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Analysis

Are pension funds actively decarbonizing their portfolios?☆

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ABSTRACT

We study whether investors are actively decarbonizing their portfolios. With the adoption of the Paris Agreement in December 2015, a better understanding of portfolio related carbon dioxide (CO_2) exposures has become increasingly important for investors, regulators and society at large. Carbon-intensive stocks still carry a substantial weight in common market benchmarks. We analyze if investors are actively divesting by deviating from market benchmark allocations to reduce carbon exposures. We utilize a stock-level holdings dataset of Dutch pension funds over the period 2009–2017 and combine this with firm-level CO_2 emissions information to measure the portfolio carbon footprint and active portfolio management. We find that pension funds that deviate from market benchmark weights have substantially lower carbon footprints. This effect is mostly driven by reduced exposures to carbon-intensive industries and is larger for pension funds that measure and report their carbon footprints. We find no evidence that deviations from the market benchmark impair risk-adjusted portfolio performance.

1. Introduction

In December 2015 world leaders signed the Paris Agreement on Climate Change and thereby committed themselves to significantly reduce carbon dioxide (CO_2) emissions. Divestment campaigns urge investors to completely divest from fossil fuel firms (Ayling and Gunningham, 2017) and more generally to reduce the carbon footprint associated with their portfolios (Fabian, 2015). Carbon-intensive investments are subject to environmental and regulatory risks, which have become more pertinent to investors and to the stability of the financial system (Battiston et al., 2017). These risks include the risk of stranded assets and long-term tail risks associated with catastrophic events related to climate change (Andersson et al., 2016; Dafermos et al., 2018; Griffin et al., 2015; Hong et al., 2016). In addition, institutional investors are subject to more public scrutiny regarding the environmental impact of their investments. In response, socially responsible investment has gained momentum among institutional investors, making them a powerful force in shaping responsible company behavior (Cox et al., 2008; Dyck et al., 2018; McCahery et al., 2016; Sievanen et al., 2013).

To aid decarbonization many investors started to measure and publicly disclose the carbon footprint associated with their stock portfolios.[1] Investors can reduce their carbon footprint in two ways: passively, when firms in their portfolio successfully decrease their carbon emissions, and actively by divesting from carbon-intensive stocks. Passive investors tracking a market benchmark obtain a substantial exposure to carbon-intensive stocks, because these stocks still retain a significant share in common market benchmarks. For example, in 2015, the MSCI All Country World Index (MSCI ACWI) contained 127 stocks of firms that own oil, gas and coal reserves, representing about 8% of its market capitalization (MSCI, 2015). Active investors could reduce their carbon footprint further by deviating from the market benchmark, i.e. active decarbonization. For instance, a straightforward way to actively decarbonize is to underweight the most carbon-intensive industries compared to the market benchmark. Alternatively, investors could screen out the most carbon-intensive firms within each industry, keeping well-diversified portfolios in terms of overall industry exposures. The latter would further spur competition among firms within

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[1] In recent years, numerous institutional investors have joined a range of initiatives that aim to reduce investors' carbon footprints including the Carbon Tracker Initiative, the Climate Disclosure Standard Board (CDSB), the Montréal Carbon Pledge, the Portfolio Decarbonization Coalition (PDC) and the United Nations Principles for Responsible Investment (PRI).

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an industry to reduce their carbon footprint (Andersson et al., 2016).

The effect of active decarbonization on portfolio performance is *a priori* unclear. Modern portfolio theory might make investors reluctant to decarbonize, because it predicts that any deviations from the market portfolio would make a portfolio less efficient, resulting in lower risk-adjusted returns (Bauer et al., 2005; Markowitz, 1952; Scholtens, 2006). Moreover, if a sufficient number of investors would divest, this would lead to relative overpricing of non-carbon-intensive stocks, further decreasing risk-adjusted performance of the divested portfolio (Dam and Scholtens, 2015; Fama and French, 2007).[2]

By contrast, a recent literature shows that deviations from the market portfolio could also improve portfolio performance. This literature highlights that the most actively managed portfolios tend to outperform well-diversified portfolios (Cremers and Petajisto, 2009; Cremers et al., 2016; Cremers and Pareek, 2016; Petajisto, 2013). Investors placing active bets on more concentrated portfolios realize excess risk-adjusted returns (Choi et al., 2017; Schumacher, 2017). Informational advantages among investors may well explain how divergences from traditional asset pricing theory could lead to better portfolio performance. It is optimal for portfolios to be under-diversified if investors acquire an informational advantage about certain firms or industries and select stocks accordingly (Van Nieuwerburgh and Veldkamp, 2009). In addition, if investors can concentrate on a smaller number of stocks or industries it allows them to better assess and monitor environmental and financial performance. This might make active ownership more cost-effective (Dimson et al., 2015; Schoenmaker and Schramade, 2019), such that active ownership and active portfolio management become self-reinforcing.

