the goal of reducing climate impact. The purpose is to engage government action within the participating countries to limit the increase in global average temperature to below 2°C. Sweden is one of the signatories and the Swedish government has set climate guidelines for financial markets in Sweden (Regeringskansliet, 2016), which promotes divestments from fossil fuel. Within the guidelines the Swedish government also encourages fund managers to present the carbon footprint of their portfolios. In line with the request for a greater transparency of fund sustainability, the Swedish Investment Fund Association (2016) presented a national standard for calculating the carbon footprint of a portfolio. The aim of reporting the carbon footprint is to facilitate comparison of investment portfolios' contribution to CO_2e emissions and aid investors in choosing funds that match their personal environmental profile. The Paris agreement along with new directions from the Swedish government could be an indicator of future policies regarding CO_2e emissions. Policy changes could increase the price of carbon on the market, which would affect return of portfolios with an exposure to CO_2e. The increased interest in sustainable financial markets could lead to investors becoming increasingly concerned with the environmental impact of their portfolios.

A calculation of the carbon footprint of investment portfolios would provide a way of comparing the emission that an investor contributes to through their investment choices. There are at least two

[1] The tracking error throughout our thesis is the *ex ante* tracking error.

possible reasons an investor will care about the carbon footprint of an investment portfolio. Firstly, for environmentally conscious investors looking to decrease their contribution to CO_2e emission, a portfolio with lower carbon footprint is preferred. Secondly, if the investor believes that the price of carbon emission will increase, the investor will want to decrease carbon exposure in their investments. A portfolio with lower CO_2e emission but with maintained financial returns would be of interest for both types of investors.

Green funds have previously been the choice for environmentally conscious investors. These funds are generally investing in companies that are engaged in environmental projects or excluding companies in carbon heavy sectors, or implementing both strategies. These strategies will naturally apply restrictions on the investment universe of these funds. A number of studies have been made to evaluate performance of green funds compared to their peers. In the paper by Ibikunle and Steffen (2015) the authors compare the financial performance of European green funds, conventional funds and fossil energy funds. While in Climent and Soriano (2011), the authors investigate the performance of green mutual funds in relation to conventional funds in the United States. In both publications the authors find that the funds underperform their conventional peers. This is suggested to be caused by the limitations in diversification. For an investor looking to reduce climate impact while maintaining returns, green funds could have a less desirable investment strategy.

An alternative to green funds was presented by Andersson et al. (2016), where the authors construct a decarbonized version of the MSCI Europe Index[2]. The authors reduce CO_2e in the index by re-weighting the constituents in the portfolio. The new weights are obtained through an optimization of tracking error (TE) using a carbon constraint. Where tracking error represents the standard deviation of the difference in the returns of the decarbonized portfolio from the benchmark portfolio. The fund's largest carbon emitters are either removed altogether or reduced in the portfolio. Their finding is that it is possible to reduce CO_2e in the portfolio, although reduction will increase the tracking error against the benchmark. The increase of TE is dependent on how much of the carbon footprint is reduced.

In the paper by Andersson et al. (2016), the motivation for constructing a decarbonized index is that carbon prices might be undervalued on the market. A policy induced increase in carbon

[2]The MSCI Europe is an index that includes mid- to large cap companies in 15 countries in Europe.

prices would affect stock prices. For sectors that emit relatively large quantities, an increase in price of CO_2e emissions is considered a risk factor. The decarbonized index is designed to match performance of the benchmark index, and to outperform the benchmark if carbon prices increase. A decarbonized portfolio could therefore be compared with having a free option on carbon (Andersson et al., 2016). An investor looking to climate hedge their portfolio could benefit from an optimized portfolio rather than a green fund. The difference between a decarbonized portfolio and a green fund, is that the former does not necessarily limit which sectors the portfolio manager can choose to invest in. Therefore this could also be an attractive alternative for an investor who wants to reduce climate impact of their investments.

The purpose of this paper is to extend the method presented by Andersson et al. (2016). This study investigates the possibility of reducing carbon exposure of Swedish equity portfolios. Despite the significant contributions of Andersson et al. (2016), the study does not include a standardized measure for carbon footprint of a portfolio nor is an analysis of sector exposure performed. This study adds to Andersson et al. (2016) more broadly in three ways: firstly, we are the first to implement this method on Swedish equity portfolios; secondly, we are the first to utilize an optimization method that includes a proposed Swedish national standard for calculating carbon footprint provided by Swedish Investment Fund Association (2016); finally, this study will include an analysis of sector exposure in the decarbonized portfolios. The analysis is limited to only include emission data from 2015, this is due to lack of data reported for years previous to 2015.

As the Swedish portfolios are substantially smaller than the global equity portfolios that have previously been decarbonized, this study will provide a valuable insight in the effect of portfolio decarbonization in a limited investment environment. In previous literature, a standard for calculating carbon footprint has not yet been set. By incorporating the Swedish national standard into the optimization, we are evaluating the standard as well as placing the decarbonization in a Swedish context. An analysis of sector exposure is included to evaluate possible risk factors in the decarbonized portfolios. An over-representation of a few sectors in the portfolio increases sector specific risks. Hedging climate risk should not be done at the cost of increasing other risks. As mentioned before, the green funds often perform slightly worse than their conventional peers which is attributed to limitations in diversification. We would therefore like to investigate the possibility

of reducing carbon footprint while still allowing for investments in a majority of sectors and without sacrificing returns.

In this study we are optimizing two large investment fund portfolios and one broad market index to identify the effect of a decarbonization. The optimization entails a minimization of the *ex ante* tracking error with regards to the national standard for calculating carbon footprint of the portfolio. This process will result in a portfolio with new asset weights and a reduced carbon footprint. The decarbonized portfolios are compared to the original portfolio with regards to carbon footprint and sector exposure to observe how the reduction of carbon footprint alters the portfolios.

In addition to the calculation of carbon footprint we provide a calculation of how much CO_2e a private investor would contribute to when investing in the original portfolios as well as in the optimized portfolios. The calculation is meant to replicate the Swedish measure of portfolio fees, the "Norman Amount" (Morningstar, 2012). This approach quantifies the amount of carbon emission owned by a single investor rather than what is held by all portfolio owners combined.

We identify four issues regarding this method of decarbonization. Firstly, an investor that wants to reduce CO_2e emissions could benefit from owning shares in companies that have inefficient emission outputs. An investor could possibly influence the company to be more efficient by acquiring voting rights, rather than removing these companies from the portfolio. Secondly, not all companies report emissions and are therefore not possible to analyze. This applies especially to smaller companies, which limits the types of portfolios that can be decarbonized, which is why we only include mid- to large cap portfolios in our analysis. Thirdly, financial companies can contribute to an indirect exposure to CO_2e through their holdings, which is not accounted for in the calculation of carbon footprint. Lastly, companies with large emission outputs in the Swedish context might be carbon efficient in a global perspective. In the paper by Sandberg et al. (2001), they find that Swedish steel companies have a more CO_2 efficient processes than European steel companies. Which indicates that an environmentally conscious investor would benefit from including Swedish steel companies in the portfolio while divesting from inefficient steel companies.

We find that it is possible to reduce the carbon footprint of Swedish equity portfolios. A reduction of CO_2e by re-weighting the constituents will increase the tracking error of the decarbonized portfolio. The increase in TE is dependent on the size of the reduction. For a reduction of 25%

we find that the average tracking error for the portfolios in our sample increases by 4 basis points. Which indicates that we could perform this reduction without suffering a loss of returns. The carbon footprint of the analyzed portfolios can be reduced by 25% without altering sector exposure to a large extent. For a reduction of the carbon footprint by more than 25%, the sector exposure will differ from the original portfolio. This shows that a large reduction of CO_2e emissions from the portfolios cannot be performed without altering the portfolio risk and return profile.

The remainder of this thesis is structured as follows: the methodology used in the analysis is presented in Section 2, where we go into depth about the optimization and the inputs; a description of the data is presented in Section 3, where factors, portfolios and emission data is thoroughly described; in Section 4, our results are presented and analyzed by using graphs and figures for a comprehensive presentation of our findings, a discussion regarding results are also found in this section; the conclusions are found in Section 5; additional information about portfolios and data from optimizations are found in Appendices; information about the method of estimating CO_2e emissions for companies as well as regression results are also included in Appendices.

2 Methodology

In this section we outline the methodology used to perform the decarbonization of Swedish equity portfolios. The objective function and constraints, construction of components used in the optimization, as well as the measure of the carbon footprint are included in this section. The method for the analysis of the portfolios is an minimization of tracking error with a CO_2e constraint.

2.1 Objective Function, Optimization, and Constraints

This analysis intends to investigate the possibility of maintaining returns while altering weighting of the securities to obtain a decarbonized portfolio. The decarbonized portfolios are constructed by minimizing tracking error with regards to a CO_2 constraint. Each original portfolio is treated as a benchmark for the decarbonized portfolios. The method used in this analysis is the minimization process presented by Andersson et al. (2016).

Weight of each stock in the original portfolio is given by $w_i^b = \left[\frac{\text{Mkt Cap(i)}}{\text{Total Mkt Cap}}\right]$. The optimization of TE with regards to carbon footprint will result in a new set of weights, w_i^g.

The objective function:

$$\text{Min TE} = sd(R^g - R^b) \tag{1}$$

where R^g is the portfolio return with new assets weights, and R^b is the return of the original portfolio. The minimization of the standard deviation (sd) of the difference in returns between re-weighted portfolio and original portfolio provides a new composition with similar returns but different portfolio characteristics.

The formula for minimizing the tracking error (Andersson et al., 2016):

$$\text{Min TE} = \left[\sqrt{(W^g - W^b)' \left(\boldsymbol{\beta}\boldsymbol{\Omega_f}\boldsymbol{\beta}' + \boldsymbol{\Delta}^{AR}\right)(W^g - W^b)}\right] \tag{2}$$

W^g = Vector of weights for the optimized portfolio
W^b = Vector of weights for the benchmark portfolio
$\boldsymbol{\beta}$ = Matrix of factor loadings
$\boldsymbol{\Omega}_f$ = Variance-covariance matrix of the factors
$\boldsymbol{\Delta}^{AR}$ = Diagonal matrix of asset risk variances

The objective function contains three constraints. The first is an upper constraint for the carbon footprint as presented in Equation 3, where a reduction of the overall footprint is expressed. The second constraint is the sum of weights in the portfolio as presented in Equation 4. This constraint ensures that the weights add up to the emission coverage of the portfolio. The final constraint is a short-sale constraint that ensures that portfolio weights cannot be negative, this is presented in Equation 5. We perform a second optimization for all portfolios, where we add a fourth constraint which is presented in Equation 6. This constraint keeps the weight of the financial companies within the portfolios constant.

Carbon constraint:

$$\frac{\sum_{i=1}^{n} \frac{w_1^g \cdot \text{Total Mkt Cap}(USD)_i}{\text{Company value}(USD)_i} \cdot \text{Company emissions}(CO_2e, tonnes)_i}{\sum_{i=1}^{n} \frac{w_1^g \cdot \text{Total Mkt Cap}(USD)_i}{\text{Company value}(USD)_i} \cdot \text{Company income}(mUSD)_i} \leq \text{Original Carbon Footprint} \tag{3}$$

The formulation of the CO_2e constraint is the proposed national standard of reporting, which we will elaborate on in Section 2.3. The new weighting of the portfolio constituents reduces carbon exposure of the original portfolio while minimizing tracking error.
Constraint that sets the sum of weights:

$$\sum_{i=1}^{n} w_i^g = \text{Emission coverage of portfolio} \tag{4}$$

This constraint ensures that the weights add up to the emission coverage of the portfolio. The weights of companies that we do not have emission data for are kept constant. Optimization is then only performed on companies for which emission data is available, and therefore the sum of weights must be equal to the emission data coverage of the portfolio. This method is chosen as it allows for the original portfolio to remain unaltered with regards to the number of securities.
Short-sale contraint:

$$w_i^g \geq 0 \tag{5}$$

This constraint ensures that the weights do not become negative when performing the optimization. We are imposing a short-sale constraint, as we are investigating whether we can reduce carbon footprint by re-weighting the portfolios, and we are excluding the possibility of short selling in our scenario.

For further analysis of the sector exposure in the optimized portfolios, a second optimization is performed using a fourth constraint. This constraint ensures that the weights of the financial companies are kept constant in the additional optimization to control for indirect exposure to carbon emissions in the portfolio.
Constraint for financial companies:

$$w_{i,f}^b = w_{i,f}^g \tag{6}$$

where f denotes that company i is within the financial sector.

2.2 Fama-French factors

The construction of the variance-covariance matrix, ($\mathbf{\Omega}_f$), is based on the Fama-French factors: the value weighted excess returns of market (MKT), the size factor Small-minus-Big (SMB), and the value factor High-minus-Low (HML) (Fama and French, 1992). With these factors, the betas of the companies are estimated.

The multifactor model

$$E[r_i] = \beta_i^{MKT}\lambda_{MKT} + \beta_i^{SMB}\lambda_{SMB} + \beta_i^{HML}\lambda_{HML} \tag{7}$$

where the β_i estimates are obtained from the regression:

$$r_{it} = a_i + \beta_i^{MKT}R_{MKT_t} + \beta_i^{SMB}SMB_t + \beta_i^{HML}HML_t + u_{it} \tag{8}$$

We use the factor model when we predict the covariances which are a vital part of the optimization with regards to tracking error. In their paper, Chan et al. (1999) investigate whether covariances based on historical values differs in prediction error compare to factor based covariances, they find that historical values have higher prediction errors. The reason for the high prediction errors can be attributed to high correlations between stocks within sectors, as well as high correlation between large stocks across sectors. To reduce prediction error, the covariances are estimated by using factors that capture more information about the underlying asset. They find that market capitalization, market beta and book-to-market ratios can better predict future movements of stock price for a company than historical prices. By using the three factors we can construct a sufficient forecast of covariances, as any additional factor will yield small effects when optimizing tracking error of portfolio (Chan et al., 1999). With the factors we can construct factor betas for the companies in the portfolio. Using these beta estimates, we create a variance-covariance matrix from the factors that is later used in the optimization. The Fama-French factors are constructed in accordance to Fama and French (1992) by dividing the securities of the Stockholm Stock Exchange by market equity and book-to-market ratios as in Table 1.

Table 1: Construction of HML and SMB

		BE/ME		
		Low 30%	Mid 40%	High 30%
ME	Low 50%	Small Growth (SG)	Small Neutral (SN)	Small Value (SV)
	High 50%	Big Growth (BG)	Big Neutral (BN)	Big Value (BV)

Note: BE/ME is the Book Equity of the security over Market Equity of the same security, ME is the total market capitalization of the company.

The objective of constructing these factors is to extract possible information about returns and risks from prices. The market factor is relatively straightforward, describing the market beta of the security. The SMB factor is constructed according to Equation 9 and the HML factor according to Equation 10. In Table 1 the division of stocks depending on market equity and book-to-market ratio is displayed.

$$SMB_t = \frac{1}{3}\left(R_{t,SG} + R_{t,SN} + R_{t,SV}\right) - \frac{1}{3}\left(R_{t,BG} + R_{t,BN} + R_{t,BV}\right) \tag{9}$$

The SMB factor represents the difference of two portfolios: a portfolio that includes small growth, small neutral and small value stocks; a portfolio consisting of large growth, large neutral and large value stocks. This isolates the contribution of size factor on prices (Fama and French, 1992). For the Swedish securities the size cut off is the 80th percentile. The portfolios are rebalanced at the end of each calendar month (AQR Capital Management LLC).

$$HML_t = \frac{1}{2}\left(R_{t,SV} + R_{t,BV}\right) - \frac{1}{2}\left(R_{t,SG} + R_{t,BG}\right) \tag{10}$$

The HML factors are constructed by taking the difference of two portfolios that isolate the book-to-market effect. The two portfolios consist of: one portfolio with small and large value stocks; one portfolio with small and large growth stocks (Fama and French, 1992).

2.3 Carbon Footprint

To restrict carbon emission of investments, the method of measuring the CO_2e in the portfolio is crucial. To calculate carbon emissions we use a national standard for calculating emissions outlined

by Swedish Investment Fund Association (2016). The metric is used to calculate carbon footprint for equity portfolios. Emissions are reported as CO_2e tonnes per calendar year (Swedish investment fund association, 2016).[3]

The formula follows as:

$$\text{Carbon Footprint} = \frac{\sum_{i=1}^{n} \frac{Investment(USD)_i}{\text{Company value}(USD)_i} \cdot \text{Company emissions}(CO_2e, tonnes)_i}{\sum_{i=1}^{n} \frac{Investment(USD)_i}{\text{Company value}(USD)_i} \cdot \text{Company income}(mUSD)_i} \tag{11}$$

$$\begin{aligned} \text{Investment}(USD)_i &= \text{Cash amount invested in company } i \\ \text{Company value}(USD)_i &= \text{Total market capitalization of company } i \\ \text{Company emissions}(CO_2e, tonnes)_i &= \text{Total (yearly) } CO_2e \text{ emission of company } i \\ \text{Company income}(mUSD)_i &= \text{Total (yearly) income of company } i \text{ in millions} \\ \text{n} &= \text{Number of companies in the portfolio} \end{aligned}$$

The portfolio will have the same carbon footprint regardless of market capitalization of the portfolio. To change the carbon footprint of a portfolio, we need to re-weight the companies in the portfolio.

2.3.1 Total Emission

In addition to the measure provided by Swedish Investment Fund Association (2016), we also calculate the CO_2e emission of the portfolios without a normalization through division by sales as in Andersson et al. (2016).

$$\text{Total } CO_2e \text{ Emission} = \sum_{i=1}^{n} \frac{\text{Investment}(USD)_i}{\text{Company Value}(USD)_i} \cdot \text{Company Emission}(CO_2e, tonnes)_i \tag{12}$$

$$\begin{aligned} \text{Investment}(USD)_i &= \text{Cash amount invested in company } i \\ \text{Company value}(USD)_i &= \text{Total (yearly) market capitalization of company } i \\ \text{Company emissions}(CO_2e, tonnes)_i &= \text{Total (yearly) } CO_2e \text{ emission of company } i \\ \text{n} &= \text{Number of companies in the portfolio} \end{aligned}$$

[3] All data for the funds are expressed in US Dollars to match the data in the factors provided by AQR Capital Management, LLC. Therefore the results are also expressed in USD throughout the paper. When needed, values are converted to Swedish Krona using the exchange rate on 31-12-2015, 0.11847 SEK/USD. Which is the date corresponding to the extraction date for portfolio constituents.

With this calculation we can determine how much the investment made in a company is contributing to the company's overall emissions. The difference between this measure and the measure for carbon footprint is that this measure is dependent on how much is invested in a specific company and not normalized by sales. This allows for a analysis of an investor's or a portfolio's CO_2e emission of investments.