To study active decarbonization, we focus on the Dutch pension fund sector, which had over 1.4 trillion euros under management at the end of 2017. Pension funds as shareholders are co-owners of the carbon emissions firms create, so we focus on pension funds' stock portfolios.[3] Pension funds provide a relevant sample to test the relationship between carbon footprint and active portfolio management, because they are subject to considerable divestment pressure from stakeholders, even though they only aim to outperform market benchmarks to a limited extent (Aglietta et al., 2012; Blake et al., 1999). Especially in the Netherlands, pension funds have been strong-armed by participants to invest responsibly and in particular to divest from carbon-intensive firms. Many pension funds have accordingly adopted decarbonization goals and have started to compute and disclose their stock portfolio's carbon footprint. This context provides us with a unique testing ground to analyze whether the relationship between decarbonization and active portfolio management is more pronounced for investors that measure and report their carbon footprint.

We conduct our analyses using a large set of stock-level holdings data of Dutch pension funds for the period 2009Q1–2017Q4, which we match with firm-level data on CO_2 emissions of 5469 firms. Following Andersson et al. (2016), we aggregate firm-level CO_2 emissions from the individual stock holdings data to the pension fund portfolio level to create a measure of portfolio carbon footprint. We further combine this with supervisory data on pension fund characteristics, covering 44 pension funds. To assess deviations from the market benchmark, our main measure is active share (Cremers and Petajisto, 2009; Petajisto, 2013), which gauges the sum of absolute deviations of portfolio weights from market benchmark weights to capture active portfolio management.

We perform four analyses. First, we investigate the relationship between active share and carbon footprint. Second, we analyze whether active share's between- or within-industry variation is driving decarbonization to test if carbon footprint reductions stem from industry divestments or screening of carbon-intensive firms within industries. Third, we test to what extent measuring and disclosing carbon footprints is related to active portfolio management and carbon footprint. Finally, we analyze how deviations from the market benchmark and reductions in carbon footprints affect risk-adjusted performance.

Our results show that pension funds with a higher active share have a significantly lower carbon footprint in almost every year in our sample, even though the carbon footprints of pension fund portfolios are generally decreasing over time. Our main regression analyses confirm this: First, active share is negatively related to pension funds' carbon footprint. This effect appears to be mostly driven by the between- instead of the within-industry variation of active share: Underweighting carbon-intensive industries appears to be mostly responsible for reductions in carbon footprints, as opposed to a strategy of divesting from the most carbon-intensive firms within industries. Second, the negative relationship between active share and carbon footprint is more pronounced for pension funds that have started to measure and report their carbon footprint. Finally, the performance analyses yield no evidence of out- or underperformance of portfolios sorted on active share and carbon footprint, which is consistent with Trinks et al. (2018) who find that fossil fuel divestment from benchmark indexes does not impair risk-adjusted performance.[4]

We make two contributions. First, we contribute to the literature on carbon risks and active portfolio management. This relatively scant body of research measures portfolio carbon footprint and shows for stocks (Andersson et al., 2016) and bonds (de Jong and Nguyen, 2016) how investors could optimally reduce carbon footprint while staying close to a market benchmark. As opposed to these optimal strategies, we contribute by investigating to what extent investors actually execute these optimal strategies. Second, we contribute to a small but growing literature on institutional investors and corporate social responsibility (CSR). This literature has focused mainly on the effect of active ownership on firms' CSR performance (e.g. Dimson et al., 2015; Dyck et al., 2018), whereas we focus on the effect of active portfolio management on investors' CSR performance. Duuren et al. (2015) show that many conventional managers also integrate CSR in their investment process in particular for red flagging and managing risks. We contribute by investigating CSR performance as an alternative outcome of the investment process and evaluate the extent to which investors alter their portfolios to improve their performance on the environmental dimension.

This paper is organized as follows: Section 2 explains how carbon exposures and active management are measured and introduces our estimation models. Section 3 presents the security-by-security holdings data, the firm-level data and the pension fund data. Section 4 provides the results. Finally, Section 5 concludes.

2. Method

2.1. Portfolio carbon footprint

We follow Andersson et al. (2016) and derive a carbon footprint measure in line with the one calculated by pension funds themselves (PGGM, 2016). We standardize firm CO_2 emissions using the firm's output and the weight of the firm in the pension fund portfolio. An adjustment for output is necessary to avoid a bias against the largest firms, and to measure pollution per unit of output, which more

[2] This general equilibrium effect could be small when there is not (yet) a sufficient mass of investors adopting the divestment approach (Ayling and Gunningham, 2017; Busch and Hoffmann, 2007; Trinks et al., 2018).

[3] In principle our approach could also be applied to pension funds' bond portfolios, like in de Jong and Nguyen (2016).

[4] We show how actual decarbonization of pension funds is related to performance. Related work on green investments has focused on the performance of green compared to conventional mutual funds using replicating portfolio techniques (e.g. Cortez et al., 2009; de Haan et al., 2012; Derwall et al., 2005; Galema et al., 2008; Ibikunle and Steffen, 2017; Rezec and Scholtens, 2017).

accurately indicates the most wasteful firms. We calculate a value-weighted average of output-adjusted CO_2 emissions to correct for the size of pension fund investments in different stocks.