2.4 Sharpe Ratio

In this subsection we will give a brief presentation of the Sharpe ratio as presented in Sharpe (1966). This ratio is calculated for all portfolios in the paper. The ratio provides a method to compare the return-risk efficiency of portfolios. The well known ratio is constructed as follows:

$$\text{Sharpe ratio} = \frac{E[r_p] - rf}{\sigma_p} \tag{13}$$

The measure provides a ratio of expected excess return and standard deviation. In our analysis, the Sharpe ratio is calculated with regards to portfolio excess return and portfolio risk. A higher Sharpe ratio indicates a more efficient portfolio (Sharpe, 1966).

3 Data

69In this section the data used for our analysis is presented.

Data for carbon emission is collected from the Thomson Reuters Eikon environmental, social and governance (ESG) database. However, the Reuters ESG database is incomplete for the Swedish market, therefore we also use data from Bloomberg where emission data is extracted for individual companies from the terminal. Data concerning price, market capitalization and sales are also retrieved from Bloomberg. Price data is daily data from 01-01-2012 to 12-31-2015 while market capitalization and sales is yearly data for 2015.[4,5]

[4]The exception being companies which were listed later than 2012, where the start dates are their respective IPO-dates.

[5]The A, B and C shares of companies which are present within the same portfolio are combined into one asset, where the price of the most traded security is used for constructing the returns. This is done to increase variation in covariances between the assets in the portfolio.

3.1 Sample Selection

We want to isolate the analysis to funds active within the Swedish equity market in 2015. All selected portfolios must have emission data coverage of 75% or more of the portfolio market capitalization according to Swedish Investment Fund Association (2016). When selecting the portfolios, the market capitalization is taken into account. We want the selected portfolios to have a market capitalization that indicates relevance on the Swedish equity market. In addition to these criteria we selected two of the portfolios based on the respective funds' inclusion of sustainability goals in their investment decisions.

An issue regarding data selection is that many smaller companies do not report CO_2e emissions, therefore this study focuses mainly on mid to large cap portfolios. Not all mid and large cap portfolios report emission either, this results in a coverage rate of less than a 100% which affects the possibility to decarbonize the whole portfolio.

Descriptive statistics for the portfolios included in the analysis is presented in Table 2. A more thorough description of the data for each fund is also presented in this section.

Table 2: List of Funds included in our Analysis

Portfolio	Type of Portfolio	No of Companies	Market Capitalization	Carbon Footprint	Total Emission	Emission Coverage
SBX Index	Broad Index Fund	69	332.84 mUSD	87.72	16,227 tonnes	99.15%
AP2	Swedish Equity Portfolio	136	41,984.66 mUSD	72.42	121,061 tonnes	92.57%
SPP	Swedish Equity Fund	72	1,335.55 mUSD	77.18	59,778 tonnes	99.23%

Note: The carbon footprint is expressed as CO2 tonnes/mUSD. Data presented is for 2015.

3.1.1 SBX Index

The first optimization is performed on SBX Index which is a capitalization-weighted index that functions as an indicator for the Stockholm stock exchange. For an analysis of Swedish Equity funds, the benchmark index is included to evaluate the success of the model when optimizing a portfolio that has no specified environmental goals (SweSif, 2017b). The index is comprised of 69 companies, of which emission data is available for 64 companies. The carbon emission coverage of the portfolio amounts to 99.15% of portfolio market capitalization, which is larger than 75%

and is therefore sufficient according to Swedish Investment Fund Association (2016). The portfolio constituents from 31-12-2015 are retrieved from Morningstar. Descriptive data for the portfolio can be found in Table 5 in Appendix A.

3.1.2 AP2 Swedish Equity Portfolio

Second analysis includes the AP2 Swedish Equity portfolio, which is one of the buffer portfolios for the Swedish Pension System. The emission data coverage for this portfolio is 92.57%. The portfolio consists of 136 companies of which emission data is available for 78 companies. The portfolio constituents from 31-12-2015 are retrieved from the AP2 website (Andra AP-Fonden, 2015). Descriptive data for the portfolio can be found in Table 6 in Appendix A. The sustainability profile of the fund can be found in Appendix B.

3.1.3 SPP Swedish Equity Fund

The final analysis is performed on SPP Swedish Equity fund which consists of 72 companies where emission is reported for 64 of them, the portfolio has emission coverage of 99.23%. The fund is profiled to select constituents based on ESG factors, where sustainability is one of the key factors. The fund tracks the OMX Stockholm Index while divesting in companies that do not fulfill ethical requirements of the Storebrand Group of which SPP is a subsidiary (SweSif, 2017a). The portfolio constituents from 31-12-2015 are retrieved from Morningstar. Descriptive data for the portfolio can be found in Table 7 in Appendix A. The sustainability profile of the fund can be found in Appendix B.

3.2 Fama French Factor Data

The Fama-French factors, used to the construct the variance-covariance matrices used in the optimization, are obtained from AQR Capital Management LLC. The factors are constructed according to the well known method presented in the paper by Fama and French (1992). The factors are constructed from daily data from 01-01-2012 until 31-12-2016, the selection of these years is motivated

by an inclusion of one business cycle in the time span.[6]

3.3 Calculation of Carbon Emissions

Carbon emissions of a company is reported as CO_2e tonnes per year (Swedish Investment Fund Association, 2016).

The carbon emissions are divided into three different categories (World Business Council for Sustainable Development and World Resources Institute, 2001):

Scope 1	— direct emission produced by the company.
Scope 2	— indirect emission from electricity, heating, and steam.
Scope 3	— upstream and downstream activities such as emission from suppliers and consumer usage as well as business travel and commuting

The scopes included when calculating carbon footprint of a portfolios are scope 1 and scope 2. Scope 3 is excluded since companies rarely report scope 3 emissions. Since the inclusion of scope 3 in calculations could also increase the risk of double counting CO_2e emissions, the measure is excluded even if the company reports these emissions. The third scope includes both upstream and downstream activities such as the emissions of subcontractors or final users. Therefore, if a portfolio consists of both the company and its subcontractor, the emission will be counted twice.

The three portfolios; SBX, AP2 Swedish equity portfolio, and SPP's Swedish equity fund, together include a total of 150 companies. Of these 150 companies in our data set, we have emission data for 88 companies. Descriptive data for company emissions can be found in Table 17 in Appendix B.

3.4 Sectors

The sector division of securities is according to the Global Industry Classification Standard (GICS) (MSCI inc., 2016). The sector classification for each security is retrieved using the Bloomberg terminal. There are eleven sectors, which are presented in Table 3.

[6]The risk free rate used in all estimations is the three month Stibor rate, STIB3M, which is an average interest rate that the large banks in Sweden offer for interbank lending.

Table 3: GICS Sector Taxonomy and Descriptive Data for CO_2e Emissions of Sectors

		Reports Emission		No Emission Reported
Sector	Number	No. of companies in sector	Average CO_2e Emission	No. of companies in sector
Consumer Discretionary	1	16	778,749	10
Financial	2	11	200,054	5
Information Technology	3	4	165,367	13
Industrials	4	22	241,815	21
Consumer Staples	5	6	605,713	2
Telecommunication Services	6	3	258,188	0
Health Care	7	6	112,983	11
Materials	8	7	3,141,362	0
Energy	9	1	110,731	3
Real Estate	10	12	8,575	2
Utilities	11	0	0	1

Note: These averages are sample averages for our data set. We have only one company within the Utilities sector in our data set, but this company does not report CO_2e emissions.

Of the companies in our dataset that do not report emissions, the majority are within the Industrial, Information Technology or Health Care sector. While, all companies within the Materials sector report emissions. The highest average emission levels are found in the Materials sector, which is expected since production releases more CO_2e than for example services. In our sample we only have one company categorized to be within the Energy sector, the sample average is therefore only the reported emission of one company. For a complete list of company emission data for our sample and estimation methods, see Table 17 in Appendix B.

4 Results

In this section our results from the decarbonization of three Swedish equity portfolios, are presented in the order: SBX Index, AP2 Swedish equity portfolio and SPP Swedish equity fund. Both tracking error and sector exposure for the portfolios are included in the analysis.[7] In this section we also present how much CO_2e an investor is contributing to when investing a 1000 SEK monthly in the respective portfolios during ten years.

The optimization is performed by minimizing tracking error with regards to carbon footprint, where carbon footprint is reduced by 5% in each optimization. We also want to investigate how

[7]The tracking error discussed in the Result section is the *ex ante* tracking error.

sector exposure changes and which sectors are dominant in the optimized portfolios. The goal is to avoid the increase of risk in the pursuit of a decarbonized portfolio. When considering indirect exposure to carbon footprint, companies within the financial sector are of importance. Financial companies, which usually do not have a high carbon footprint, tend to own shares in companies from most sectors. In that sense, by investing in financial companies one might be exposed to an indirect carbon risk and therefore we have also included an optimization where the weights for all companies within the financial sector are kept constant.

For clarity the list of sectors and their representative numbers are provided in Table 3. Additionally the *ex post* returns and Sharpe ratios of all the portfolios are provided in Appendix A for comparison.

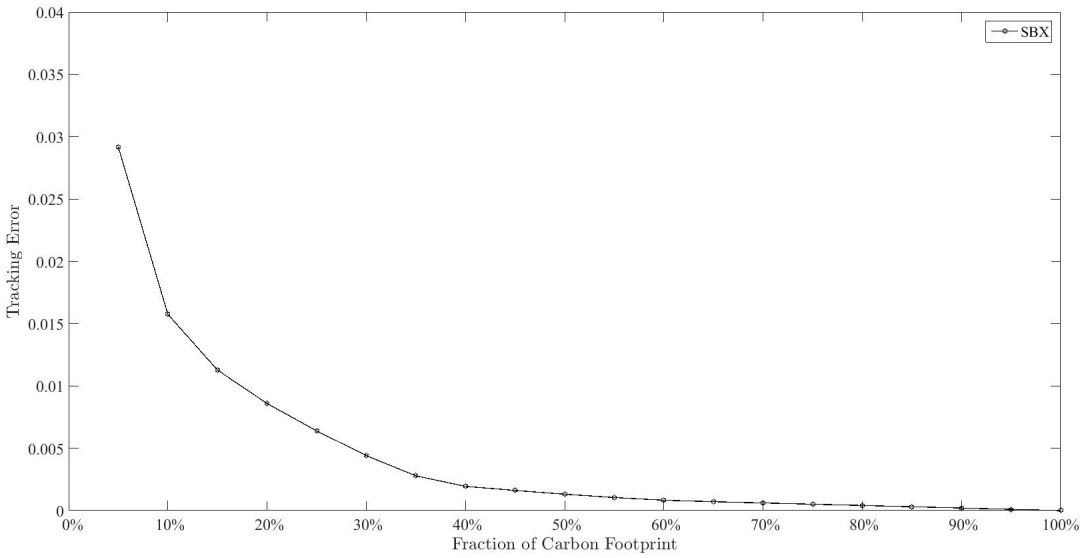
4.1 Decarbonized SBX Index

Investigation of the possibility of decreasing carbon footprint in a portfolio will begin with the SBX index. The results from the optimization are presented in Figure 1, which illustrates the relationship between a reduction of carbon footprint on the x-axis and the tracking error on the y-axis. As carbon footprint is reduced, tracking error increases. The TE starts to increases more rapidly when the portfolio is decarbonized past 55% of the initial footprint. In Table 8 in Appendix A descriptive data about each optimization can be found which shows that the *ex post* returns outperform the benchmark with every 5% reduction of original carbon footprint until they reach a turning point at a decarbonization level of 55%, after that returns remain lower than benchmark as CO_2e level is decreased to 5%. The highest *ex post* return is observed at 65% of the footprint, where returns are 7 basis points (bp) higher than the original portfolio. The Sharpe ratio is 0.2868 for all optimized portfolios until a decarbonization of 40%, where the Sharpe ratio starts to decrease.

4.1.1 Sector Exposure SBX

We want to analyze the sector exposure of the decarbonized portfolios to observe how the portfolios with a reduced carbon footprint differ from the original portfolio. Figure 2 illustrates the sector exposures of the portfolios with 75%, 50%, 25% and 5% of original carbon footprint, where the x-axis represents the sectors while the y-axis displays the percentage of the portfolio market cap-

Figure 1: Relationship between a Reduction of Carbon Footprint and Tracking Error of **SBX Index** 2015

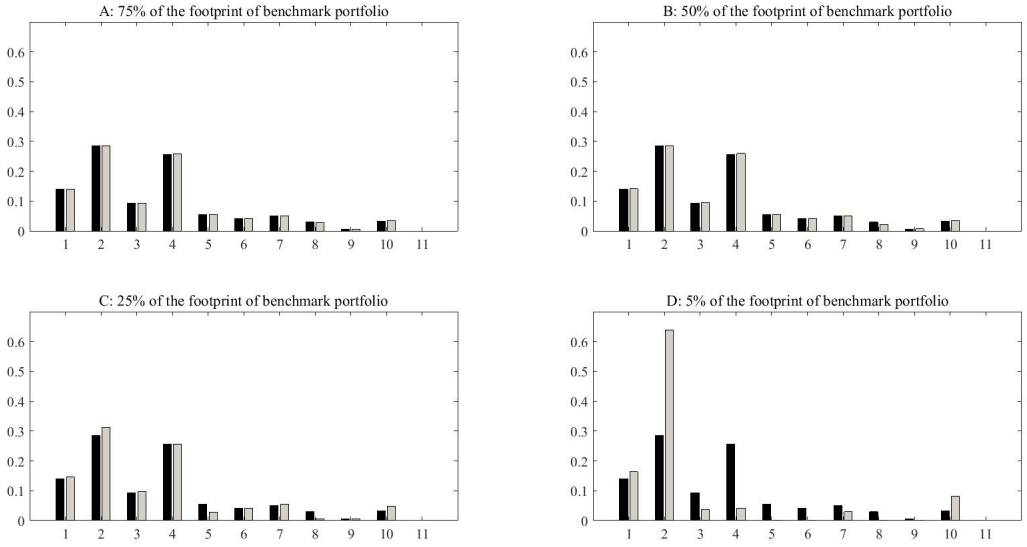


Note: The percentage points in the figure represents the percentage reduction of the total carbon footprint of the portfolio which is 84.72 tonnes CO_2e/mUSD. The TE is expressed in yearly values. Descriptive data which includes returns and carbon footprint for the decarbonized portfolios can be found in Table 8 in Appendix A

italization in the portfolio within a sector. As can be seen in panel A and B, the sector exposure changes marginally at the 75% and 50% level. Sector composition differs increasingly from the original portfolio as carbon footprint is reduced further. At 25% investors are 3% more exposed to Financials, while around 3% less exposed to both Consumer Staples and Material, which we can see in panel C in Figure 2. When the portfolio contains 5% of original carbon footprint, over 60% of the portfolio assets are within the financial sector, which is an increase of over 30%. As shown in panel D, sector composition is altered as follows: exposure to Industrial has decreased by 20% compared to the original portfolio; the portfolio has almost no exposure to Consumer Staples, Telecommunication Services, or Materials. The ten largest holdings in each portfolio displayed in Figure 2 can be viewed in Table 9 in Appendix A.

Due to financial companies investing in the market, we want to keep these companies' weights constant in a second optimization. When applying the constraint where Financials are kept constant, the portfolios have an altered sector exposure at the 25% and 5% levels. At the 25% sector

Figure 2: Sector Exposure in **SBX Index** 2015 for 75%, 50%, 25% and 5% Optimizations of Carbon Footprint in Relation to the Original Portfolio



Note: The decarbonized portfolios are compared to the original portfolio with respect to sector exposure. The corresponding GICS sectors can be found in Table 3.

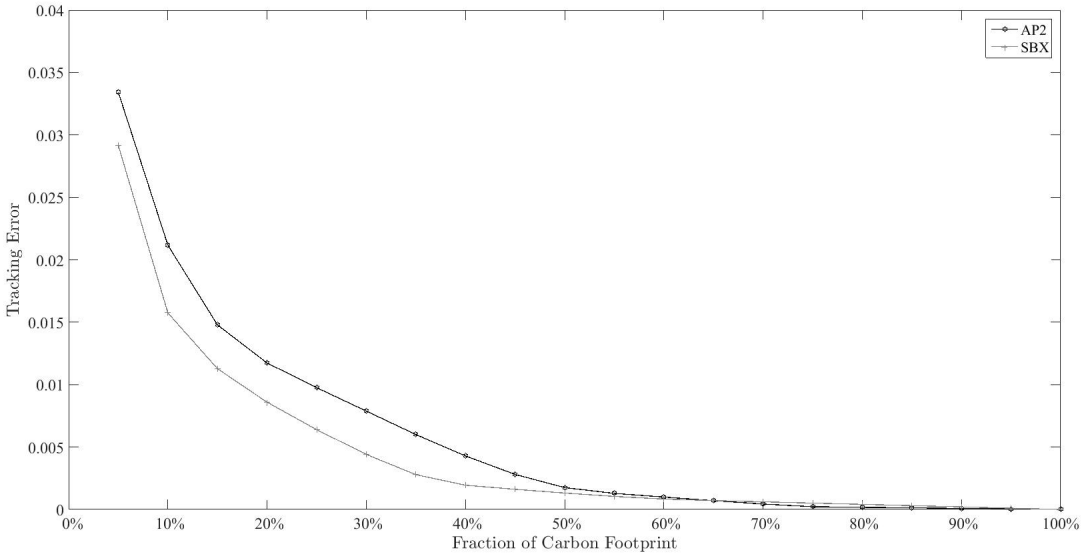
exposure increases in Real Estate, Industrials, and Consumer Discretionary. We observe a decrease in Consumer Staples and Materials. These results are presented in Figure 7 in Appendix A. When looking at the exposure at the 5% level more than 70% of the portfolio market capitalization is held within Consumer Discretionary and almost all in one company. Exposure to all other sectors except Consumer Discretionary and Financials has at this level decreased to almost 0% since the Financial sector is kept constant around 30%. The ten largest holdings in each portfolio displayed in Figure 7 can be viewed in Table 10 in Appendix A.

4.2 Decarbonized AP2 Swedish Equity Portfolio

The optimization is also performed on the AP2 Swedish equity portfolio and the results from the decarbonization as well as a sector analysis are presented in this section. The AP2 Swedish equity portfolio is managed according to Principles for Responsible Investments (PRI), where ESG factors

are incorporated into portfolio management decisions.[8]

Figure 3: Relationship between a Reduction of Carbon Footprint and Tracking Error of **AP2 Swedish Equity portfolio** 2015



Note: The percentage points in graph represents the percentage reduction of the total carbon footprint of the portfolio which is 72.42 tonnes CO_2e/mUSD. The TE is expressed in yearly values. Descriptive data which includes returns and Carbon Footprint for the decarbonized portfolios can be found in Table 11 in Appendix A.