Specifically, firm *j*'s carbon (in)efficiency $CI_{j,t}$ is defined as a ratio of CO_2 exposure in tonnes to sales at time *t*. The carbon footprint, $CFP_{i,t}$, of each pension fund *i* equals the value-weighted average of $CI_{j,t}$ in equity investments:

$$CFP_{i,t} = \sum_{j=1}^{n} w_{i,j,t} \times CI_{j,t}$$

where $w_{i,j,t}$ indicates pension fund *i*'s portfolio weight in stock *j* at time *t*. Thus, $CFP_{i,t}$ captures the weighted average of how many units of CO_2 are emitted per unit of sales for each euro invested by pension fund *i* at time *t*. Using this method, we obtain a consistent measure of $CFP_{i,t}$ across pension funds' stock portfolios. A key advantage of this measure is that it is a relative carbon efficiency measure and is thus neither affected by the size of the stock holdings of the pension fund nor by the coverage of stocks in our dataset.[5]

2.2. Active share and tracking error

We measure active portfolio management following Cremers and Petajisto (2009) and Petajisto (2013). They propose to use "Active share" which intuitively measures whether an investor deviates its portfolio weights from market benchmark weights. Active share measures the extent to which pension funds deviate from the market benchmark, thereby indicating the extent to which they actively manage their portfolios. Active share is calculated as follows:

$$\text{Active Share}_{i,t} = \frac{1}{2}\sum_{j=1}^{n} |w_{i,j,t} - w_{m,j,t}|$$

where $w_{i,j,t}$ and $w_{m,j,t}$ are the portfolio weights of stock *j* at time *t* in the pension fund portfolio and the market benchmark, respectively. The sum is taken over the universe of all stocks for which we have carbon footprint data. An active share of zero implies completely following the market benchmark (most passive investors), while an active share of 100% implies completely deviating from it (implying very active portfolio management). A similar approach can be taken at the industry level where the industry weight against the market benchmark is used to derive the industry active share. Active share thus captures mostly either stock selection or industry allocations.

Cremers and Petajisto (2009) and Petajisto (2013) also use tracking error to capture active portfolio management. Tracking error represents the volatility of the difference between a portfolio return and the return of the market benchmark. It is commonly defined as the standard deviation of the difference between the investor's portfolio return and the market benchmark return. This common definition effectively assumes a market beta of 1; any deviations from a beta of 1 will thus create tracking error. To prevent any persistent allocations to contribute to tracking error, we follow Cremers and Petajisto (2009) and obtain tracking error as follows[6]:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_i (R_{m,t} - R_{f,t}) + \epsilon_{i,t}$$
$$\text{Tracking error} = StDev[\epsilon_{i,t}]$$

where $R_{i,t}$ is pension fund *i*'s portfolio return, $R_{f,t}$ is the risk-free rate, α_i the excess return and $R_{m,t}$ the market benchmark return. Thus, tracking error measures whether portfolio returns deviate from those of the market benchmark.[7]

For both these measures we define the benchmark universe as all the worldwide stocks for which Thomson ASSET4 reports CO_2 emissions ($n = 5469$) and the market benchmark return $R_{m,t}$ is the value-weighted average return on these stocks. For comparison, the MSCI ACWI is based on 2400 stocks and is highly correlated with our market benchmark ($\rho = 0.96$). To illustrate, Fig. 1 graphs the cumulative returns of different market indexes, which shows that our market benchmark quite closely follows the MSCI ACWI.

For our purposes we focus mainly on active share, because this directly measures all deviations from the market benchmark. By contrast, with tracking error, the return of the market benchmark can still be replicated quite accurately even if portfolio weights deviate from those of the market benchmark, as Andersson et al. (2016) show in the context of decarbonization of stock portfolios.

2.3. Estimation methods

To explain the carbon footprint (CFP) of pension fund's *i* stock portfolio at time *t* the most extensive specification we estimate is:

$$CFP_{i,t} = \beta_0 + \beta_1 X_{i,t-1} + \beta_2 \textit{Year-quarter}_t + \beta_3 \textit{Pension fund}_i + \epsilon_{i,t} \quad (1)$$

where X_{it-1} includes our explanatory variables, which are lagged by one quarter to prevent simultaneity. $\textit{Year-quarter}_t$ indicates time fixed effects, which are estimated using dummy variables based on a quarterly date variable. $\textit{Pension fund}_i$ indicates pension fund fixed effects, for which we use a within estimator. We include time fixed effects in all estimations, because there is a clear time trend in the carbon footprint, and pension fund fixed effects in some estimations. Standard errors are clustered at the pension fund level throughout.

For our performance analyses we follow the procedure in Cremers and Petajisto (2009): We create equally weighted portfolios based on pension fund portfolios sorted on active management and carbon footprint. For each of these portfolios *p* we estimate a standard four-factor model (see Carhart, 1997).

$$R_{p,t} - R_{f,t} = \alpha_p + \beta_{p,1}(R_{m,t} - R_{f,t}) + \beta_{p,2} SMB_t + \beta_{p,3} HML_t + \beta_{p,4} MOM_t + \epsilon_{p,t} \quad (2)$$

where $R_{p,t} - R_{f,t}$ is the excess return on portfolio *p* and $R_{m,t} - R_{f,t}$ is the market risk premium, which is the return on a market portfolio in excess of the risk-free rate. SMB_t (Small minus Big) is the return on a portfolio long in small cap stocks and short in large cap stocks. The HML_t (High minus Low) factor measures the return differential between high and low book-to-market stocks. MOM_t (Momentum factor) represents the return on a portfolio long in stocks with the highest returns and short in those with the worst returns in the previous 12 months. Finally, α_p is the portfolio's abnormal return, which is our coefficient of interest.

3. Data

3.1. Sampling

We combine several data sources to obtain the carbon footprint of

[5] Overall, our $CFP_{i,t}$ measures for end-2017 are very similar to the ones disclosed by pension funds which use the same method to derive their carbon footprint. This high comparability further validates our measure and was based on *Pensioenfonds Zorg & Welzijn*, *Pensioenfonds Metaal & Techniek* and *Pensioenfonds van de Metalektro* which together had more than 300 billion euros under management and average reported *CFP* of 203 in 2017, against 209 on average across all pension funds in our sample for 2017.

[6] To ensure consistent estimates, monthly (instead of quarterly) portfolio regressions are applied using 12 months of past data for each pension fund and quarter. Note that this implies we cannot calculate tracking error for the first year (2009).

[7] The two measures of active portfolio management are related, but as shown by Cremers and Petajisto (2009), tracking error includes the covariance matrix of returns and therefore puts more weight on correlated active bets, whereas active share puts equal weight on all active bets regardless of diversification.

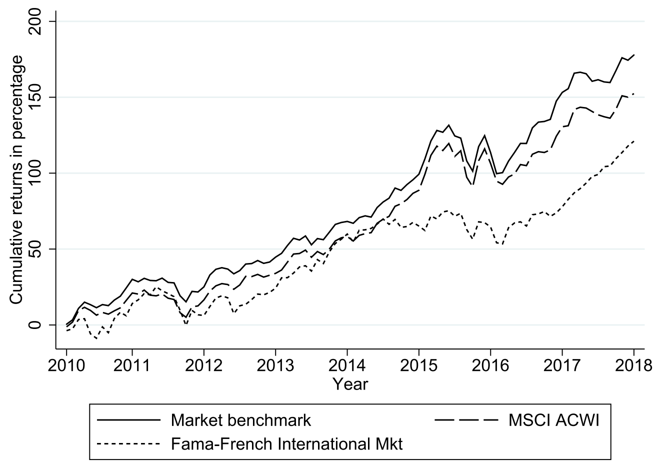

Fig. 1. Cumulative returns market benchmarks.

pension fund portfolios. First, we obtain information on pension funds' stock investments from a confidential dataset from the Dutch Central Bank (DNB). These data contain quarterly security-by-security portfolio investment positions in stocks of pension funds. In addition, we extract mutual funds' holdings for a number of pension funds that hold a substantial amount of fiduciary investment through specialized mutual funds that act on behalf of these pension funds. We use security-by-security stock holdings of 16 mutual funds and attribute these positions in proportion to the ownership shares of each pension fund in the particular mutual fund (i.e. a 'look through' approach). In practice nearly all the mutual funds' holdings are managed for these pension funds. In total, we have data on 44 pension funds with stock holdings in 6597 unique stocks for the period 2009Q1–2017Q4. These security-by-security stock holdings consist of 2,156,303 observations of pension funds' stock positions over time.

Second, the Thomson Reuters ASSET4 database provides quarterly CO_2 emission levels, CE_{jt} for 5469 firms j over the period 2009–2017. Thomson Reuters utilizes company reports to obtain data on CO_2 emissions, which are reported in line with the Greenhouse Gas Protocol, Kyoto Protocol or EU Trading Scheme, where the reported Greenhouse Gas Protocol score is the preferred measure.[8] If a firm does not report carbon emissions, Thomson Reuters estimates them using their Carbon Data & Estimate Model (Thomson Reuters, 2016). We link the firm-level CO_2 data to stock returns from Thomson Datastream and industry NACE classifications from the ECB Centralized Securities Database (CSDB). Finally, we obtain manually collected information on when pension funds start measuring and reporting their carbon footprint from pension funds' websites and annual reports.

We merge the granular data on stock holdings and firm level characteristics to the pension fund portfolio level. Next, we obtain pension fund characteristics from aggregate supervisory reports provided by DNB. The coverage of the merged security-by-security data included in our final analysis is high compared to the aggregated supervisory data: on average 82.4 %. To our knowledge, we are the first to use the security-by-security holdings data for Dutch pension funds. For more details on the supervisory data and the Dutch pension sector more generally, see de Dreu and Bikker (2012) and de Haan (2018).

[8] The CO_2 emissions include direct and indirect equivalents of emissions, i.e. Scope 1 and Scope 2. Our carbon footprint variable is based solely on data covering Scope 1 (direct emissions) and Scope 2 (indirect emissions resulting from the company's purchases of energy). Scope 3 emissions covering third-party emissions tied to firms' sales (suppliers and consumers) are not accounted for due to lack of data.

3.2. Variables

Table 1 provides summary statistics for all the pension fund-years for which we have carbon footprint data. Our dependent variable $CFP_{i,t}$ averages 272.1 tonnes CO_2 per million euro of sales. The average carbon footprint calculated for the market benchmark is 401.2 (see also Table 2 below), so Dutch pension funds perform relatively well on average. Still, there is much carbon footprint variation across pension funds (Std. Dev. = 78.8).