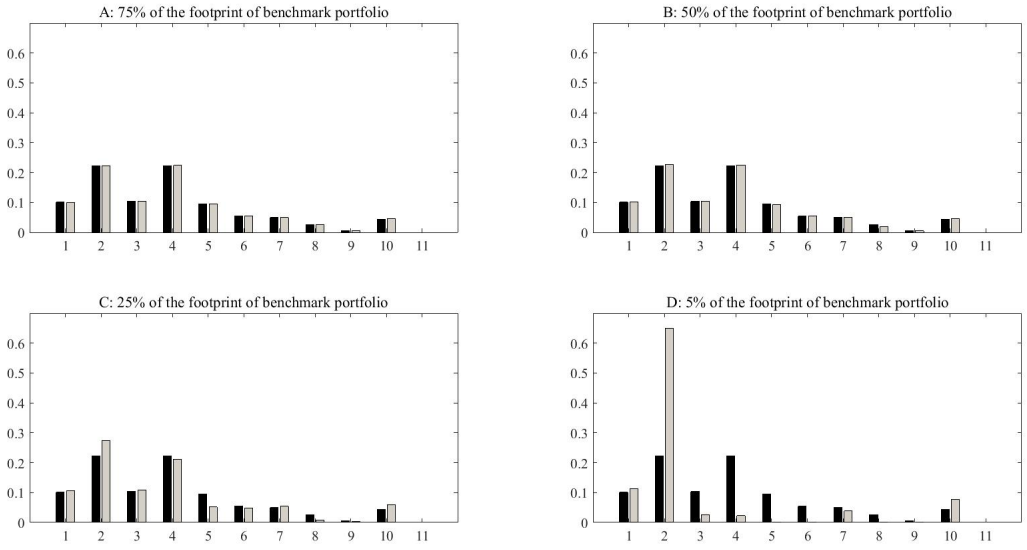
The results from the optimization are presented in Figure 3 which shows the same relationship as in Figure 1. The AP2 Swedish equity portfolio exhibits a steeper curve than the SBX, with a faster escalation of the TE per 5% reduction of CO_2e footprint. However, when the AP2 is decarbonized from 95% to 70%, the AP2 exhibits a lower TE than the SBX index. In Table 11 in Appendix A descriptive data about each optimization can be found, which shows that the *ex post* returns are constant down to a 80% level of original footprint, where returns decrease compared to the original portfolios' *ex post* returns. At the 80% level the *ex ante* TE is 1,76E-04, which suggests that a decrease of the carbon footprint is possible without sacrificing returns and without

[8]PRI urges investors to integrate environmental, social and corporate governance (ESG) into decision making policies, as well as encourage companies they have investments in to disclose ESG data (PRI Association, 2016).

increasing TE significantly. The Sharpe ratios of the portfolios is 0.2891 until a decarbonization of 30% is reached, at this point Sharpe ratio lies below the original value. Again, we must observe the sector exposure of the various portfolios to examine how other aspects of risk differ from the original portfolio.

4.2.1 Sector Exposure AP2

Figure 4: Sector Exposure in **AP2 Swedish Equity Portfolio** for 75%, 50%, 25% and 5% Optimizations of Carbon Footprint in Relation to the Original Portfolio



Note: The decarbonized portfolios are compared to the original portfolio with respect to sector exposure. The corresponding GICS sectors can be found in Table 3.

When analyzing the sector exposure for the AP2 Swedish equity portfolio, we find that sectors are relatively similar to the original portfolio down to a 50% level of CO_2e footprint as presented in Figure 4, which shows the same relationship as in Figure 2. However, as can be seen in panel A and B, at 75% and 50% of original carbon footprint, we observe a slight increase in Financials, Real Estate, and Industrial sectors while holdings in Materials decreases. In panel C we can see that financial sector increases in the portfolio, while Consumer Staples displays the largest

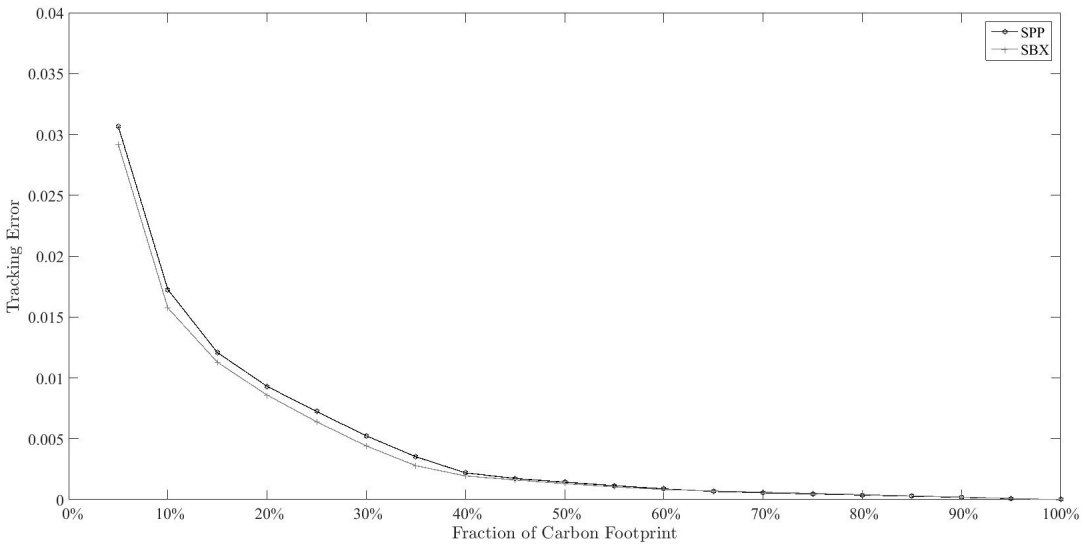
relative decrease. When the portfolio includes 5% of the original carbon footprint, the Financial sector accounts for over 60% of the portfolio's holdings, which represents over a 40% increase in investments within that sector. Industrials decreases by 40% compared to the original portfolio and exposure to Consumer Staples, Telecommunication Services, Materials, and Energy is reduced to almost zero holdings. The ten largest holdings in each portfolio displayed in Figure 4 can be viewed in Table 12 in Appendix A.

Again, to evaluate how the sector exposure would look like when keeping holdings in the financial sector constant, we run an optimization with an additional sector constraint. In Figure 8 in Appendix A we can see the results. By applying this constraint, we see a different trend in the panels C and D when comparing with the original optimizations. We observe an increase in Consumer Discretionary and Real Estate while the Consumer Staples decreases by 4.5%. At 5% of original carbon footprint we mainly invest in Consumer Discretionary, Financials, Health Care and Real Estate. The ten largest holdings in each portfolio displayed in Figure 8 can be viewed in Table 13 in Appendix A.

4.3 SPP Swedish Equity Fund

The SPP fund is a mutual fund which aims to follow the development of the OMX index. The fund is managed according to ESG factors. The optimization yields similar results as for the SBX. Our results for the optimizations of the SPP Swedish equity fund can be seen in Figure 5, this figure shows the same relationship as in Figure 1 and Figure 3. By examining our results, we can observe that the TE increases at a similar rate as for the SBX. In Table 14 in Appendix A descriptive data about each optimization can be found, which shows that the *ex post* returns are higher than the benchmark down to a 65% level of carbon reduction. When CO_2e footprint of the portfolio is decreased further, the *ex post* returns fall below the benchmark returns. The optimizations yields a slightly lower TE than the SBX in the initial 7 optimized portfolios, where the decarbonization level lies between 95% to 65%. The Sharpe ratios show a similar trend as in both the SBX and AP2 and are constant at 0.2866 down to a 30% level but decrease to 0.2793 at the 5% level.

Figure 5: Relationship between a Reduction of Carbon Footprint and Tracking Error of **SPP Swedish Equity fund** 2015

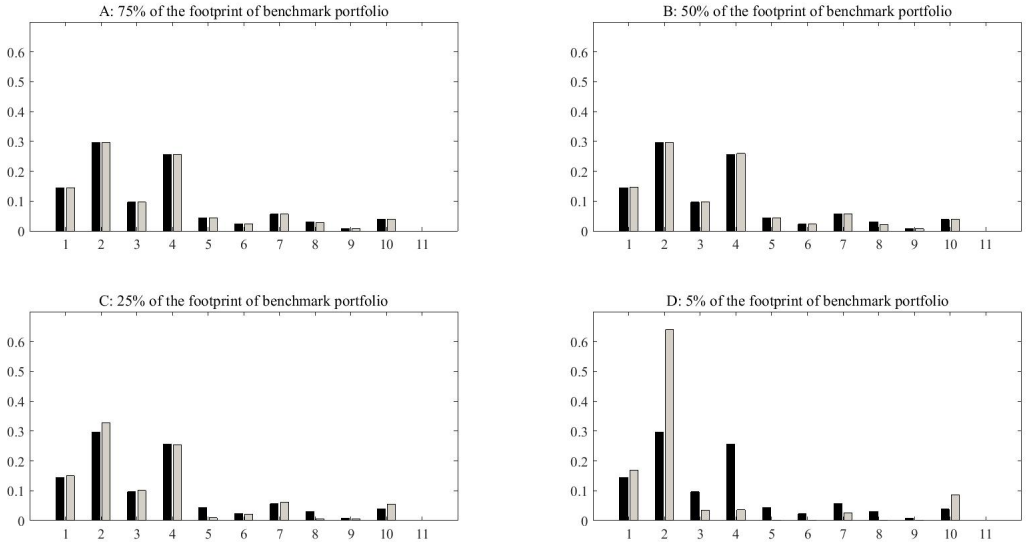


Note: The percentage points in graph represents the percentage reduction of the total carbon footprint of the portfolio which is 77.18 tonnes CO_2e/mUSD. The TE is expressed in yearly values. Descriptive data which includes returns and Carbon Footprint for the decarbonized portfolios can be found in Table 14 in Appendix A.

4.3.1 Sector Exposure SPP

The sector exposure for the SPP Swedish equity fund is presented in Figure 6, which shows the same relationship as in Figure 2 and Figure 4. When analyzing the sector exposure we find them to be similar to the original portfolio in panel A and B. Panel C shows a transition from Consumer Staples and Materials towards Financial and Real Estate. As in the analysis of sector exposure for SBX and AP2, panel D shows a clear increase in sector risk where more than 60% of the investments are within the financial sector. In addition to an increase in the financial sector, the sectors Real Estate and Consumer Discretionary have increased. We observe a decrease in Industrials by over 20% compared to the original portfolio. Sector exposure in Consumer Staple, Telecommunication Service, Materials and Energy decreases to almost 0%. The ten largest holdings in each portfolio displayed in Figure 6 can be viewed in Table 15 in Appendix A.

Figure 6: Sector Exposure in **SPP Swedish Equity Fund** for 75%, 50%, 25% and 5% Optimizations of Carbon Footprint in Relation to the Original Portfolio



Note: The decarbonized portfolios are compared to the original portfolio with respect to sector exposure. The corresponding GICS sectors can be found in Table 3.

By adding a constraint on the financial sector we see a similar trend in panels A and B, as can be viewed in Figure 9 in Appendix A. However, panel C increases more in Real Estate, Industrials and Consumer Discretionary than the non-constricted one. When adding the constraint on financial companies the results in panel D show that sector exposure is close to 0% in all sectors except Financials and Consumer Discretionary. These two sectors represent all of the portfolio now. The ten largest holdings in each portfolio displayed in Figure 9 can be viewed in Table 16 in Appendix A.

4.4 Calculating Carbon Contribution

In this subsection we present a measure that is meant to replicate the Swedish "Norman Amount". The Norman amount is meant to represent the fee charges of funds for an investor that invests 1000 SEK per month for ten years. The measure takes into account the compounded interest

which is based on an assumption of annual growth (Morningstar, 2012). We present a measure that represents the amount of CO_2e that an investor will contribute to when investing in a fund. Similarly to the Norman amount, our measure represents an investment of a 1000 SEK per month in a fund over ten years. This measure is a way of tracking the emission level of portfolios in a comprehensive way for both private and institutional investors. Therefore, for every 1000 SEK invested in a portfolio monthly for each year, an investors respective yearly carbon emission would be calculated using Equation 14.[9]

$$\text{Investor } CO_2e \text{ emission} = \sum_{i=1}^{n} \frac{\text{Investment}(USD)_i}{\text{Company Value}(USD)_i} \cdot \text{Company emission}(CO_2e, kg)_i \qquad (14)$$

We present a calculation of the amount of emission owned by an investor that invests the equivalent of 1000 SEK per month for ten years in each of the three portfolios: SBX, AP2, and SPP. Furthermore, we calculate the emission contribution for each decarbonized portfolio. The results presented in Table 4 are calculated using Equation 14. We make a modest assumption that the initial investment will be compounded and increase by 4% every year and then adding the results for the ten years together.

[9]Since Company Value is in USD we convert the 1000 SEK to USD by multiplying with the SEK/USD exchange rate on 31-12-2015, which is 0.11847.

Table 4: Kg CO_2e Contribution of a Ten Year Investment in Portfolios

	Investor CO_2e Emission		
Fraction of Total Emission	SBX	AP2	SPP
1.00	864.90	671.69	794.05
0.95	819.98	638.05	752.94
0.90	775.22	604.54	711.97
0.85	730.62	571.00	671.15
0.80	686.18	537.58	630.45
0.75	641.91	504.03	589.90
0.70	597.81	470.98	549.49
0.65	553.89	437.69	509.82
0.60	510.74	404.15	470.55
0.55	468.01	370.44	431.19
0.50	425.17	338.21	391.75
0.45	382.30	306.81	352.34
0.40	339.64	272.22	313.40
0.35	295.80	235.67	272.74
0.30	250.15	195.76	230.22
0.25	202.69	155.06	186.43
0.20	155.93	116.61	143.32
0.15	106.02	81.49	98.11
0.10	63.99	49.63	60.52
0.05	23.67	15.99	19.91

Note: The amount of carbon emission is presented in CO_2e kilograms and calculated in USD.

The AP2 portfolio has the lowest amount of carbon emission per the equivalent of 1000 SEK invested for the original portfolio and all of the optimizations. That is in line with our result from the optimizations where the carbon footprint for AP2 amounted to 72.42 $CO_2e/mUSD$. SBX has the highest emission per 1000 SEK invested, while SPP has lower values. This reflects the three portfolios different environmental policies regarding investments. As advertised by both the AP2 Swedish equity portfolio and the SPP Swedish equity fund, they have a lower carbon footprint as well as investor contribution than the SBX index.

4.5 Discussion

We find that it is possible to reduce the carbon footprint for all three original portfolios. When carbon footprint is reduced to 75% of original values, we observe an average tracking error of 4 bp. At this level we detect a minor increase in financial sector although this does not alter the sector exposure to a large extent. We can reduce the carbon footprint by 25% without altering the risk-return profile of the portfolio.

The SBX index has the highest initial carbon footprint of the three original portfolios, this should come as no surprise as it is a broad index and is not specialized according to sustainability perspective. Our results show that it is possible to decarbonize the index without sacrificing returns. This is consistent with the findings of Andersson et al. (2016), where a broad European index is decarbonized. The results from our analysis of the SBX functions as a benchmark to compare the results from AP2 and SPP.

The AP2 Swedish equity portfolio initially displays a lower tracking error compared to the SBX index and the SPP Swedish equity fund. This trend is consistent until a decarbonization of 65% of the original carbon footprint where the tracking error starts to increase more rapidly for the AP2 compared to SBX and SPP. As the portfolio is managed according to the Principles for Responsible Investments (PRI) the portfolio has already lowered their climate impact. Naturally, a percentage reduction of a smaller value will be harder to achieve. The lower tracking error compared to SBX and SPP for decarbonized portfolios above 65% of the original carbon footprint can also be explained by the efforts of the AP2 portfolio managers to reduce the initial carbon footprint. Since the AP2 Swedish equity portfolio includes more companies with low carbon emissions than the SBX, it is easier to re-weight between companies and still maintain return and a low carbon footprint. Our results, imply that it is possible to decarbonize the AP2 Swedish equity portfolio even further than the fund management have done thus far, without altering the portfolio return or sector exposure.

The results for SPP resemble the results for SBX, with the difference of SPP having a slightly lower TE in the optimized portfolios from 95% to 60% of initial carbon footprint. Since the fund tracks the Swedish stock market, similarities with the SBX index are expected. The differences between the SPP and the SBX could also be explained by the SPP fund management investing

according to Storebrand investment principles regarding sustainability, which results in a lower initial carbon footprint (SweSif, 2017a). Of the three original portfolios, SPP displays an initial carbon footprint that lies between the AP2 and the SBX values.

When carbon footprint is reduced by 50% we observe an increase of TE by a sample average of 15bp. The sector exposure towards Financials increases and we observe that the exposure towards carbon heavy sectors such as Industrials and Materials decreases. The removal of the most carbon heavy sectors needs to be closely examined. Companies within the Industrial sector may be excluded in the Swedish framework, but might add value to the portfolio in a global perspective. As an example, according to Sandberg et al. (2001) the Swedish steel industry displays lower CO_2e emissions when compared to European peers. Removing these companies from the portfolio could have a negative effect on future returns and be contra productive from an environmental standpoint.

When portfolios are decarbonized to include only 25% of the initial carbon footprint, we observe an increase in skewness towards Financials in the portfolios. At this level the average *ex ante* tracking error is 80 bp. For a portfolio tracking the original benchmark portfolio, this increase affects sector risk in portfolio. Sector risk in a decarbonized portfolio should be investigated as financial companies may be investing in carbon heavy sectors, which will be indirectly included in the portfolio.

Due to the financial sector representing the market, we add a constraint to keep the weights of financial companies constant in the portfolios. When applying the constraint on financial companies, we observe an increase in other sectors such as Consumer Discretionary, Real Estate and Health Care. However, a large portion of the portfolios are only investing in only a few companies when the portfolios is to contain only 5% of the initial carbon footprint. Our results from adding this constraint suggest that a decarbonization at a low level must be achieved by applying an active management approach, and cannot be done without altering the risk-return profile of the portfolio.

An alternative solution to indirect exposure is to treat financial companies as portfolios, as they have holdings in companies in other sectors. Since financial companies' direct emissions are small, the optimization favors this sector. However, the financial companies on the Swedish market own companies from most sectors and are therefore a representation of the overall market. To solve the problem with an indirect increase in the carbon footprint through financial company holdings, an

option is to include company holdings' contribution to total emission. This is however outside the scope of this paper as it touches on indirect emissions.

We identify some issues with the proposed national standard for calculating carbon footprint. The method of calculating carbon footprint is somewhat complicated in its design, which could make interpretation of the carbon footprint difficult for some investors. The measure weighs each investment with the market capitalization of the company when calculating the emission contribution, which could result in a favoring of overvalued companies in the portfolio. To offset this bias a more active stock picking strategy should be implemented to increase returns in a decarbonized portfolio.

The calculation of the carbon equivalent to the Norman amount, where we calculate how much CO_2e emission an investor would own when investing in the various portfolios support that a decarbonization is applicable on the three original portfolios. We can clearly see that emission owned by the investor decreases in the decarbonized portfolios. In our opinion, this would be a comprehensive approach to quantifying the emission levels for an investor, to increase comparability of the portfolios.