Considering our main explanatory variables related to active portfolio management, both active share with an average of 34.5% and tracking error with an average of 1.9% are relatively low. This is to be expected, given that pension funds tend to closely follow the market benchmark and typically refrain from stock picking and placing active bets (Aglietta et al., 2012; Blake et al., 1999). Compared to Cremers and Petajisto (2009) the average active share of Dutch pension funds is much lower than that of US all-equity mutual funds, which have a median active share between 60–70%, again suggesting that pension funds are less active investors than other asset managers. Still, there is substantial variation in both measures, indicating that some pension funds manage their stock portfolios more actively than their peers. The industry active share ($ActiveShareInd_{i,t}$) is calculated over maximum 15 industries. The average of 12.4% also indicates that pension funds' industry weights are typically quite close to the market benchmark's industry weights.

In further analyses we split the variation of active share in variables

Table 1
Summary statistics.

Variable	Mean	Std. dev.	p10	p90	N
CFP_{it}	272.11	78.75	183.04	377.47	1200
$ActiveShare_{it}$	34.54	9.34	21.29	46.34	1199
$TrackingError_{it}$	1.86	1.06	0.90	3.28	1023
$ActiveShareInd_{it}$	12.35	6.41	6.86	18.77	1200
$ActiveShareWithin_{it}$	34.43	10.84	21.36	47.68	1199
$ActiveShareBetween_{it}$	27.90	10.91	15.16	44.00	1199
$ExcessReturns_{it}$ in %	−0.55	2.18	−3.10	1.54	1199
Number of $stocks_{it}$, in thousands	1.21	0.93	0.15	2.49	1199
log $TotalAssets_{it}$	15.88	1.24	14.53	17.34	1163
$ShareEquity_{it}$ in %	30.42	7.62	20.69	40.00	1163
$FundRatio_{it}$	109.08	12.10	95.20	125.40	1175
$TotalReturn_{it}$	2.33	4.14	−2.70	7.30	1171
$IndustryWidePFDum_i$	0.60	0.49	0.00	1.00	1195
$FirstReportDum_{it}$	0.03	0.18	0.00	0.00	1200
$FirstMeasuredDum_{it}$	0.07	0.26	0.00	0.00	1200
PRI Dum_{it}	0.52	0.50	0.00	1.00	1200
2016-2017 Dum_t	0.25	0.43	0.00	1.00	1200

This table reports summary statistics for pension fund portfolios. Carbon footprint (CFP_{it}) is measured in terms of tonnes of CO_2 per million euros of sales. The variables $ActiveShare_{it}$ and $TrackingError_{it}$ measure active share and tracking error based on individual stock positions. $ActiveShareInd_{it}$ is based on pension funds' industry weights. $ActiveShareWithin_{it}$ and $ActiveShareBetween_{it}$ split up $ActiveShare_{it}$ in within- and between-industry variation. $ExcessReturns_{it}$ indicates the excess returns of the stock portfolio over the benchmark. Number of stocks in $thousands_{it}$ indicates the number of stocks in the portfolio. log $TotalAssets_{it}$ indicates the natural logarithm of total assets in the entire pension fund portfolio. $ShareEquity_{it}$ indicates the share of the entire pension fund portfolio allocated to equity. $FundRatio_{it}$ indicates the funding ratio, which measures the extent to which the pension fund is able to cover its future pension liabilities. $TotalReturn_{it}$ is the return on the pension fund's entire asset portfolio. $IndustryWidePFDum_i$ is an indicator variable equal to one when the pension fund is for an entire industry, as opposed to a single firm. $FirstMeasuredDum_{it}$ and $FirstReportDum_{it}$ are indicator variables that become one when a pension funds starts to measure and report, respectively, carbon footprint, and zero otherwise. PRI Dum_{it} is an indicator variable that becomes one when a pension fund signs the Principles for Responsible Investment and is zero otherwise. 2016–2017 Dum_t is a indicator variable equal to one for the years 2016 and 2017 and zero otherwise.

Table 2
Summary statistics: security-level carbon footprint by industry.

Industry	Mean	Std. dev.	p10	p90	N	n
B. Mining and quarrying	1742.77	2717.79	640.85	3421.91	2361	342
C. Manufacturing	263.69	32.79	230.81	306.00	11,130	1503
D. Electricity, gas, steam	3098.31	425.37	2339.44	3470.28	1314	177
E. Water supply; sewerage, waste management	642.34	105.74	602.57	725.01	232	32
F. Construction	302.22	123.57	217.76	402.50	1143	152
G. Wholesale and retail trade	68.95	13.84	48.37	87.26	2294	308
H. Transportation and storage	667.21	77.37	504.57	782.46	1349	181
I. Accommodation and food service activities	181.80	58.51	137.62	314.37	527	75
J. Information and communication	42.74	9.43	31.30	57.67	3063	465
K. Financial and insurance activities	17.21	4.23	13.16	26.80	5899	860
L. Real estate activities	130.21	19.90	103.07	157.85	1849	292
M. Professional, scientific and technical activities	304.66	69.33	212.73	395.67	5212	764
N. Administrative and support service activities	140.91	48.66	95.61	243.38	596	88
R. Arts, entertainment and recreation	46.66	7.80	35.76	53.10	252	37
Z. Other	405.74	153.86	169.12	607.48	1241	193
Total	401.17	936.14	17.00	644.41	38,462	5469