5 Conclusion

In this section, we present our conclusions regarding the analysis of the decarbonization of the three equity portfolios.

An investor can be said to own parts of the CO_2e emission that a company produces. This could pose a dilemma for both environmentally conscious investor and investors that are concerned about the risk of an increase of carbon prices due to an environmental policy change. One approach to climate hedging is to reduce carbon footprint of the portfolio by re-weighting the constituents through minimization of the tracking error with a carbon constraint. We investigate whether a straightforward decarbonization of Swedish equity portfolios could decrease climate impact for the investor and how it would affect the tracking error of the portfolio.

In our paper we analyze the effect of reducing CO_2e emission of three Swedish equity portfolios. Each portfolio is re-weighted through optimization of tracking error with respect to the portfolio's carbon footprint. For each portfolio, a set of nineteen portfolios were constructed, where the

carbon footprint is reduced by five percent for each new optimization. The new sets of weights are analyzed with respect to *ex ante* tracking error, *ex post* returns, Sharpe ratio, and sector exposure. Furthermore, we analyze an investor's contribution to CO_2e emission if they would invest 1000 SEK per month for ten years in each of the portfolios. We provide a comparison of the contribution for each original portfolio as well as for the optimized portfolios.

We find that the portfolios can withstand a reduction of around 25% of the carbon footprint without altering the risk-return profile of the portfolios. Using the optimization to re-weight the portfolio yields results that support the findings of Andersson et al. (2016). As the portfolio carbon footprint is lowered, the *ex ante* tracking error increases. The tracking error increases substantially when carbon footprint is lowered by more than 50%. This increase indicates a change in portfolio composition. An analysis of portfolio composition with regards to portfolio risk and sector exposure has to be taken into account when constructing a decarbonized portfolio. This finding shows that in a limited investment environment a decarbonization displays less efficient results than the results presented by Andersson et al. (2016), where the authors found that a decarbonization of the MSCI Europe index of 50% could be achieved without sacrificing returns.

Our results regarding the differences between the three original portfolios imply that the sustainability focus of the AP2 Swedish equity portfolio and the SPP fund has an effect on the optimized portfolios when comparing with results for the decarbonized SBX portfolios. For a smaller reduction of the carbon footprint, the portfolios with lower initial carbon footprint display a smaller tracking error against the original portfolios. However, when CO_2 is decreased to a larger extent, the optimized AP2 and SPP display a larger tracking error against the original portfolios compared to the SBX.

When calculating the emission of companies, some of the financial companies need to be analyzed with regards to their holdings in other companies. These companies have lower direct emissions but contribute to indirect CO_2 exposure through investments. This could be applied to companies that outsource manufacturing as well. However, it is more straightforward to perform this analysis for financial companies as investments are the main activity for many of these companies.

When constructing a portfolio through an optimization to decrease carbon footprint, additional

controls need to be added to obtain an optimal portfolio. As the Swedish national standard for calculating carbon footprint may favor companies that have a large market capitalization, the holdings must be adjusted according to management preferences to be able to offset possible biases.

Our findings suggest that this method of decarbonization is applicable on Swedish equity portfolios. A decrease of the carbon footprint by 25% in all three portfolios can be achieved without altering portfolio sector exposure to a large extent or suffering loss of returns. This indicates that it is possible to reduce carbon footprint of portfolios to meet consumer demand for less environmental impact with maintained returns.

5.1 Future Research

The method of decarbonizing portfolios presented in this study provides a first step in construction of a portfolio with lower carbon footprint. Future research could analyze additional approaches to form a portfolio that provides a more focused climate hedge that depends on investor preferences and return and risk profile of the fund. Further research could investigate whether a decarbonized portfolio could produce alpha returns, as well as examine the method of decarbonizing using the Swedish national standard for calculating carbon footprint to investigate a possible bias towards overvalued companies. Future research can also factor in data for years after 2015, which could give more insight in how emission of companies changes if calculation and reporting of carbon footprint becomes a more common practice for investment funds. If more companies report emission data it would be possible to include small- to mid cap portfolios in the analysis. It could also be of interest to investigate whether the offering of decarbonized portfolios has any signaling effect on companies to decrease their emissions or if it is just as effective to buy emission rights to obtain the same amount of reduction.

Appendices

A Appendix

A.1 Descriptive Data for Portfolios in Sample

Table 5: Descriptive Data for **SBX Index** 2015

SBX Index 2015

Company	Weight	Emission in tonnes	Gics Sector
Hennes & Mauritz AB B	8.28%	15,1753	Consumer Discretionary
Nordea Bank AB	7.57%	24885	Financials
LM Ericsson Telephone Co B	6.27%	266,000	Information Technology
Swedbank AB A	4.77%	20184	Financials
Svenska Handelsbanken A	4.23%	8,677	Financials
Assa Abloy AB B	4.23%	429997	Industrials
Skandinaviska Enskilda Banken AB A	3.88%	5898	Financials
Svenska Cellulosa AB B	3.44%	3,032,000	Consumer Staples
Atlas Copco AB A	3.50%	126,000	Industrials
Investor AB B	3.56%	234	Financials
Volvo AB B	2.89%	221,000	Industrials
TeliaSonera AB	2.74%	418,347	Telecommunication Services
Sandvik AB	2.09%	365,000	Industrials
Hexagon AB B	2.17%	131,158	Information Technology
ABB Ltd	1.98%	1,475,000	Industrials
Skanska AB B	1.57%	379,965	Industrials
Autoliv Inc DR	1.98%	290,000	Consumer Discretionary
AstraZeneca PLC	1.99%	597,800	Health Care
Atlas Copco AB B	1.81%	126,000	Industrials
Swedish Match AB	1.48%	54,398	Consumer Staples
SKF AB B	1.30%	502,038	Industrials
Electrolux AB B	1.31%	661,781	Consumer Discretionary
Kinnevik Investment AB B	1.54%	43,843	Financials
Alfa Laval AB	1.22%	66,647	Industrials
Securitas AB B	1.02%	113,582	Industrials
Meda AB A	0.69%	27,882	Health Care
Getinge AB B	1.12%	40,964	Health Care
Investor AB A	0.96%	#N/A	Financials
Trelleborg AB B	1.00%	280,000	Industrials
Boliden AB	0.93%	889,000	Materials
Industrivarden AB A	0.85%	73	Financials
Lundin Petroleum AB	0.67%	110,731	Energy
Fingerprint Cards AB B	0.92%	31,809	Information Technology

Elekta AB B	0.67%	7,574	Health Care
Millicom International Cellular SA DR	0.77%	200,064	Telecommunication Services
NCC AB B	0.55%	251,000	Industrials
BillerudKorsnas AB	0.70%	5,192,000	Materials
Hexpol AB B	0.60%	117,000	Materials
Tele2 AB B	0.68%	156,154	Telecommunication Services
Husqvarna AB B	0.58%	165,221	Consumer Discretionary
Castellum AB	0.52%	11,359	Real Estate
NIBE Industrier AB B	0.59%	10,900	Industrials
Volvo AB A	0.51%	221,000	Industrials
Industrivarden AB C	0.60%	#N/A	Financials
L E Lundbergforetagen AB B	0.54%	2,080,011	Financials
Intrum Justitia AB	0.53%	11,156	Industrials
Saab AB B	0.45%	108,074	Industrials
Fabege AB	0.46%	1,600	Real Estate
AAK AB	0.46%	234,000	Consumer Staples
Loomis AB B	0.41%	745,600	Industrials
Swedish Orphan Biovitrum AB	0.55%	253	Health Care
NetEnt AB B	0.38%	#N/A	Information Technology
J M AB	0.47%	7,297	Consumer Discretionary
Hufvudstaden AB A	0.36%	1,657	Real Estate
Fastighets AB Balder B	0.45%	13,942	Real Estate
Betsson AB B	0.45%	1,055	Consumer Discretionary
Wallenstam AB B	0.34%	4,067	Real Estate
Hemfosa Fastigheter AB	0.31%	10,596	Real Estate
Holmen AB B	0.32%	240,000	Materials
Modern Times Group MTG AB B	0.28%	7,294	Consumer Discretionary
Wihlborgs Fastigheter AB	0.30%	8,451	Real Estate
Pandox AB B	0.25%	#N/A	Consumer Discretionary
Kungsleden AB	0.23%	23,985	Real Estate
Atrium Ljungberg AB B	0.17%	4,093	Real Estate
Stora Enso Oyj R	0.16%	3,902,110	Materials
Cloetta AB B	0.16%	41,900	Consumer Staples
SSAB AB A	0.13%	10,924,000	Materials
AB Sagax B	0.14%	7,560	Real Estate
Mekonomen AB	0.12%	#N/A	Consumer Discretionary
Klovern AB B	0.11%	10,186	Real Estate
SSAB AB B	0.09%	10,924,000	Materials
Africa Oil Corp	0.09%	#N/A	Energy
Etrion Corp	0.01%	#N/A	Utilities
Kindred Group Plc	0.59%	1,807	Consumer Discretionary

Note: This table displays the original constituents on 31st of December 2015 in the fund, prior to merging of stocks and optimization

Table 6: Descriptive Data for **AP2 Swedish Equity Portfolio** 2015

AP2 Portfolio 2015

Company	Weight	Emission in tonnes	Gics Sector
Addnode Group AB	0.018%	#N/A	Information Technology
Addtech	0.069%	#N/A	Industrials
Alfa Laval	1.285%	66,647	Industrials
Arcam AB	0.043%	#N/A	Industrials
Assa Abloy B	3.893%	429,997	Industrials
Atlas Copco A	3.199%	126,000	Industrials
Atlas Copco B	1.314%	126,000	Industrials
Atrium Ljungberg B	0.069%	4,093	Real Estate
Attendo AB	0.248%	#N/A	Health Care
Avanza AB	0.075%	111	Financials
BB Tools AB (fd. Bergman Beving B)	0.015%	#N/A	Industrials
Beijer Alma B	0.049%	#N/A	Industrials
Beijer Ref AB	0.055%	18,445	Industrials
Betsson AB	0.298%	1,055	Consumer Discretionary
Bilia A	0.065%	#N/A	Consumer Discretionary
Billerudkorsnas AB	0.617%	5,192,000	Materials
Biogaia B	0.049%	#N/A	Health Care
Boliden	0.852%	889,000	Materials
Bure Equity	0.326%	#N/A	Financials
Byggmax Group AB	0.001%	#N/A	Consumer Discretionary
Castellum	0.476%	11,359	Real Estate
Clas Ohlson B	0.000%	19,772	Consumer Discretionary
Cloetta B	0.001%	41,900	Consumer Staples
Collector AB-wi	1.317%	#N/A	Financials
Concentric AB	0.032%	#N/A	Industrials
Coor Service Management Hold	0.580%	#N/A	Industrials
CTT Systems	0.009%	781	Industrials
Cellavision AB	0.006%	#N/A	Health Care
d. Carnegie co	0.000%	5,402	Real Estate
Duni AB	0.030%	19,174	Consumer Discretionary
Diös Fastigheter AB	0.010%	#N/A	Real Estate
Electrolux B	1.002%	661,781	Consumer Discretionary
Elekta B	1.268%	7,574	Health Care
Ericsson (lm) B	5.143%	266,000	Information Technology
Fabege	0.092%	1,600	Real Estate
Fagerhult	0.027%	7,620	Industrials
Fastighets AB Balder B	1.712%	13,942	Real Estate
Fingerprint Cards B	1.553%	31,809	Information Technology
Formpipe Software AB	0.074%	#N/A	Information Technology
Getinge B	1.689%	40,964	Health Care
Haldex	0.025%	#N/A	Industrials

Hemfosa Fastigheter AB	0.786%	10,596	Real Estate
Hennes Mauritz B	7.091%	151,753	Consumer Discretionary
Hexagon B	3.687%	131,158	Information Technology
Hexpol AB	1.179%	117,000	Materials
HIQ International	0.020%	#N/A	Information Technology
HMS Industrial Networks	0.025%	#N/A	Information Technology
Hufvudstaden A	0.036%	1,657	Real Estate
Husqvarna AB B	1.068%	165,221	Consumer Discretionary
IAR Systems Group AB (Intoi AB)	0.541%	#N/A	Information Technology
Ica Gruppen AB (f.d Hakon Invest)	0.000%	246,127	Consumer Staples
(Ifsind Fin Systems B) Delisted	0.067%	#N/A	Financials
Industrivarden A	0.003%	73	Financials
Industrivarden C	0.319%	73	Financials
Indutrade AB	0.117%	#N/A	Industrials
Intrum Justitia	0.061%	11,156	Industrials
Investor A	0.043%	#N/A	Financials
Investor B	4.942%	234	Financials
Inwido AB	0.048%	#N/A	Industrials
Itab Shop Concept AB	0.065%	#N/A	Industrials
JM	0.081%	7,297	Consumer Discretionary
Kappahl Holding AB	0.178%	6,114.24	Consumer Discretionary
Kinnevik Investment B	0.333%	43,843	Financials
Klövern AB A	0.000%	10,186	Real Estate
Klövern AB B	0.129%	10,186	Real Estate
Knowit	0.008%	#N/A	Information Technology
Kungsleden	0.637%	23,985	Real Estate
Lagercrantz Group B	0.044%	#N/A	Information Technology
Lifco AB-B shs	0.153%	#N/A	Health Care
Lindab International AB	0.002%	33083	Industrials
Loomis AB B	0.386%	745,600	Industrials
Lundbergs B	0.000%	2,080,011	Financials
Lundin Petroleum	0.524%	110,731	Energy
Malmbergs Elektriska B	0.005%	#N/A	Industrials
Meda A	1.066%	27,882	Health Care
Mekonomen B	0.005%	#N/A	Consumer Discretionary
Micro Systemation AB	0.089%	#N/A	Information Technology
Micronic	0.234%	#N/A	Information Technology
Midsona AB-B shs	0.205%	#N/A	Consumer Staples
Moberg Derma AB	0.006%	#N/A	Health Care
MQ Holding AB	0.014%	2,074.86	Consumer Discretionary
MTG Modern Times Group B	0.011%	7,294	Consumer Discretionary
NCC B	1.034%	251,000	Industrials
Nederman Holdings	0.027%	#N/A	Industrials
Net Entertainment B	0.677%	#N/A	Information Technology
Net Insight B	0.020%	#N/A	Information Technology
Neurovive Pharmaceutical AB	0.003%	#N/A	Health Care
New Wave B	0.018%	#N/A	Consumer Discretionary

Nibe Industrier B	0.805%	10,900	Industrials
Nobia AB	0.138%	34,224	Consumer Discretionary
Nolato B	0.057%	57,000	Industrials
Nordax Group AB-wi	0.448%	#N/A	Financials
Nordea Bank	7.272%	24,885	Financials
Nordnet B	0.057%	269	Financials
NP3 Fastigheter AB	0.000%	#N/A	Real Estate
Opus Prodox AB	0.431%	#N/A	Information Technology
Oriflame Cosmetics	0.000%	25,850	Consumer Staples
Peab B	0.080%	108,134	Industrials
Proact IT Group	0.012%	#N/A	Information Technology
Probi AB	0.013%	#N/A	Health Care
Raysearch Laboratories AB	0.772%	#N/A	Health Care
Recipharm AB-B shs	0.023%	#N/A	Health Care
Restaurant Brands International	0.060%	156962	Consumer Discretionary
Retail and Brand	0.007%	2,458.51	Consumer Discretionary
Saab B	0.241%	108074	Industrials
Sagax AB B Shares	0.431%	7,560	Real Estate
Sandvik	1.362%	365000	Industrials
SCA sv Cellulosa A	0.189%	3,033,000	Consumer Staples
SCA sv Cellulosa B	4.080%	3,032,000	Consumer Staples
Scandi Standard AB-wi	0.040%	#N/A	Consumer Staples
Sectra B	0.026%	3,424	Health Care
Securitas B	0.712%	113,582	Industrials
Semcon	0.006%	#N/A	Industrials
Skand.Enskilda Banken A	4.581%	5,898	Financials
Skanska B	1.527%	379,965	Industrials
SKF B	1.420%	502038	Industrials
Skistar AB	0.000%	#N/A	Consumer Discretionary
SSAB Svenskt Stal A	0.001%	10,924,000	Materials
Svenska Handelsbanken A	0.569%	8,677	Financials
Svolder B	0.013%	#N/A	Financials
Sweco B	0.109%	#N/A	Industrials
Swedbank AB A	4.141%	20,184	Financials
Swedish Match	4.697%	54,398	Consumer Staples
Swedish Orphan Biovitrum AB	0.895%	253	Health Care
Swedol AB B	0.010%	#N/A	Consumer Discretionary
Tele2 B	4.091%	156,154	Telecommunication Services
Teliasonera	1.317%	418,347	Telecommunication Services
Tethys Oil AB	0.003%	#N/A	Energy
Thule Group AB/the	0.111%	10,933,000	Consumer Discretionary
Transcom Worldwide AB	0.028%	#N/A	Industrials
Trelleborg B	1.667%	280,000	Industrials
Troax Group AB-wi	0.022%	#N/A	Industrials
VBG B	0.016%	8,900	Industrials
Vitrolife AB	0.096%	#N/A	Health Care
Volvo A	0.301%	221,000	Industrials

Volvo B	2.866%	221,000	Industrials
Wallenstam B	0.004%	4,067	Real Estate
Wihlborgs Fastigheter	0.070%	8,451	Real Estate
Xano Industri B	0.010%	#N/A	Industrials
ÅF AB	0.090%	#N/A	Industrials
Århuskarlshamn AB	0.500%	234,000	Consumer Staples
Öresund	0.000%	#N/A	Financials

Note: This table displays the original constituents on 31st of December 2015 in the portfolio, prior to merging of stocks and optimization

Table 7: Descriptive Data for **SPP Swedish Equity Fund** 2015

SPP Fund 2015

Company	Weight	Emission in tonnes	Gics Sector
Hennes & Mauritz AB B	8.552%	151,753	Consumer Discretionary
Nordea Bank AB	7.716%	24,885	Financials
LM Ericsson Telephone Co B	6.374%	266,000	Information Technology
Swedbank AB A	4.850%	20,184	Financials
Assa Abloy AB B	4.292%	429,997	Industrials
Svenska Handelsbanken A	4.345%	8,677	Financials
Investor AB B	4.541%	234	Financials
Skandinaviska Enskilda Banken AB A	4.037%	5,898	Financials
Svenska Cellulosa AB B	3.535%	3,032,000	Consumer Staples
Volvo AB B	3.352%	221,000	Industrials
Atlas Copco AB A	3.297%	126,000	Industrials
AstraZeneca PLC	2.362%	597,800	Health Care
ABB Ltd	2.221%	1,475,000	Industrials
Sandvik AB	2.085%	365,000	Industrials
Hexagon AB B	2.193%	131,158	Information Technology
Atlas Copco AB B	2.035%	126,000	Industrials
Autoliv Inc DR	1.905%	290,000	Consumer Discretionary
Skanska AB B	1.616%	379,965	Industrials
Kinnevik AB B	1.596%	43,843	Financials
SKF AB B	1.310%	502,038	Industrials
Alfa Laval AB	1.281%	66,647	Industrials
Electrolux AB B	1.323%	661,781	Consumer Discretionary
Tele2 AB B	1.361%	156,154	Telecommunication Services
Getinge AB B	1.251%	40,964	Health Care
Securitas AB B	1.069%	113,582	Industrials
Industrivarden AB C	1.082%	73	Financials
Trelleborg AB B	0.980%	280,000	Industrials
Castellum AB	0.846%	11,359	Real Estate
Lundin Petroleum AB	0.761%	110,731	Energy
NCC AB B	0.656%	251,000	Industrials

Fingerprint Cards AB B	0.907%	31,809	Information Technology
Millicom International Cellular SA DR	0.890%	200,064	Telecommunication Services
Boliden AB	0.839%	889,000	Materials
Unibet Group PLC	0.770%	1,808	Consumer Discretionary
Meda AB A	0.775%	27,882	Health Care
Intrum Justitia AB	0.647%	11,156	Industrials
AAK AB	0.694%	234,000	Consumer Staples
Husqvarna AB B	0.640%	165,221	Consumer Discretionary
Elekta AB B	0.692%	7,574	Health Care
BillerudKorsnas AB	0.695%	5,192,000	Materials
Fabege AB	0.624%	1,600	Real Estate
Hufvudstaden AB A	0.573%	1,657	Real Estate
L E Lundbergforetagen AB B	0.590%	2,080,011	Financials
NIBE Industrier AB B	0.641%	10,900	Industrials
Hexpol AB B	0.643%	117,000	Materials
J M AB	0.523%	7,297	Consumer Discretionary
Swedish Orphan Biovitrum AB	0.561%	253	Health Care
Holmen AB B	0.471%	240,000	Materials
Wihlborgs Fastigheter AB	0.409%	8,451	Real Estate
Wallenstam AB B	0.415%	4,067	Real Estate
Betsson AB B	0.424%	1,055	Consumer Discretionary
Industrivarden AB A	0.366%	73	Financials
Modern Times Group MTG AB B	0.323%	7,294	Consumer Discretionary
NetEnt AB B	0.366%	#N/A	Information Technology
Fastighets AB Balder B	0.318%	13,941.77	Real Estate
Ratos AB B	0.294%	16,406	Financials
Hemfosa Fastigheter AB	0.303%	10,596	Real Estate
Kungsleden AB	0.280%	23,985	Real Estate
Cloetta AB B	0.197%	41,900	Consumer Staples
Nokia Oyj	0.160%	232,500	Information Technology
Stora Enso Oyj R	0.174%	3,902,110	Materials
Mekonomen AB	0.132%	#N/A	Consumer Discretionary
Investor AB A	0.137%	234	Financials
Kambi Group PLC B	0.121%	#N/A	Consumer Discretionary
Saab AB B	0.057%	108,074	Industrials
SSAB AB A	0.102%	10,924,000	Materials
Loomis AB B	0.043%	745,600	Industrials
Lundin Mining Corp DR	0.088%	725,427	Materials
SSAB AB B	0.070%	10,924,000	Materials
Atrium Ljungberg AB B	0.063%	4,093	Real Estate
Tethys Oil AB	0.054%	#N/A	Energy
Pandox AB B	0.029%	#N/A	Consumer Discretionary
Rezidor Hotel Group AB	0.043%	#N/A	Consumer Discretionary
Haldex AB	0.024%	#N/A	Industrials
Etrion Corp	0.004%	#N/A	Utilities
Volvo AB A	0.004%	221,000	Industrials
AB Sagax B	0.002%	7,560	Real Estate

Note: This table displays the original constituents on 31st of December 2015 in the fund, prior to merging of stocks and optimization

A.2 Descriptive Data for Optimized Portfolios

Table 8: Descriptive Statistics for Decarbonized Portfolios of the **SBX Index** 2015

		SBX 2015			
Fraction of Carbon Footprint	Returns	Sharpe Ratio	Footprint	TE	Absolute CO_2e Emission (tonnes)
1.00	0.14106	0.2868	84.72	-	16,227.25
0.95	0.14116	0.2868	80.48	1.03246E-4	15,384.51
0.90	0.14126	0.2868	76.24	2.06071E-4	14,544.7
0.85	0.14136	0.2868	72.01	3.08473E-4	13,707.89
0.80	0.14147	0.2868	67.77	4.10448E-4	12,874.15
0.75	0.14157	0.2868	63.54	5.11994E-4	12,043.53
0.70	0.14168	0.2868	59.3	6.13109E-4	11,216.14
0.65	0.14178	0.2868	55.07	7.13791E-4	10,392.04
0.60	0.14145	0.2868	50.83	8.33444E-4	9,582.44
0.55	0.14075	0.2868	46.59	1.04620E-3	8,780.84
0.50	0.14006	0.2868	42.36	1.31629E-3	7,976.95
0.45	0.13938	0.2868	38.12	1.61518E-3	7,172.77
0.40	0.13846	0.2867	33.89	1.94446E-3	6,372.4
0.35	0.13592	0.2867	29.65	2.78305E-3	5,549.75
0.30	0.13165	0.2867	25.41	4.41650E-3	4,693.25
0.25	0.12800	0.2866	21.18	6.38712E-3	3,802.95
0.20	0.12502	0.2865	16.94	8.59286E-3	2,925.51
0.15	0.12978	0.2861	12.71	1.12950E-2	1,989.15
0.10	0.12800	0.2851	8.47	1.57468E-2	1,200.64
0.05	0.07747	0.2800	4.24	2.80200E-2	444.03

Note: All values are expressed yearly. Absolute CO_2e emission in tonnes is calculated as the fraction invested of the total market cap of the company times their yearly emission values according to Equation 12. Carbon Footprint is calculated according to the metric presented by the Swedish Investment Fund Association.

Table 9: Ten largest holdings in the **SBX Index** for 75%, 50%, 25% and 5% of the original carbon footprint.

75%		50%	
Hennes & Mauritz AB B	0.0829	Hennes & Mauritz AB B	0.0832
Nordea Bank AB	0.0758	Nordea Bank AB	0.0762
LM Ericsson Telephone Co B	0.0627	LM Ericsson Telephone Co B	0.0629
Atlas Copco AB A&B	0.0533	Atlas Copco AB A&B	0.0536
Swedbank AB A	0.0478	Swedbank AB A	0.0482
Investor AB A&B	0.0454	Investor AB A&B	0.0461
Svenska Handelsbanken A	0.0424	Svenska Handelsbanken A	0.0428
Assa Abloy AB B	0.0424	Assa Abloy AB B	0.0426
Skandinaviska Enskilda Banken AB A	0.0390	Skandinaviska Enskilda Banken AB A	0.0393
Svenska Cellulosa AB B	0.0344	Volvo AB A&b	0.0346
	0.5262		**0.5294**

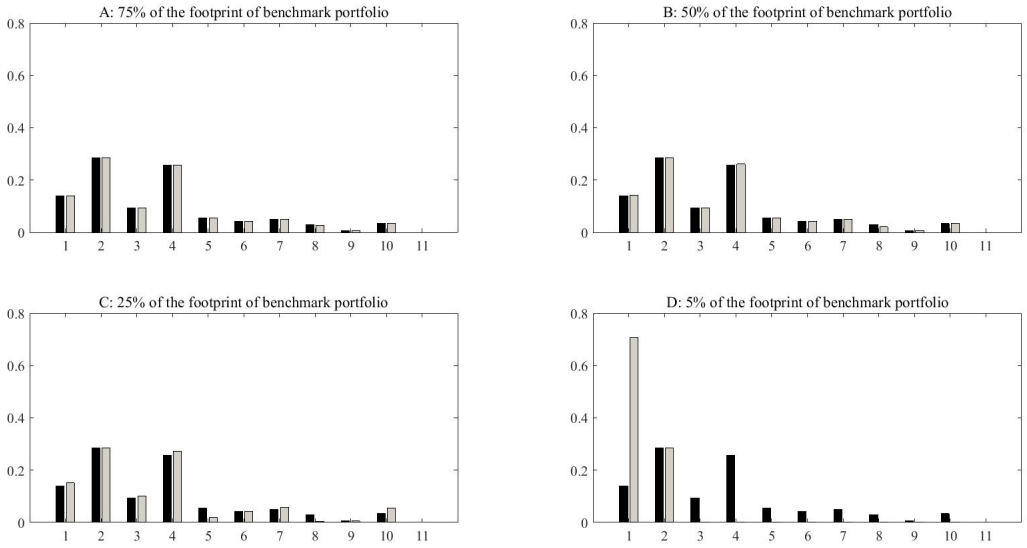
25%		5%	
Hennes & Mauritz AB B	0.0864	Investor AB A&B	0.1479
Nordea Bank AB	0.0807	Nordea Bank AB	0.1288
LM Ericsson Telephone Co B	0.0657	Svenska Handelsbanken A	0.0951
Atlas Copco AB A&B	0.0562	Hennes & Mauritz AB B	0.0935
Investor AB A&B	0.0535	Skandinaviska Enskilda Banken AB A	0.0930
Swedbank AB A	0.0525	Swedbank AB A	0.0892
Svenska Handelsbanken A	0.0469	Industrivarden AB A&C	0.0670
Skandinaviska Enskilda Banken AB A	0.0435	LM Ericsson Telephone Co B	0.0386
Assa Abloy AB B	0.0419	Hufvudstaden AB A	0.0349
Volvo AB A&b	0.0408	Atlas Copco AB A&B	0.0315
	0.5682		**0.8194**

Table 10: Ten largest holdings in the **SBX Index** for 75%, 50%, 25% and 5% of the original carbon footprint where the holdings in companies within the financial sector are kept constant.

75%		50%	
Hennes & Mauritz AB B	0.0830	Hennes & Mauritz AB B	0.0833
Nordea Bank AB	0.0757	Nordea Bank AB	0.0757
LM Ericsson Telephone Co B	0.0628	LM Ericsson Telephone Co B	0.0630
Atlas Copco AB A&B	0.0533	Atlas Copco AB A&B	0.0538
Swedbank AB A	0.0477	Swedbank AB A	0.0477
Investor AB A&B	0.0452	Investor AB A&B	0.0452
Assa Abloy AB B	0.0424	Assa Abloy AB B	0.0427
Svenska Handelsbanken A	0.0423	Svenska Handelsbanken A	0.0423
Skandinaviska Enskilda Banken AB A	0.0388	Skandinaviska Enskilda Banken AB A	0.0388
Svenska Cellulosa AB B	0.0344	Volvo AB A&b	0.0348
	0.5256		**0.5273**

25%		5%	
Hennes & Mauritz AB B	0.0888	Modern Times Group MTG AB B	0.7064
Nordea Bank AB	0.0757	Nordea Bank AB	0.0757
LM Ericsson Telephone Co B	0.0680	Swedbank AB A	0.0477
Atlas Copco AB A&B	0.0596	Investor AB A&B	0.0452
Swedbank AB A	0.0477	Svenska Handelsbanken A	0.0423
Volvo AB A&b	0.0455	Skandinaviska Enskilda Banken AB A	0.0388
Investor AB A&B	0.0452	Kinnevik Investment AB B	0.0154
Assa Abloy AB B	0.0427	Industrivarden AB A&C	0.0145
Svenska Handelsbanken A	0.0423	L E Lundbergforetagen AB B	0.0054
Skandinaviska Enskilda Banken AB A	0.0388	NetEnt AB B	0.0038
	0.5543		**0.9952**

Figure 7: Sector Exposure in **SBX Index** for 75%, 50%, 25% and 5% Optimizations of Carbon Footprint in Relation to the Original Portfolio where the holdings in companies within the financial sector are kept constant.



Note: The decarbonized portfolios are compared to the benchmark with respect to sector exposure. The corresponding GICS sectors can be found in Table 3.

Table 11: Descriptive Statistics for Decarbonized Portfolios of the **AP2 Swedish Equity Portfolio** 2015

	AP2 Portfolio 2015				
Fraction of Carbon Footprint	Annual Return	Sharpe Ratio	Footprint	TE	Absolute CO_2e Emission (tonnes)
1.00	0.31117	0.2891	72.42	-	121,061.31
0.95	0.31118	0.2891	68.8	4.19230E-5	114,999.78
0.90	0.31118	0.2891	65.18	8.52490E-5	108,958.68
0.85	0.31118	0.2891	61.56	1.28700E-4	102,915.07
0.80	0.31116	0.2891	57.94	1.76200E-4	96,890.98
0.75	0.31109	0.2891	54.32	2.21500E-4	90,843.93
0.70	0.31055	0.2891	50.69	4.29700E-4	84,886.85
0.65	0.31001	0.2891	47.07	7.06300E-4	78,886.77
0.60	0.30950	0.2891	43.45	9.95500E-4	72,842.10
0.55	0.30900	0.2891	39.83	1.28940E-3	66,766.88
0.50	0.30742	0.2891	36.21	1.75250E-3	60,956.56
0.45	0.30374	0.2891	32.59	2.80970E-3	55,297.44
0.40	0.29979	0.2891	28.97	4.29080E-3	49,063.5
0.35	0.29571	0.2891	25.35	6.00160E-3	42,475.44
0.30	0.29242	0.2891	21.73	7.88240E-3	35,283.66
0.25	0.29012	0.2890	18.11	9.75670E-3	27,947.63
0.20	0.28977	0.2889	14.48	1.17345E-2	21,016.52
0.15	0.28861	0.2883	10.86	1.47837E-2	14,687.34
0.10	0.27007	0.2861	7.24	2.01007E-2	8,944.26
0.05	0.20760	0.2812	3.62	3.45928E-2	2,881.52

Note: All values are expressed yearly. Absolute CO_2e emission in tonnes is calculated as the fraction invested of the total market cap of the company times their yearly emission values according to Equation 12. Carbon Footprint is calculated according to the metric presented by the Swedish Investment Fund Association.

Table 12: Ten largest holdings in the **AP2 Swedish Equity Portfolio** for 75%, 50%, 25% and 5% of the original carbon footprint.

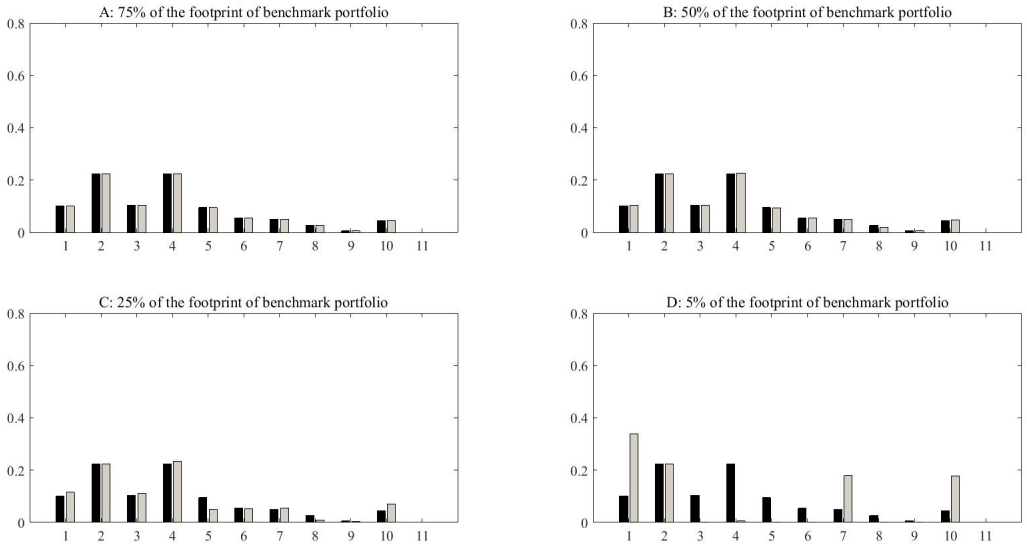
75%		50%	
Nordea Bank	0.0727	Nordea Bank	0.0734
Hennes Mauritz B	0.071	Hennes Mauritz B	0.0714
Ericsson (Lm) B	0.0514	Ericsson (Lm) B	0.0519
Investor B	0.0499	Investor B	0.0507
Swedish Match	0.047	Swedish Match	0.0471
Skand.Enskilda Banken A	0.0458	Skand.Enskilda Banken A	0.0464
Atlas Copco B	0.0452	Atlas Copco B	0.0455
Sca Sv Cellulosa B	0.0426	Swedbank AB A	0.042
Swedbank AB A	0.0414	Tele2 B	0.0409
Tele2 B	0.0409	Sca Sv Cellulosa B	0.0403
	0.508		**0.5095**

25%		5%	
Nordea Bank	0.0803	Investor B	0.1664
Hennes Mauritz B	0.0758	Nordea Bank	0.1305
Investor B	0.0621	Skand.Enskilda Banken A	0.1057
Ericsson (Lm) B	0.0557	Swedbank AB A	0.0854
Skand.Enskilda Banken A	0.0528	Hennes Mauritz B	0.0766
Atlas Copco B	0.0497	Svenska Handelsbanken A	0.0643
Swedbank AB A	0.0485	Industrivarden A	0.0642
Swedish Match	0.0477	Hufvudstaden A	0.0349
Volvo B	0.0413	Fabege	0.0263
Hexagon B	0.0377	Elekta B	0.0184
	0.5516		**0.7728**

Table 13: Ten largest holdings in the **AP2 Swedish Equity Portfolio** for 75%, 50%, 25% and 5% of the original carbon footprint where the holdings in companies within the financial sector are kept constant.

75%		50%	
Nordea Bank	0.0727	Nordea Bank	0.0727
Hennes Mauritz B	0.0710	Hennes Mauritz B	0.0716
Ericsson (Lm) B	0.0514	Ericsson (Lm) B	0.0520
Investor B	0.0499	Investor B	0.0499
Swedish Match	0.0470	Swedish Match	0.0471
Skand.Enskilda Banken A	0.0458	Skand.Enskilda Banken A	0.0458
Atlas Copco B	0.0452	Atlas Copco B	0.0458
Sca Sv Cellulosa B	0.0427	Swedbank AB A	0.0414
Swedbank AB A	0.0414	Tele2 B	0.0409
Tele2 B	0.0409	Sca Sv Cellulosa B	0.0403
	0.508		**0.5075**
25%		5%	
Hennes Mauritz B	0.0783	Betsson AB	0.2197
Nordea Bank	0.0727	Swedish Orphan Biovitrum AB	0.1732
Ericsson (Lm) B	0.0577	Mtg Modern Times Group B	0.1071
Atlas Copco B	0.0533	FABege	0.0962
Investor B	0.0499	Nordea Bank	0.0727
Swedish Match	0.0482	Hufvudstaden A	0.0727
Skand.Enskilda Banken A	0.0458	Investor B	0.0499
Volvo B	0.0446	Skand.Enskilda Banken A	0.0458
Swedbank AB A	0.0414	Swedbank AB A	0.0414
Hexagon B	0.0394	Collector AB-Wi	0.0132
	0.5313		**0.8919**

Figure 8: Sector Exposure in **AP2 Swedish Equity Portfolio** for 75%, 50%, 25% and 5% Optimizations of Carbon Footprint in Relation to the Original Portfolio where the holdings in companies within the financial sector are kept constant.