This table reports summary statistics of security-level carbon footprint for a panel dataset of all stocks in our sample (2009Q1–2017Q4), weighted by market value to total industry market value. Portfolio weights are rebalanced each quarter for each industry. Industries are classified according to NACE level 1. Industry Z. 'Other' is created and consists of the following industries with limited stock market presence: A. 'Agriculture, forestry and fishing', O. 'Public administration and defense; compulsory social security', P. 'Education', Q. 'Human health and social work activities' and S. 'Other service activities'. *N* indicates the number of observations, *n* indicates the number of stocks.

capturing its between- and within-industry variation: $\text{ActiveShareBetween}_{i,t}$ and $\text{ActiveShareWithin}_{i,t}$, respectively. The procedure is similar to deriving within and between estimators in panel data. We apply the same active share calculation as before, but we redefine the weights. First, we calculate for each pension fund-industry-time combination the average weight across stocks, for both the pension fund and the market benchmark. Next, we subtract these two average weights from the pension fund portfolio and market benchmark weights, respectively, to obtain $\text{ActiveShareWithin}_{i,t}$. $\text{ActiveShareBetween}_{i,t}$ is then based on just the difference between the average weights. Table 1 shows that $\text{ActiveShareWithin}_{i,t}$ is on average higher than $\text{ActiveShareBetween}_{i,t}$.

We also include measures that indicate whether pension funds are measuring and reporting their carbon footprint: $\text{FirstMeasuredDum}_{i,t}$ and $\text{FirstReportDum}_{i,t}$, respectively. $\text{FirstMeasuredDum}_{i,t}$ is defined as an indicator variable equal to one starting in the quarter when a pension fund publicly discloses that it starts measuring its carbon footprint (internally), as reported on their website or in their annual report, and zero before that. Likewise, $\text{FirstReportDum}_{i,t}$ is defined as an indicator variable equal to one starting in the quarter-end of the year when pension funds start externally reporting carbon emissions, typically in their annual report. The averages of these variables are low, reflecting the fact that most pension funds did not start (internally) measuring or externally reporting carbon emissions until 2016, if at all. By 2017, 23% of the pension funds disclosed the environmental performance related to their stock portfolio's carbon emissions. To check whether there is a general time effect, on top of the year-quarter time fixed effect, we also define the indicator variable 2016–2017Dum_t which equals one in 2016 and 2017 and zero otherwise. Finally, we want to check whether the measuring and reporting effect is a proxy for a more general preference for socially responsible investment, so we include an indicator variable equal to one in the quarter when a pension fund signed the Principles for Responsible Investment (PRI $\text{Dum}_{i,t}$) (see Hoepner and Schopohl, 2016; Woods and Urwin, 2010, on the relevance of the PRI for pension funds).

The following control variables are included (see Table 1). To account for differences in pension fund performance on their stock investments, the return over the market benchmark ($\text{ExcessReturns}_{i,t}$) is included. To capture the size of the equity portfolio and the size of the pension fund, the Number of $\text{stocks}_{i,t}$ and log Total $\text{Assets}_{i,t}$ respectively are included. Number of stocks averages about 1200, which suggests pension fund equity portfolios are very diversified. Pension funds differ in their overall allocation to stocks as captured by the $\text{ShareEquity}_{i,t}$, which is the percentage of the entire asset portfolio allocated to stock investments. To control for the pension fund's financial health, the funding ratio[9] ($\text{FundRatio}_{i,t}$) and the total return on the pension fund's asset portfolio ($\text{TotalReturn}_{i,t}$) are used. Finally, an indicator is included to capture if the pension fund acts on behalf of a range of firms within an industry ($\text{IndustryWidePFDum}_i = 1$) or is a company-specific pension fund ($\text{IndustryWidePFDum}_i = 0$).

4. Results

In this section, Subsection 4.1 provides a number of descriptive analyses to show (i) how carbon footprint varies across industries, (ii) how pension fund industry allocations differ from benchmark industry allocations, and (iii) how pension fund portfolio carbon footprints change across active portfolio management buckets. Next we turn to the regression results, where Subsection 4.2 provides our main results, Subsection 4.3 analyzes the role of measuring and reporting carbon footprints by pension funds, and Subsection 4.4 provides the results of our performance analyses.

4.1. Descriptive analyses

Table 2 shows how carbon footprints vary across industries based on only the security-level data from Thomson Reuters ASSET4. It presents summary statistics of security-level carbon footprint for a panel dataset of all 5469 stocks in our sample (2009Q1–2017Q4). These figures are weighted by the stock's market value against total industry market value. That is, we compute carbon footprint for different industry portfolios. Two stylized facts stand out. First, there is much variation in carbon footprints across industries with significant differences in the mean. Across industries, the highest carbon footprint scores are in the

[9] The funding ratio is defined as the market value of the assets over the market value of the liabilities, which is calculated as the present value of future pension benefits using the term structure of the risk-free market interest rate (like a swap rate) as discount factor (de Haan, 2018). In the Netherlands, the supervisor has regulatory powers to demand an investment recovery scheme of pension funds once they are underfunded, i.e. having a funding ratio of less than the minimum 105%. This limit is set by the supervisor and once it is breached, pension funds must ensure they take precautionary actions against underfunding as set out in their mandatory recovery scheme.