Note: The decarbonized portfolios are compared to the benchmark with respect to sector exposure. The corresponding GICS sectors can be found in Table 3.

Table 14: Descriptive Statistics for Decarbonized Portfolios of the **SPP Swedish Equity Fund** 2015

		SPP Fund 2015			
Fraction of Carbon Footprint	Returns	Sharpe Ratio	Footprint	TE	Absolute CO_2e Emission (tonnes)
1.00	0.10926	0.2866	77.18	-	59,777.79
0.95	0.10937	0.2866	73.32	9.77080E-5	56,682.45
0.90	0.10945	0.2866	69.46	1.89498E-4	53,598.79
0.85	0.10954	0.2866	65.60	2.83000E-4	50,525.35
0.80	0.10963	0.2866	61.75	3.76600E-4	47,461.73
0.75	0.10973	0.2866	57.89	4.69900E-4	44,408.73
0.70	0.10982	0.2866	54.03	5.62800E-4	41,366.69
0.65	0.10953	0.2866	50.17	6.77200E-4	38,380.37
0.60	0.10893	0.2866	46.31	8.86900E-4	35,424.14
0.55	0.10833	0.2866	42.45	1.14950E-3	32,460.82
0.50	0.10775	0.2866	38.59	1.43680E-3	29,491.68
0.45	0.10717	0.2866	34.73	1.73720E-3	26,524.45
0.40	0.10522	0.2866	30.87	2.20211E-3	23,593.03
0.35	0.10153	0.2866	27.01	3.53000E-3	20,532.19
0.30	0.09742	0.2866	23.15	5.24400E-3	17,331.51
0.25	0.09397	0.2865	19.3	7.22300E-3	14,034.76
0.20	0.09202	0.2863	15.44	9.30750E-3	10,789.23
0.15	0.09640	0.2859	11.58	1.20773E-2	7,386.09
0.10	0.08641	0.2844	7.72	1.65454E-2	4,555.73
0.05	0.03117	0.2793	3.86	3.06655E-2	1,498.92

Note: All values are expressed yearly. Absolute CO_2e emission in tonnes is calculated as the fraction invested of the total market cap of the company times their yearly emission values according to Equation 12. Carbon Footprint is calculated according to the metric presented by the Swedish Investment Fund Association.

Table 15: Ten largest holdings in the **SPP Swedish Equity Fund** for 75%, 50%, 25% and 5% of the original carbon footprint.

75%		50%	
Hennes & Mauritz AB B	0.0856	Hennes & Mauritz AB B	0.086
Nordea Bank AB	0.0773	Nordea Bank AB	0.0777
LM Ericsson Telephone Co B	0.0638	LM Ericsson Telephone Co B	0.064
Atlas Copco AB A	0.0535	Atlas Copco AB A	0.0538
Swedbank AB A	0.0486	Swedbank AB A	0.049
Investor AB B	0.047	Investor AB B	0.0477
Svenska Handelsbanken A	0.0435	Svenska Handelsbanken A	0.0439
Assa Abloy AB B	0.043	Assa Abloy AB B	0.0432
Skandinaviska Enskilda Banken AB A	0.0405	Skandinaviska Enskilda Banken AB A	0.0409
Svenska Cellulosa AB B	0.0353	Svenska Cellulosa AB B	0.0349
	0.538		**0.541**

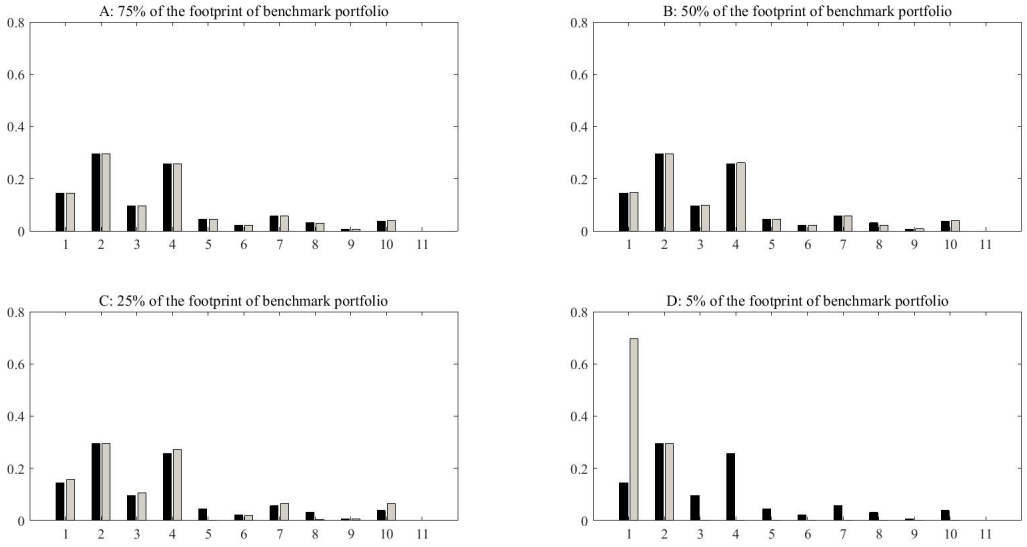
25%		5%	
Hennes & Mauritz AB B	0.0894	Investor AB B	0.1518
Nordea Bank AB	0.0825	Nordea Bank AB	0.134
LM Ericsson Telephone Co B	0.067	Skandinaviska Enskilda Banken AB A	0.0976
Atlas Copco AB A	0.0567	Svenska Handelsbanken A	0.0975
Investor AB B	0.0552	Hennes & Mauritz AB B	0.0937
Swedbank AB A	0.0533	Swedbank AB A	0.0893
Svenska Handelsbanken A	0.0482	Industrivarden AB C	0.0699
Skandinaviska Enskilda Banken AB A	0.0453	Hufvudstaden AB A	0.0385
Assa Abloy AB B	0.0423	LM Ericsson Telephone Co B	0.0314
Volvo AB B	0.0407	Fabege AB	0.0306
	0.5806		**0.8341**

Table 16: Ten largest holdings in the **SPP Swedish Equity Fund** for 75%, 50%, 25% and 5% of the original carbon footprint where the holdings in companies within the financial sector are kept constant.

75%		50%	
Hennes & Mauritz AB B	0.0856	Hennes & Mauritz AB B	0.0860
Nordea Bank AB	0.0772	Nordea Bank AB	0.0772
LM Ericsson Telephone Co B	0.0638	LM Ericsson Telephone Co B	0.0641
Atlas Copco AB A	0.0535	Atlas Copco AB A	0.0540
Swedbank AB A	0.0485	Swedbank AB A	0.0485
Investor AB B	0.0468	Investor AB B	0.0468
Svenska Handelsbanken A	0.0435	Svenska Handelsbanken A	0.0435
Assa Abloy AB B	0.0430	Assa Abloy AB B	0.0433
Skandinaviska Enskilda Banken AB A	0.0404	Skandinaviska Enskilda Banken AB A	0.0404
Svenska Cellulosa AB B	0.0353	Svenska Cellulosa AB B	0.0348
	0.5375		**0.5386**

25%		5%	
Hennes & Mauritz AB B	0.0931	Modern Times Group MTG AB B	0.6967
Nordea Bank AB	0.0772	Nordea Bank AB	0.0772
LM Ericsson Telephone Co B	0.0700	Swedbank AB A	0.0485
Atlas Copco AB A	0.0612	Investor AB B	0.0468
Swedbank AB A	0.0485	Svenska Handelsbanken A	0.0435
Volvo AB B	0.0472	Skandinaviska Enskilda Banken AB A	0.0404
Investor AB B	0.0468	Kinnevik AB B	0.0160
Svenska Handelsbanken A	0.0435	Industrivarden AB C	0.0145
Assa Abloy AB B	0.0433	L E Lundbergforetagen AB B	0.0059
Skandinaviska Enskilda Banken AB A	0.0404	NetEnt AB B	0.0037
	0.5710		**0.9930**

Figure 9: Sector Exposure in **SPP Swedish Equity Fund** for 75%, 50%, 25% and 5% Optimizations of Carbon Footprint in Relation to the Original Portfolio when weight for financial sector is kept constant



Note: The decarbonized portfolios are compared to the benchmark with respect to sector exposure. The corresponding GICS sectors can be found in Table 3.

B Appendix

B.1 Sustainability Profile of Portfolios in Sample

Sustainability profile of the AP2 Swedish equity portfolio Second Swedish national Pension Fund (2015):

- Investment decision depends on the relative amount of carbon dioxide emissions.
- Divestment from companies engaged in unethical weapon manufacturing and companies in breach of human rights.
- AP2 Swedish equity portfolio has signed the Principles for Responsible Investments, (PRI Association, 2016)

Sustainability of the SPP Swedish equity fund SweSif (2017a):

- No investments in companies where more than 30% of revenue comes from coal.
- Divestment from companies that are included in the tenth percentile of companies with low sustainability profiles (For example companies involved in production of coal, palm oil, and oil sands.)
- Divestment from companies involved in production of nuclear weapons, chemical and biological weapons, tobacco, and pornography.

B.2 Emission data and Method of Estimation

As previously mentioned, data for emissions are retrieved from Thomson Reuters ESG database as well as the Bloomberg terminal. Some data are estimated, either by us or by Reuters.

Reuters uses three types of estimation methods Thomson Reuters (2017):

- CO2 model - When companies report CO2 emission for a previous year but not present year, the previous emissions are divided by number of employees and net sales for that year. These fractions are then multiplied with the number of employees and net sales respectively for the year one wishes to estimate emission.
- Energy model - The latest available total energy consumed is divided by number of employees. The ratio is computed for all companies within the same industry, where the companies are then ranked per percentile. The CO2 is computed for the companies in the same sample, and the companies are ordered by the ranking in previous step. The ranking serves to find the ratio of the CO2 for the company we want estimates for. The same steps are then taken with regards to net sales and an average CO2 estimate is attributed to the company.

- Median model - The CO2 emission is divided by number of employees for all companies within the same sector. Thereafter a median is calculated. These steps are repeated with regards to net sales, after which an average of the two numbers are used as an estimate for the company emission.

For companies not included in the Reuters ESG database, we use Bloomberg to find possible reported emission data that is not available in Reuters. For companies we have estimated emission for, the data is retrieved from Bloomberg terminal. For three of the Swedish stocks we calculate a peer-median using $\frac{emission}{revenue}$, where the median is multiplied with the revenue for that year, the number of peers required for this metric is set to a minimum of six peers. For missing data on five Swedish real estate companies we construct a peer median by using kg CO_2e/square meter using four similar companies as peers.

Table 17: List of Emissions and Origin of Data for Companies in Sample

Company name	Emission (*tonnes*)	Sector	Emission data (*origin*)
AAK AB	234,000	Consumer Staples	Bloomberg Reported
AB Sagax B	7,560	Real Estate	Median us
ABB Ltd	1,475,000	Industrials	Reuters Reported
Alfa Laval AB	66,647	Industrials	Reuters Reported
Assa Abloy AB B	429,997	Industrials	Reuters Reported
AstraZeneca PLC	597,800	Health Care	Reuters Reported
Atlas Copco AB A&B	126,000	Industrials	Reuters Reported
Atrium Ljungberg AB B	4,093	Real Estate	Median us
Autoliv Inc DR	290,000	Consumer Discretionary	Reuters Reported
Avanza AB	111	Financials	Bloomberg Reported
BEIJER REF AB	18,445	Industrials	Reuters Median
Betsson AB B	1,055	Consumer Discretionary	Bloomberg Reported
BillerudKorsnas AB	5,192,000	Materials	Reuters Reported
Boliden AB	889,000	Materials	Reuters Reported
Castellum AB	11,359	Real Estate	Reuters Reported
Clas Ohlson B	19,772	Consumer Discretionary	Reuters Median
Cloetta AB B	41,900	Consumer Staples	Bloomberg Reported
CTT Systems	781	Industrials	Reuters Median
D. Carnegie CO	5,402	Real Estate	Reuters Median
Duni AB	19,174	Consumer Discretionary	Bloomberg Reported
Electrolux AB B	661,781	Consumer Discretionary	Reuters CO2
Elekta AB B	7,574	Health Care	Reuters CO2
Fabege AB	1,600	Real Estate	Reuters Reported
Fagerhult	7,620	Industrials	Bloomberg Reported
Fastighets AB Balder B	13,942	Real Estate	Median us
Fingerprint Cards AB B	31,809	Information Technology	Reuters Median
Getinge AB B	40,964	Health Care	Reuters CO2
Hemfosa Fastigheter AB	10,596	Real Estate	Median us
Hennes & Mauritz AB B	151,753	Consumer Discretionary	Reuters Reported
Hexagon AB B	131,158	Information Technology	Reuters Median
Hexpol AB B	117,000	Materials	Bloomberg Reported
Holmen AB B	240,000	Materials	Reuters Reported
Hufvudstaden AB A	1,657	Real Estate	Reuters CO2
Husqvarna AB B	165,221	Consumer Discretionary	Reuters Reported
ICA Gruppen AB (f.d Hakon Invest)	246,127	Consumer Staples	Reuters Reported
Industrivarden AB A&C	73	Financials	Reuters CO2
Intrum Justitia AB	11,156	Industrials	Reuters Median
Investor AB A&B	234	Financials	Reuters CO2

J M AB	7,297	Consumer Discretionary	Reuters Reported
Kappahl Holding AB	6,114	Consumer Discretionary	Median Bloomberg
Kinnevik Investment AB B	43,843	Financials	Reuters CO2
Klovern AB B	10,186	Real Estate	Median us
Kungsleden AB	23,985	Real Estate	Reuters Reported
L E Lundbergforetagen AB B	2,080,011	Financials	Reuters Energy
LINDAB International AB	33,083	Industrials	Reuters Reported
LM Ericsson Telephone Co B	266,000	Information Technology	Reuters Reported
Loomis AB B	745,600	Industrials	Bloomberg Reported
Lundin Mining Corp DR	725,427	Materials	Bloomberg Reported
Lundin Petroleum AB	110,731	Energy	Reuters Reported
Meda AB A	27,882	Health Care	Bloomberg Reported
Millicom International Cellular SA DR	200,064	Telecommunication Services	Reuters Reported
Modern Times Group MTG AB B	7,294	Consumer Discretionary	Reuters Reported
MQ Holding AB	2,075	Consumer Discretionary	Median Bloomberg
NCC AB B	251,000	Industrials	Reuters Reported
NIBE Industrier AB B	10,900	Industrials	Reuters Reported
Nobia AB	34,224	Consumer Discretionary	Reuters CO2
Nokia Oyj	232,500	Information Technology	Reuters Reported
NOLATO B	57,000	Industrials	Bloomberg Reported
Nordea Bank AB	24,885	Financials	Reuters Reported
Nordnet B	269	Financials	Bloomberg Reported
Oriflame Cosmetics	25,850	Consumer Staples	Bloomberg Reported
PEAB B	108,134	Industrials	Bloomberg Reported
Ratos AB B	16,406	Financials	Reuters Median
Restaurant Brand International	156,962	Consumer Discretionary	Reuters Median
Retail and Brand	2,459	Consumer Discretionary	Median Bloomberg
Saab AB B	108,074	Industrials	Reuters Median
Sandvik AB	365,000	Industrials	Reuters Reported
Sectra B	3,424	Health Care	Reuters Median
Securitas AB B	113,582	Industrials	Reuters Reported
Skandinaviska Enskilda Banken AB A	5,898	Financials	Reuters Reported
Skanska AB B	379,965	Industrials	Reuters Reported
SKF AB B	502,038	Industrials	Reuters Reported
SSAB AB A&B	10,924,000	Materials	Bloomberg Reported
Stora Enso Oyj R	3,902,110	Materials	Bloomberg Reported
Swedbank AB A	20,184	Financials	Reuters Reported
Swedish Match AB	54,398	Consumer Staples	Reuters Reported
Swedish Orphan Biovitrum AB	253	Health Care	Reuters Reported
Svenska Cellulosa AB B	3,032,000	Consumer Staples	Reuters Reported
Svenska Handelsbanken A	8,677	Financials	Reuters Reported
Tele2 AB B	156,154	Telecommunication Services	Reuters Reported
TeliaSonera AB	418,347	Telecommunication Services	Reuters Reported
THULE Group AB/THE	10,933,000	Consumer Discretionary	Bloomberg Reported
Trelleborg AB B	280,000	Industrials	Reuters Reported
Unibet Group PLC	1,808	Consumer Discretionary	Reuters Reported
Wallenstam AB B	4,067	Real Estate	Bloomberg Reported
VBG B	8,900	Industrials	Reuters Median
Wihlborgs Fastigheter AB	8,451	Real Estate	Reuters Reported
Volvo AB A&b	221,000	Industrials	Reuters Reported

Note: Reported values are values reported by company in annual report. Reuters estimated values are named; CO2, median and energy. Estimates produced by us are labeled Estimated us.

C Appendix

C.1 Betas and Estimation Statistics for Portfolios in Sample

Table 18: Betas and estimation statistics for **SBX Index**

	SBX_Fund_2015								
Company name	β_{MKT}	t-stat	p-value	β_{SMB}	t-stat	p-value	β_{HML}	t-stat	p-value
Hennes & Mauritz AB B	1.0348	55.6111	0	0.1328	4.5041	0,00000	-0.1708	-4.5486	0
Nordea Bank AB	1.037	56.7546	0	-0.136	-4.6987	0	0.099	2.6851	0.0073
LM Ericsson Telephone Co B	0.8489	29.9674	0	-0.3477	-7.7502	0	0.4986	8.7238	0
Atlas Copco AB A&B	1.1961	58.5496	0	-0.1263	-3.9018	0.0001	-0.0706	-1.7117	0.087
Swedbank AB A	0.9515	52.6902	0	-0.1959	-6.8472	0	0.2442	6.6999	0
Investor AB A&B	1.0259	81.7988	0	-0.07	-3.5217	0.0004	0.0455	1.7976	0.0723
Svenska Handelsbanken A	1.0023	56.2403	0	-0.0494	-1.7505	0.08	0.0465	1.2918	0.1964
Assa Abloy AB B	1.0349	51.3004	0	-0.0314	-0.9814	0.3264	-0.0041	-0.1013	0.9193
Skandinaviska Enskilda Banken AB A	1.0319	54.1885	0	-0.1365	-4.5268	0,00000	0.1039	2.7036	0.0069
Svenska Cellulosa AB B	0.8575	37.2743	0	-0.1223	-3.3568	0.0008	0.2653	5.716	0
Volvo AB A&b	1.1046	46.9913	0	-0.1724	-4.6312	0	0.0707	1.4915	0.1358
TeliaSonera AB	0.8537	49.5579	0	-0.021	-0.7688	0.442	0.1674	4.817	0
Hexagon AB B	1.0881	41.0548	0	-0.1098	-2.6162	0.0089	0.021	0.3932	0.6942
Sandvik AB	1.1824	50.145	0	-0.1305	-3.4937	0.0005	-0.0538	-1.1305	0.2583
AstraZeneca PLC	0.6718	27.8234	0	0.12	3.1378	0.0017	0.2095	4.2995	0
ABB Ltd	0.8257	44.8071	0	0.0433	1.4824	0.1382	0.1314	3.5325	0.0004
Autoliv Inc DR	0.8453	35.2488	0	0.1336	3.5179	0.0004	0.0189	0.3912	0.6957
Skanska AB B	0.9805	52.9754	0	-0.0067	-0.2267	0.8207	0.0281	0.7533	0.4513
Kinnevik Investment AB B	0.9365	34.7258	0	-0.2653	-6.2093	0	0.3308	6.0782	0
Swedish Match AB	0.7328	29.1864	0	0.193	4.8531	0	0.074	1.4604	0.1442
Industrivarden AB A&C	1.0304	67.0353	0	-0.0428	-1.7558	0.0791	0.0147	0.474	0.6355
Electrolux AB B	1.0523	34.1534	0	-0.0694	-1.4222	0.155	0.0178	0.2857	0.7751
SKF AB B	1.0887	45.4624	0	-0.1482	-3.9061	0.0001	0.056	1.1585	0.2467
Alfa Laval AB	1.0795	48.5356	0	-0.0854	-2.4244	0.0153	0.0065	0.1437	0.8858
Getinge AB B	0.8992	29.9664	0	0.0928	1.9518	0.051	0.0081	0.1329	0.8943
Securitas AB B	0.9441	39.4395	0	0.0285	0.7522	0.452	0.0266	0.5506	0.5819
Trelleborg AB B	1.0923	47.6261	0	-0.1148	-3.1601	0.0016	0.0221	0.478	0.6327
Boliden AB	1.176	35.6115	0	-0.3249	-6.2106	0	0.1557	2.3368	0.0195
Fingerprint Cards AB B	1.487	14.2098	0	1.5646	9.4394	0	-2.0371	-9.6477	0
Millicom International Cellular SA DR	0.8643	28.5145	0	0.1896	3.9496	0.0001	-0.0548	-0.8953	0.3706
BillerudKorsnas AB	0.9916	36.5105	0	-0.033	-0.767	0.4431	0.0397	0.7249	0.4685
Meda AB A	0.6782	13.5259	0	0.3076	3.8734	0.0001	0.0115	0.1135	0.9096
Tele2 AB B	0.8493	35.053	0	0.0175	0.4555	0.6488	0.1326	2.713	0.0067
Lundin Petroleum AB	0.9967	28.4001	0	-0.0378	-0.6799	0.4966	0.0428	0.6048	0.5454
Elekta AB B	0.7622	20.5606	0	0.1255	2.1365	0.0326	0.11	1.4702	0.1415
Hexpol AB B	0.9734	29.8032	0	0.0876	1.6925	0.0905	-0.0632	-0.9585	0.3378
Unibet Group PLC	0.7313	25.5771	0	0.2797	6.1762	0	-0.0138	-0.2398	0.8105
NIBE Industrier AB B	1.021	35.0913	0	0.14	3.0384	0.0024	-0.1619	-2.758	0.0058
Husqvarna AB B	1.0104	37.5158	0	-0.0813	-1.9066	0.0566	0.0712	1.3097	0.1903
Swedish Orphan Biovitrum AB	0.9281	19.886	0	0.3553	4.8057	0	-0.2854	-3.0311	0.0024
NCC AB B	0.9896	44.6149	0	0.0136	0.3856	0.6998	-0.0027	-0.0608	0.9515
L E Lundbergforetagen AB B	0.9327	57.7551	0	0.1146	4.4801	0	-0.0466	-1.4295	0.1529
Intrum Justitia AB	0.829	29.7882	0	0.0723	1.6408	0.1009	0.0951	1.6929	0.0905
Castellum AB	0.8261	44.7682	0	0.0928	3.1733	0.0015	0.081	2.1741	0.0297
J M AB	1.0465	36.9324	0	0.0866	1.9294	0.0537	-0.136	-2.3779	0.0174
AAK AB	0.8042	32.8814	0	0.2599	6.7099	0	-0.0674	-1.3651	0.1722
Fabege AB	0.8844	41.1069	0	0.1258	3.6908	0.0002	-0.006	-0.1376	0.8906
Saab AB B	0.8939	29.4238	0	0.1059	2.1996	0.0278	0.0034	0.0552	0.956
Betsson AB B	0.8845	22.8119	0	0.2291	3.7303	0.0002	-0.1137	-1.4536	0.1461
Loomis AB B	0.7986	24.9795	0	0.1819	3.5917	0.0003	0.0183	0.2835	0.7768
Fastighets AB Balder B	0.9562	35.2469	0	0.2182	5.0769	0	-0.1734	-3.1677	0.0015
NetEnt AB B	1.0101	25.1858	0	0.2971	4.6771	0	-0.3075	-3.7993	0.0002
Hufvudstaden AB A	0.8298	44.6184	0	0.1574	5.344	0	0.0163	0.4338	0.6644
Wallenstam AB B	0.894	43.7449	0	0.1189	3.672	0.0002	-0.013	-0.3142	0.7533
Holmen AB B	0.8195	41.7599	0	0.0471	1.5158	0.1296	0.1338	3.3786	0.0007
Hemfosa Fastigheter AB	0.9605	41.5966	0	0.1998	5.4638	0	-0.1586	-3.4049	0.0007
Wihlborgs Fastigheter AB	0.869	40.1326	0	0.1682	4.9045	0	-0.0372	-0.8503	0.3952
Modern Times Group MTG AB B	1.0479	33.2827	0	0.0202	0.4053	0.6852	-0.0685	-1.0775	0.2813
Pandox AB B	0.8634	55.0479	0	0.3582	14.4188	0	-0.2475	-7.8197	0
Kungsleden AB	0.8938	28.1448	0	0.1239	2.4637	0.0138	-0.017	-0.2645	0.7914
SSAB AB A&B	1.2149	28.5882	0	-0.1658	-2.4629	0.0138	-0.0491	-0.5722	0.5672
Atrium Ljungberg AB B	0.7378	28.1074	0	0.2591	6.2302	0	0.0043	0.0816	0.935
Stora Enso Oyj R	1.002	33.8433	0	-0.1981	-4.2243	0	0.1929	3.2295	0.0012
Cloetta AB B	0.6779	19.9309	0	0.381	7.0713	0	-0.0605	-0.8808	0.3784

AB Sagax B	0.8574	24.7197	0	0.2809	5.1132	0	-0.1313	-1.8767	0.0606
Mekonomen AB	0.8281	27.5712	0	0.3111	6.5394	0	-0.1373	-2.2649	0.0235
Klovern AB B	0.9079	42.4699	0	0.2784	8.2226	0	-0.1792	-4.1537	0
Africa Oil Corp	0.9541	12.2219	0	0.2335	1.8883	0.059	-0.2042	-1.2962	0.1949
Etrion Corp	0.6513	4.8069	0	0.5772	2.6893	0.0072	-0.2365	-0.8651	0.387

Note: T-statistics (t-stat) are calculated using the standard OLS errors. The t-statistics are high for all of the MKT estimates, this is due to stock price being highly dependent on the general market movements.

Table 19: Betas and estimation statistics for **AP2 Swedish Equity Portfolio**

	AP2 Fund 2015								
Company name	β_{MKT}	t-stat	p-value	β_{SMB}	t-stat	p-value	β_{HML}	t-stat	p-value
Addnode Group AB	0.7159	19.3702	0	0.4387	7.4943	0	-0.1549	-2.0769	0.0378
Addtech	0.7451	21.3245	0	0.4719	8.5259	0	-0.2251	-3.1923	0.0014
Alfa Laval	1.0795	48.5356	0	-0.0854	-2.4244	0.0153	0.0064	0.1437	0.8858
Arcam AB	1.3381	16.7273	0	1.0731	8.4687	0	-1.4171	-8.7793	0
Assa ABloy B	1.0349	51.3004	0	-0.0314	-0.9814	0.3264	-0.0041	-0.1013	0.9193
Atlas Copco B	1.1961	58.5496	0	-0.1263	-3.9018	0.0001	-0.0706	-1.7117	0.087
Atrium Ljungberg B	0.7378	28.1074	0	0.259	6.2302	0	0.0043	0.0816	0.935
Attendo AB	0.8356	30.6648	0	0.4711	10.9153	0	-0.2453	-4.4618	0
Avanza AB	0.9178	29.6177	0	0.1981	4.0364	0.0001	-0.1185	-1.8954	0.058
Bb Tools AB (Fd. Bergman Beving B)	0.7794	21.1004	0	0.3023	5.1664	0	-0.0814	-1.0916	0.275
Beijer Alma B	0.7291	25.3134	0	0.4679	10.2564	0	-0.1967	-3.384	0.0007
Beijer Ref AB	0.7592	21.798	0	0.4609	8.3538	0	-0.2227	-3.1685	0.0015
Betsson AB	0.8845	22.8119	0	0.2291	3.7303	0.0002	-0.1137	-1.4536	0.1461
Bilia A	0.9652	29.3221	0	0.3144	6.0307	0	-0.2804	-4.2213	0
Billerudkorsnas AB	0.9916	36.5105	0	-0.033	-0.767	0.4431	0.0397	0.7249	0.4685
Biogaia B	0.7554	17.664	0	0.3723	5.4967	0	-0.1214	-1.4066	0.1595
Boliden	1.176	35.6115	0	-0.3248	-6.2106	0	0.1557	2.3368	0.0195
Bure Equity	0.8553	28.6687	0	0.3459	7.3202	0	-0.2023	-3.3601	0.0008
Byggmax Group AB	0.9289	24.74	0	0.335	5.6336	0	-0.2621	-3.4601	0.0005
Castellum	0.8261	44.7682	0	0.0928	3.1733	0.0015	0.081	2.1741	0.0297
Clas Ohlson B	0.8437	29.7891	0	0.3067	6.8374	0	-0.1513	-2.6482	0.0081
Cloetta B	0.6779	19.9308	0	0.381	7.0713	0	-0.0605	-0.8808	0.3784
Collector AB-Wi	0.9856	33.9969	0	0.4878	10.6232	0	-0.4612	-7.8842	0
Concentric AB	0.991	25.706	0	0.311	5.092	0	-0.3057	-3.93	0.0001
Coor Service Management Hold	0.6658	28.5204	0	0.5598	15.1372	0	-0.2254	-4.7842	0
Ctt Systems	0.6277	14.1308	0	0.5569	7.9147	0	-0.1858	-2.0729	0.0382
Cellavision AB	0.7857	16.8775	0	0.54	7.3226	0	-0.3237	-3.4457	0.0006
D. Carnegie Co	0.8358	36.3938	0	0.1351	3.7148	0.0002	0.0277	0.5975	0.5502
Duni AB	0.7255	22.0836	0	0.4516	8.6792	0	-0.1806	-2.7242	0.0064
Diös Fastigheter AB	0.7213	30.0584	0	0.3317	8.7278	0	-0.0542	-1.1203	0.2626
Electrolux B	1.0523	34.1534	0	-0.0694	-1.4222	0.155	0.0178	0.2857	0.7751
Elekta B	0.7622	20.5605	0	0.1255	2.1365	0.0326	0.11	1.4702	0.1415
Ericsson (Lm) B	0.8489	29.9674	0	-0.3477	-7.7501	0	0.4986	8.7238	0
FABege	0.8844	41.1068	0	0.1258	3.6908	0.0002	-0.006	-0.1376	0.8906
Fagerhult	0.6437	16.8954	0	0.4752	7.874	0	-0.1176	-1.5297	0.1261
Fastighets AB Balder B	0.9562	35.2469	0	0.2181	5.0769	0	-0.1734	-3.1677	0.0015
Fingerprint Cards B	1.487	14.2098	0	1.5646	9.4394	0	-2.0371	-9.6476	0
Formpipe Software AB	0.695	17.6749	0	0.4782	7.6782	0	-0.1769	-2.2296	0.0258
Getinge B	0.8991	29.9664	0	0.0928	1.9518	0.051	0.008	0.1329	0.8943
Haldex	1.1241	27.1238	0	-0.0577	-0.8785	0.3797	-0.0652	-0.7794	0.4357
Hemfosa Fastigheter AB	0.9605	41.5966	0	0.1998	5.4638	0	-0.1586	-3.4049	0.0007
Hennes Mauritz B	1.0348	55.6111	0	0.1328	4.5041	0	-0.1708	-4.5486	0
Hexagon B	1.0881	41.0548	0	-0.1098	-2.6162	0.0089	0.021	0.3932	0.6942
Hexpol AB	0.9734	29.8031	0	0.0876	1.6925	0.0905	-0.0632	-0.9585	0.3378
Hiq International	0.8285	25.5448	0	0.4634	9.0188	0	-0.2919	-4.4597	0
Hms Industrial Networks	0.6512	16.0899	0	0.6779	10.575	0	-0.331	-4.0534	0.0001
Hufvudstaden A	0.8297	44.6184	0	0.1574	5.344	0	0.0163	0.4338	0.6644
Husqvarna AB B	1.0104	37.5158	0	-0.0813	-1.9066	0.0566	0.0712	1.3097	0.1903
Iar Systems Group AB (Intoi AB)	0.7365	20.2813	0	0.3793	6.5944	0	-0.1131	-1.5436	0.1227
Ica Gruppen AB (F.D Hakon Invest)	0.6855	24.2424	0	0.2686	5.9965	0	0.0457	0.8003	0.4236
Ifsind Fin Systems B	0.3049	10.9714	0	0.3059	6.9498	0	0.3909	6.9711	0
Industrivarden A	1.0304	67.0353	0	-0.0427	-1.7558	0.0791	0.0147	0.474	0.6355
Indutrade AB	0.8873	33.8656	0	0.1438	3.4649	0.0005	-0.0323	-0.6105	0.5415
Intrum Justitia	0.829	29.7882	0	0.0723	1.6408	0.1008	0.0951	1.6929	0.0905
Investor B	1.0259	81.7988	0	-0.07	-3.5217	0.0004	0.0455	1.7976	0.0722
Inwido AB	0.9047	37.1107	0	0.1792	4.6405	0	-0.0826	-1.6798	0.093
ItAB Shop Concept AB	0.8813	21.9945	0	0.4388	6.9129	0	-0.3255	-4.0261	0.0001
Jm	1.0465	36.9324	0	0.0866	1.9294	0.0537	-0.136	-2.3779	0.0174
Kappahl Holding AB	0.9895	21.5903	0	0.4447	6.126	0	-0.437	-4.7256	0
Kinnevik Investment B	0.9365	34.7258	0	-0.2653	-6.2093	0	0.3308	6.0782	0