Table 3
Summary statistics: industry weights and active share.

	Market	Pension funds	Industry active share (%) < 10	10–14	14–18	≥18
B. Mining and quarrying	6.58	5.91	5.63	5.84	6.77	4.84
C. Manufacturing	33.46	28.76	31.07	28.52	26.62	24.17
D. Electricity, gas, steam	2.92	2.66	2.81	2.61	2.64	2.38
E. Water supply; sewerage, waste management	0.21	0.23	0.26	0.18	0.27	0.32
F. Construction	1.28	2.31	1.65	2.73	2.32	2.21
G. Wholesale and retail trade	5.62	4.73	5.21	4.71	4.15	4.19
H. Transportation and storage	2.35	1.91	2.10	1.85	1.78	1.77
I. Accommodation and food service activities	0.95	0.79	0.96	0.76	0.62	0.69
J. Information and communication	11.43	9.16	10.15	8.95	8.50	7.16
K. Financial and insurance activities	18.31	19.39	18.20	20.25	19.88	15.84
L. Real estate activities	1.67	7.63	5.59	8.40	9.05	7.05
M. Professional, scientific and technical activities	12.73	11.74	13.31	11.18	10.79	11.06
N. Administrative and support service activities	0.58	0.66	0.67	0.66	0.63	0.65
R. Arts, entertainment and recreation	0.59	0.43	0.37	0.48	0.41	0.38
Z. Other	1.32	3.70	2.03	2.88	5.58	17.29
Total	100.00	100.00	100.00	100.00	100.00	100.00

This table reports Industry weights. The column Market is based on the sum of stocks' market values over all stocks and time periods in the sample($\bar{w}_{m,j,t}$). The column Pension funds is based on the sum of investments over all pension funds, stocks and time periods in the sample ($\bar{w}_{i,j,t}$). The columns labeled Industry active share take the same sum as in the column Pension funds, but split according to four Industry active share buckets: < 10%, 10–14%, 14–18% and ≥18%. See Table 2 for details on industry definitions.

Table 4
Average pension fund carbon footprint by active management buckets.

Year	2010	2011	2012	2013	2014	2015	2016	2017	Total	'17–'10	P-value
Panel A: active share (%)											
< 25	347	324	295	275	271	235	224	214	253	−134	0.000
25–35	337	321	288	293	299	271	245	229	291	−108	0.000
35–45	300	286	280	270	263	231	231	203	261	−97	0.000
≥45	241	278	229	212	225	169	180	186	201	−55	0.020
Total	313	304	281	271	271	230	224	209	260	−104	0.000
High–Low	−106	−46	−66	−63	−47	−67	−44	−28	−52		
P-value	0.001	0.079	0.000	0.000	0.000	0.000	0.000	0.002	0.000		
Panel B: tracking error (%)											
< 1	303	311	295	295	296	264	239	221	262	−82	0.000
1–2	337	313	279	272	268	227	231	218	268	−120	0.000
2–3	303	289	293	285	272	231	215	175	262	−128	0.000
≥3	264	249	273	222	231	171	183	183	216	−81	0.001
Total	313	304	281	271	271	230	224	209	260	−104	0.000
High–Low	−38	−62	−22	−73	−64	−93	−56	−38	−45		
P-value	0.186	0.038	0.685	0.001	0.001	0.000	0.000	0.001	0.000		
Panel C: industry active share (%)											
< 10	391	329	295	283	286	254	240	222	269	−168	0.000
10–14	323	302	285	262	257	215	217	209	275	−114	0.000
14–18	270	288	248	257	246	208	208	197	232	−74	0.002
≥18	244	218	244	225	208	198	183	168	204	−76	0.000
Total	313	304	281	271	271	230	224	209	260	−104	0.000
High–Low	−147	−110	−51	−57	−77	−56	−58	−55	−65		
P-value	0.000	0.000	0.004	0.004	0.000	0.000	0.000	0.000	0.000		

This table reports average pension fund carbon footprint for different active share buckets (Panel A), tracking error buckets (Panel B) and industry active share buckets (Panel C) and years. High–Low indicates the difference in mean carbon footprint between the highest and lowest bucket of active share, tracking error and industry active share. This is calculated for each year and in total. P-value in the final row of each panel indicates a P-value of testing for a difference in mean between the highest and the lowest bucket. '17–'10 indicates the differences between 2017 and 2010, which is calculated for each active share, tracking error and industry active share bucket and in total. P-value in the final column indicates a P-value of testing for a difference in mean carbon footprint between 2017 and 2010.

'Electricity, gas and steam' and 'Mining and quarrying' industries. Second, there is considerable within-industry variation in carbon footprints with rather large standard deviations for several industries. For example, the top decile of carbon footprint for the overall sample (p90 = 644.41) is comparable to the lowest decile of carbon footprint (p10 = 640.85) within the 'Mining and quarrying' industry.

Next, to provide a first indication of the extent to which pension funds deviate their portfolio from the market benchmark, Table 3 provides overall portfolio industry weights within the market benchmark and for the pension funds' portfolios. The pension funds' industry weights are created by summing per industry all pension fund investments over time and taking a percentage of the total investments across all industries. The market weights are created for the same pension fund positions, but replacing investments with stocks' market values. Finally, in addition to overall industry weights, we also split the pension fund investments sample according to four industry active share buckets, where we follow the same procedure as for the total sample.