Klövern AB B	0.9079	42.4699	0	0.2784	8.2226	0	-0.1792	-4.1537	0
Knowit	0.759	23.6602	0	0.3362	6.6159	0	-0.0939	-1.4506	0.1469
Kungsleden	0.8938	28.1447	0	0.1239	2.4637	0.0138	-0.0169	-0.2645	0.7914
Lagercrantz Group B	0.8123	20.5297	0	0.276	4.4045	0	-0.0928	-1.1622	0.2451
Lifco AB-B Shs	0.8417	29.8333	0	0.1498	3.3523	0.0008	0.0078	0.1368	0.8912
LindAB International AB	1.0021	29.0858	0	0.1689	3.0956	0.002	-0.1719	-2.4722	0.0134
Loomis AB B	0.7986	24.9795	0	0.1819	3.5917	0.0003	0.0183	0.2835	0.7768
Lundbergs B	0.9327	57.7551	0	0.1146	4.4801	0	-0.0466	-1.4295	0.1529
Lundin Petroleum	0.9967	28.4001	0	-0.0378	-0.6799	0.4966	0.0428	0.6047	0.5453
Malmbergs Elektriska B	0.6901	18.9774	0	0.3691	6.4078	0	-0.0544	-0.7419	0.4581
Meda A	0.6782	13.5259	0	0.3076	3.8734	0.0001	0.0115	0.1135	0.9096
Mekonomen B	0.8281	27.5712	0	0.3111	6.5394	0	-0.1373	-2.2649	0.0235
Micro Systemation AB	0.8661	16.6318	0	0.4588	5.5624	0	-0.3294	-3.1348	0.0017
Micronic	0.793	16.7159	0	0.2476	3.2947	0.001	-0.0465	-0.4863	0.6268
Midsona AB-B Shs	0.5478	10.9838	0	0.5188	6.5679	0	-0.0623	-0.6188	0.5361
Moberg Derma AB	0.8167	15.6272	0	0.3659	4.4202	0	-0.1905	-1.8063	0.0709
Mq Holding AB	0.7136	19.4795	0	0.2861	4.9303	0	0.0025	0.0332	0.9735
Mtg Modern Times Group B	1.0479	33.2827	0	0.0202	0.4053	0.6852	-0.0685	-1.0775	0.2813
Ncc B	0.9896	44.6149	0	0.0135	0.3856	0.6998	-0.0027	-0.0608	0.9515
Nederman Holdings	0.7036	15.1873	0	0.3129	4.2637	0	-0.0242	-0.2586	0.796
Net Entertainment B	1.0101	25.1858	0	0.2971	4.6771	0	-0.3075	-3.7993	0.0001
Net Insight B	0.8779	15.2226	0	0.3554	3.8909	0.0001	-0.2435	-2.0923	0.0364
Neurovive Pharmaceutical AB	0.9232	8.7705	0	1.2367	7.4178	0	-1.1529	-5.4281	0
New Wave B	0.895	22.3036	0	0.1775	2.7923	0.0052	-0.0769	-0.9499	0.3422
Nibe Industrier B	1.021	35.0913	0	0.14	3.0384	0.0024	-0.1619	-2.758	0.0058
Nobia AB	1.021	26.0543	0	0.2064	3.3254	0.0009	-0.2295	-2.9019	0.0037
Nolato B	0.9015	28.6961	0	0.3728	7.4911	0	-0.2759	-4.3526	0
Nordax Group AB-Wi	0.7572	34.2519	0	0.481	13.736	0	-0.2336	-5.236	0
Nordea Bank	1.037	56.7546	0	-0.136	-4.6987	0	0.099	2.6851	0.0073
Nordnet B	0.8649	23.4288	0	0.2991	5.1152	0	-0.1649	-2.2134	0.0269
Np3 Fastigheter AB	0.7035	35.3867	0	0.3969	12.6032	0	-0.0942	-2.3483	0.0189
Opus Prodox AB	0.7981	14.0444	0	0.459	5.0987	0	-0.2616	-2.2818	0.0225
Oriflame Cosmetics	0.8103	28.6941	0	0.398	8.8972	0	-0.2042	-3.5834	0.0003
PeAB B	1.0297	43.2196	0	0.0366	0.9695	0.3323	-0.0658	-1.3685	0.1712
Proact It Group	0.7865	20.2384	0	0.5181	8.4172	0	-0.2991	-3.8145	0.0001
Probi AB	0.8039	14.297	0	0.6268	7.0376	0	-0.4301	-3.7907	0.0002
Raysearch LABoratories AB	0.8219	16.4188	0	0.474	5.9779	0	-0.2929	-2.8992	0.0037
Recipharm AB-B Shs	0.8498	28.0111	0	0.2764	5.7525	0	-0.1251	-2.0443	0.0409
Restaurant Brands International	0.533	22.2881	0	0.0779	2.0579	0.0396	0.3887	8.0551	0
Retail And Brand	0.7615	9.2608	0	0.0991	0.7605	0.447	0.1362	0.8206	0.4119
SaAB B	0.8939	29.4238	0	0.1059	2.1996	0.0278	0.0034	0.0552	0.956
Sagax AB B Shares	0.8574	24.7197	0	0.2809	5.1132	0	-0.1313	-1.8767	0.0606
Sandvik	1.1824	50.145	0	-0.1305	-3.4937	0.0005	-0.0538	-1.1305	0.2582
Sca Sv Cellulosa B	0.8575	37.2743	0	-0.1223	-3.3568	0.0008	0.2653	5.716	0
Scandi Standard AB-Wi	0.7237	28.7629	0	0.3856	9.674	0	-0.1115	-2.1968	0.028
Sectra B	0.671	16.3068	0	0.4347	6.6706	0	-0.1065	-1.2831	0.1994
Securitas B	0.9441	39.4395	0	0.0285	0.7522	0.452	0.0266	0.5506	0.5819
Semcon	0.8975	22.3605	0	0.275	4.325	0	-0.1677	-2.0707	0.0384
Skand.Enskilda Banken A	1.0319	54.1885	0	-0.1365	-4.5268	0	0.1039	2.7036	0.0069
Skanska B	0.9805	52.9753	0	-0.0066	-0.2267	0.8207	0.0281	0.7533	0.4513
Skf B	1.0887	45.4624	0	-0.1482	-3.9061	0.0001	0.056	1.1585	0.2467
Skistar AB	0.6845	24.1792	0	0.4297	9.5829	0	-0.1061	-1.8574	0.0633
SsAB Svenskt Stal A	1.2628	28.8824	0	-0.248	-3.5816	0.0003	-0.0137	-0.1557	0.8763
Svenska Handelsbanken A	1.0023	56.2403	0	-0.0494	-1.7505	0.08	0.0465	1.2918	0.1964
Svolder B	0.7874	33.9373	0	0.3853	10.4835	0	-0.1725	-3.684	0.0002
Sweco B	0.7965	25.6052	0	0.2753	5.5868	0	-0.0697	-1.1102	0.2669
Swedbank AB A	0.9515	52.6902	0	-0.1959	-6.8472	0	0.2441	6.6999	0
Swedish Match	0.7328	29.1864	0	0.193	4.8531	0	0.074	1.4604	0.1442
Swedish Orphan Biovitrum AB	0.9281	19.886	0	0.3553	4.8057	0	-0.2854	-3.0311	0.0024
Swedol AB B	0.7551	17.4742	0	0.4875	7.1227	0	-0.2458	-2.8195	0.0048
Tele2 B	0.8493	35.053	0	0.0175	0.4555	0.6488	0.1326	2.713	0.0067
Teliasonera	0.8537	49.5579	0	-0.021	-0.7688	0.442	0.1674	4.817	0
Tethys Oil AB	0.8823	21.048	0	0.2793	4.2063	0	-0.1569	-1.8551	0.0636
Thule Group AB/The	0.8865	38.5372	0	0.3971	10.8975	0	-0.2864	-6.1688	0
Transcom Worldwide AB	0.7912	23.9197	0	0.5452	10.4061	0	-0.3334	-4.9954	0
Trelleborg B	1.0923	47.6261	0	-0.1148	-3.1601	0.0016	0.0221	0.478	0.6327
Troax Group AB-Wi	0.7279	28.7204	0	0.3978	9.9076	0	-0.172	-3.3641	0.0008
Vbg B	0.6981	18.3145	0	0.5311	8.7975	0	-0.2268	-2.9494	0.0032
Vitrolife AB	0.8565	19.7022	0	0.4821	7.0007	0	-0.3476	-3.9625	0.0001
Volvo B	1.1046	46.9913	0	-0.1724	-4.6312	0	0.0707	1.4915	0.1358
Wallenstam B	0.894	43.7449	0	0.1189	3.672	0.0002	-0.013	-0.3142	0.7533
Wihlborgs Fastigheter	0.869	40.1326	0	0.1682	4.9045	0	-0.0372	-0.8503	0.3952
Xano Industri B	0.6485	11.9697	0	0.5642	6.5751	0	-0.2111	-1.9313	0.0534
Åf AB	0.877	28.5214	0	0.2941	6.0375	0	-0.1696	-2.7336	0.0063
Åhuskarlshamn AB	0.8042	32.8814	0	0.2599	6.7099	0	-0.0674	-1.3651	0.1722
Öresund	0.803	31.8007	0	0.3749	9.3718	0	-0.1788	-3.5087	0.0005

Note: T-statistics (t-stat) are calculated using the standard OLS errors. The t-statistics are high for all of the MKT estimates, this is due to stock price being highly dependent on the general market movements.

Table 20: Betas and estimation statistics for **SPP Swedish Equity Fund**

	SPP Fund 2015								
Company name	β_{MKT}	t-stat	p-value	β_{SMB}	t-stat	p-value	β_{HML}	t-stat	p-value
Hennes & Mauritz AB B	1.0406	54.3286	0	0.1372	4.5217	0	-0.1809	-4.6816	0
Nordea Bank AB	1.0337	54.0444	0	-0.1318	-4.35	0	0.0981	2.5405	0
LM Ericsson Telephone Co B	0.8512	29.5986	0	-0.3441	-7.5551	0	0.4927	8.4916	0
Atlas Copco AB A	1.1929	57.1541	0	-0.1322	-3.9977	0.0001	-0.0614	-1.4582	0.0001
Swedbank AB A	0.954	48.6216	0	-0.1995	-6.4177	0	0.2455	6.2006	0
Investor AB B	1.0277	75.8565	0	-0.0717	-3.343	0.0008	0.0456	1.6691	0.0008
Svenska Handelsbanken A	1.0106	53.1295	0	-0.0501	-1.6612	0.0967	0.039	1.0149	0.0967
Assa Abloy AB B	1.0332	51.1111	0	-0.0293	-0.9139	0.3608	-0.0044	-0.1083	0.3608
Skandinaviska Enskilda Banken AB A	1.0331	51.4081	0	-0.1319	-4.1437	0	0.0982	2.4218	0
Svenska Cellulosa AB B	0.8534	36.9512	0	-0.1236	-3.3798	0.0007	0.2708	5.8102	0.0007
Volvo AB B	1.1055	46.4944	0	-0.1786	-4.7421	0	0.0761	1.5852	0
AstraZeneca PLC	0.6336	25.2499	0	0.1415	3.5605	0.0004	0.2257	4.4562	0.0004
ABB Ltd	0.7924	41.4425	0	0.0632	2.087	0.0369	0.145	3.7581	0.0369
Hexagon AB B	1.0879	41.2567	0	-0.1073	-2.5682	0.0102	0.0187	0.3508	0.0102
Sandvik AB	1.1784	49.3175	0	-0.1273	-3.3643	0.0008	-0.0529	-1.0977	0.0008
Autoliv Inc DR	0.8428	35.0777	0	0.1393	3.6597	0.0003	0.016	0.3301	0.0003
Skanska AB B	0.9836	50.3915	0	-0.0018	-0.0596	0.9525	0.0203	0.516	0.9525
Kinnevik AB B	0.9432	34.4429	0	-0.2577	-5.9411	0	0.3165	5.7282	0
Industrivarden AB C	1.0363	63.0051	0	-0.0222	-0.8534	0.3934	-0.0118	-0.3551	0.3934
Tele2 AB B	0.8274	27.7093	0	-0.019	-0.4015	0.688	0.1914	3.1772	0.688
Electrolux AB B	1.0595	33.8622	0	-0.0681	-1.3735	0.1696	0.0093	0.1478	0.1696
SKF AB B	1.0881	44.9858	0	-0.1486	-3.8785	0.0001	0.0571	1.1704	0.0001
Alfa Laval AB	1.0786	47.6712	0	-0.0732	-2.0415	0.0412	-0.0048	-0.1044	0.0412
Getinge AB B	0.9023	30.0411	0	0.0927	1.9477	0.0515	0.0051	0.0835	0.0515
Securitas AB B	0.946	38.9706	0	0.0273	0.7098	0.4778	0.0259	0.5283	0.4778
Trelleborg AB B	1.0875	47.4989	0	-0.1151	-3.175	0.0015	0.0274	0.5927	0.0015
Fingerprint Cards AB B	1.487	14.2098	0	1.5646	9.4394	0	-2.0371	-9.6476	0
Millicom International Cellular SA DR	0.863	28.206	0	0.1717	3.5431	0.0004	-0.0355	-0.5745	0.0004
Castellum AB	0.8238	42.8959	0	0.1007	3.3108	0.0009	0.0753	1.9444	0.0009
Boliden AB	1.1818	35.5805	0	-0.3251	-6.1785	0	0.15	2.2382	0
Meda AB A	0.6766	13.5005	0	0.313	3.9433	0.0001	0.0077	0.0761	0.0001
Unibet Group PLC	0.7264	25.172	0	0.2811	6.1501	0	-0.0102	-0.1752	0
Lundin Petroleum AB	0.9967	28.4001	0	-0.0378	-0.6799	0.4966	0.0428	0.6047	0.4966
BillerudKorsnas AB	0.9896	35.9646	0	-0.0283	-0.6493	0.5162	0.0371	0.6676	0.5162
AAK AB	0.8075	32.8533	0	0.2626	6.7462	0	-0.0734	-1.4793	0
Elekta AB B	0.7617	20.5622	0	0.1283	2.1873	0.0287	0.1076	1.4398	0.0287
NCC AB B	0.9888	42.0969	0	0.0111	0.2991	0.7648	0.0005	0.0102	0.7648
Intrum Justitia AB	0.825	30.0299	0	0.0642	1.4762	0.1399	0.1074	1.9365	0.1399
Hexpol AB B	0.9736	29.672	0	0.0864	1.663	0.0963	-0.0622	-0.9399	0.0963
NIBE Industrier AB B	1.0206	35.0069	0	0.1396	3.0227	0.0025	-0.161	-2.7362	0.0025
Husqvarna AB B	1.0206	37.5782	0	-0.0736	-1.71	0.0873	0.0532	0.9705	0.0873
Fabege AB	0.8784	39.8128	0	0.1267	3.6259	0.0003	-0.0008	-0.0189	0.0003
L E Lundbergforetagen AB B	0.9368	57.3727	0	0.1171	4.5281	0	-0.0531	-1.6127	0
Hufvudstaden AB A	0.8286	43.6052	0	0.1601	5.32	0	0.0148	0.3863	0
Swedish Orphan Biovitrum AB	0.9281	19.886	0	0.3553	4.8057	0	-0.2854	-3.0311	0
J M AB	1.0471	36.5101	0	0.0942	2.0731	0.0382	-0.144	-2.4885	0.0382
Holmen AB B	0.8142	40.3147	0	0.0405	1.2647	0.206	0.1459	3.58	0.206
Betsson AB B	0.8819	22.5796	0	0.2415	3.9033	0.0001	-0.1235	-1.5665	0.0001
Wallenstam AB B	0.894	43.5046	0	0.119	3.6556	0.0003	-0.0131	-0.3148	0.0003
Wihlborgs Fastigheter AB	0.8664	39.2468	0	0.1736	4.9635	0	-0.0399	-0.895	0
NetEnt AB B	1.0105	25.1839	0	0.3015	4.7444	0	-0.3123	-3.8571	0
Modern Times Group MTG AB B	1.0445	32.8489	0	0.0121	0.2412	0.8094	-0.0568	-0.8859	0.8094
Fastighets AB Balder B	0.9562	35.2469	0	0.2181	5.0769	0	-0.1734	-3.1677	0
Hemfosa Fastigheter AB	0.9593	41.4364	0	0.2066	5.6343	0	-0.1642	-3.5156	0
Ratos AB B	0.9939	37.165	0	0.0035	0.083	0.9338	0.0079	0.1471	0.9338
Kungsleden AB	0.8874	27.655	0	0.1171	2.3036	0.0212	-0.0036	-0.0552	0.0212
Cloetta AB B	0.6772	19.9107	0	0.3819	7.0884	0	-0.0606	-0.8832	0
Stora Enso Oyj R	0.9949	33.1091	0	-0.1996	-4.1943	0	0.2018	3.3281	0
SSAB AB B	1.2171	28.604	0	-0.1656	-2.4565	0.014	-0.0515	-0.6001	0.014
Nokia Oyj	0.8583	16.5204	0	-0.3137	-3.8125	0.0001	0.4548	4.338	0.0001
Mekonomen AB	0.8321	27.5566	0	0.3257	6.8099	0	-0.1559	-2.558	0
Kambi Group PLC B	0.8956	21.9663	0	0.679	10.513	0	-0.5804	-7.0547	0
Lundin Mining Corp DR	1.1644	25.2494	0	-0.1807	-2.4737	0.0134	0.0201	0.2158	0.0134
Atrium Ljungberg AB B	0.733	27.7971	0	0.2561	6.1324	0	0.0122	0.2294	0
Saab AB B	0.8921	29.1786	0	0.1107	2.2854	0.0223	0.0005	0.0085	0.0223
Tethys Oil AB	0.8846	21.045	0	0.2715	4.0785	0	-0.1514	-1.7849	0

Loomis AB B	0.8026	25.2295	0	0.1858	3.6878	0.0002	0.0103	0.161	0.0002
Rezidor Hotel Group AB	0.9292	23.3223	0	0.1724	2.7311	0.0063	-0.1015	-1.2629	0.0063
Pandox AB B	0.866	54.8211	0	0.3538	14.1374	0	-0.2477	-7.7693	0
Haldex AB	1.1217	26.9661	0	-0.0611	-0.9279	0.3535	-0.0593	-0.7068	0.3535
Etrion Corp	0.6513	4.8069	0	0.5772	2.6892	0.0072	-0.2365	-0.8651	0.0072
AB Sagax B	0.8547	24.6383	0	0.2851	5.1878	0	-0.1328	-1.897	0

Note: T-statistics (t-stat) are calculated using the standard OLS errors. The t-statistics are high for all of the MKT estimates, this is due to stock price being highly dependent on the general market movements.

References

Mats Andersson, Patrick Bolton, and Frédéric Samama. Hedging Climate Risk. *Financial Analysts Journal*, 72(3), 2016.

Andra AP-Fonden. Andra AP-Fonden, 2015. URL `http://www.ap2.se/en/`.

AQR Capital Management LLC. AQR-Alternative Investments. URL `https://www.aqr.com/library/data-sets/the-devil-in-hmls-details-factors-daily`.

Louis K C Chan, Jason Karceski, and Josef Lakonishok. On portfolio optimization: Forecasting covariances and choosing the risk model. *Review of Financial Studies*, 1999. ISSN 08939454. doi: 10.1093/rfs/12.5.937.

Francisco Climent and Pilar Soriano. Green and Good? The Investment Performance of US Environmental Mutual Funds. *Journal of Business Ethics*, 2011. ISSN 01674544. doi: 10.1007/s10551-011-0865-2.

Eugene F Fama and Kenneth R French. The Cross-Section of Expected Stock Returns. (2), 1992.

Gbenga Ibikunle and Tom Steffen. European Green Mutual Fund Performance: A Comparative Analysis with their Conventional and Black Peers. *Journal of Business Ethics*, 2015. doi: 10.1007/s10551-015-2850-7.

Morningstar. Norman-belopp visar 10-årskostnad, 2012. URL `http://www.morningstar.se/Article.aspx?title=norman-belopp-fonder-kostnad-10-ar`.

MSCI inc. GICS Sector definitions, 2016. URL `https://www.msci.com/documents/10199/4547797/GICS+Sector+definitions-Sep+2016.pdf/7e5236a8-2ddd-4e29-a8bf-18f394c7f0fb`.

PRI Association. Principles for Responsible Investment. Technical report, PRI Association, London, 2016. URL `https://www.unpri.org/about`.

Regeringskansliet. Hållbar finansmarknad, 2016. URL `http://www.regeringen.se/artiklar/2016/12/hallbar-finansmarknad/`.

Hans Sandberg, Rune Lagneborg, Birgitta Lindblad, Helén Axelsson, and Lars Bentell. CO 2 emissions of the Swedish steel industry. *Scandinavian Journal of Metallurgy*, 30:420–425, 2001. ISSN 0371-0459.

Second Swedish national Pension Fund. Hållbarhets och Ägarstyrningsrapport 2015. Technical report, Andra AP Fonden, Göteborg, 2015.

William F Sharpe. Mutual Fund Performance. *The Journal of Business*, 39(2):119–138, 1966. URL http://www.jstor.org/stable/2351741.

Swedish Investment Fund Association. The Swedish fund industry agrees on carbon reporting for funds, 2016. URL http://fondbolagen.se/en/Press/Press-releases/2016/The-Swedish-fund-industry-agrees-on-carbon-reporting-for-funds/.

SweSif. SPP Aktiefond Sverige. Technical report, Sveriges Forum för Hå¨llbara Investeringar, Stockholml, 2017a. URL http://www.hallbarhetsprofilen.se/fund.html?isin=SE0000529992.

SweSif. XACT OMXSB -Utd. Technical report, Sveriges Forum för Hållbara Investeringar, Stockholm, 2017b. URL http://www.hallbarhetsprofilen.se/fund.html?isin=SE0001056045.

The European Commission. The Paris Protocol. Technical report, The European Comission, Brussels, 2015. URL https://ec.europa.eu/clima/sites/clima/files/international/paris_protocol/docs/com_2015_81_en.pdf.

Thomson Reuters. Thomson Reuters ESG Carbon Data and Estimate Models. Technical report, Thomson Reuters, 2017. URL http://financial.thomsonreuters.com/en/products/data-analytics/company-data/esg-research-data.html.

World Business Council for Sustainable Development and World Resources Institute. The Greenhouse Gas Protocol, 2001.