As Table 3 shows, the industry weights of the market benchmark and those of pension funds are relatively close. Manufacturing firms comprise about 33.5% of the market benchmark whereas pension funds

Table 5
Main results: pension fund portfolio carbon footprint and active management.

	(1)	(2)	(3)	(4)	(5)	(6)
$ActiveShare_{it}$	−1.4191***			0.2124	0.0875	−0.0927
	[0.415]			[0.366]	[0.290]	[0.537]
$TrackingError_{it}$		−16.5594***		−12.5423**	−7.6882	−1.8311
		[4.331]		[5.152]	[4.931]	[5.641]
$ActiveShareInd_{it}$			−3.0119***	−1.9411**	−3.1039***	−1.6514**
			[0.728]	[0.924]	[0.903]	[0.666]
$ExcessReturns_{it}$ in %				0.6096	0.3388	0.2690
				[1.144]	[0.935]	[0.693]
Number of stocks in $thousands_{it}$				0.8121	−4.3831	6.0080
				[5.267]	[7.934]	[5.742]
log $TotalAssets_{it}$					11.1878**	−28.7293
					[4.403]	[46.046]
$ShareEquity_{it}$ in %					−0.4983	−1.3564**
					[0.533]	[0.633]
$FundRatio_{it}$					−0.0776	−0.2819
					[0.364]	[0.690]
$TotalReturn_{it}$					0.7344	0.3219
					[0.683]	[0.468]
$IndustryWidePFDum_{i}$					−24.1891*	
					[12.993]	
Constant	319.4979***	291.9470***	307.5423***	299.1363***	170.6362**	847.7184
	[14.288]	[10.465]	[10.087]	[21.309]	[76.338]	[711.134]
Observations	1199	1023	1200	1023	992	992
Adjusted R^2	0.455	0.406	0.487	0.424	0.516	0.757
Number of pension funds	44	43	44	43	40	40
Pension fund fixed effects	No	No	No	No	No	Yes

This table reports main effects of estimating Eq. (1). All explanatory variables are lagged by one period and explained in the notes of Table 1. All estimations include year-quarter fixed effects. Standard errors are clustered at the pension fund level and are reported in parentheses.
*** Corresponds to the 1% level of significance.
** Corresponds to the 5% level of significance.
* Corresponds to the 10% level of significance.

invest about 28.8% in this industry. Of the two industries with the highest average carbon footprints, we find that market benchmark weights are 2.9% and 6.6% for 'Electricity, gas and steam' and 'Mining and quarrying' industries, respectively or 9.5% combined. Pension funds invest on average less in these carbon-intensive industries: 8.6% combined. The industry active share buckets show that pension funds with an industry active share larger than 18% (the highest bucket) have lower weights in these carbon-intensive industries than pension funds overall.

Industry deviations from the market benchmark weights appear relatively modest, but small weight changes could have large effects on the carbon footprint. For instance, Table 2 shows how divesting from a 90th percentile carbon footprint firm in the 'Mining and quarrying' industry and investing the proceeds in the 10th percentile firm from the 'Information and communication' industry would imply only a small change in industry weights, but a relatively large change in the carbon footprint. As shown by Andersson et al. (2016), it is possible to deviate only little from the market benchmark but still reduce the carbon footprint of the stock portfolio considerably, because carbon emissions are very asymmetrically distributed across firms (Koch and Bassen, 2013).

To further assess this, we evaluate to what extent pension fund carbon footprints vary with active portfolio management. Table 4, Panel A shows a tabulation of the average carbon footprint of the stock portfolio over time against four buckets of active share (< 25%; 25% ≤ to < 35%; 35% ≤ to < 45%; ≥ 45%). The results show that pension funds have, on average, significantly reduced their carbon footprint over time. The row Total displays a consistent reduction in pension funds' carbon footprint over the years, with the average carbon footprint declining significantly from 313 in 2010 to 209 in 2017, reflecting a difference of about 100 tonnes CO_2 per million euro of sales. The reduction is strongest in 2015 in absolute and relative terms, the year in which the Paris Agreement was reached.

Table 4, Panel A signifies that the average carbon footprint also consistently declined over time within a given active share bucket. However, the reduction in carbon footprints is the largest for the low active share bucket and the smallest for the high active share bucket. This likely reflects that pension funds with relatively little active portfolio management have benefited relatively the most from the general reduction of the carbon footprint of firms in the market benchmark (see e.g. Ibikunle and Steffen, 2017), whereas the pension funds that actively managed their stock investments already obtained a relatively low carbon footprint at the start of the sample. We consistently find that pension funds with a high active share have a significantly lower carbon footprint across all time periods, although this difference is decreasing over time. For example, in 2010 the difference between the carbon footprints of pension funds with high and low active portfolio management was 106, against a (significant) difference of 28 in 2017. In economic terms, even in 2017 this represents a difference in the carbon footprint of more than 13% between pension funds with a high and low active share. This suggests that pension funds that actively manage their stock portfolios are able to significantly reduce the carbon emissions associated with their portfolio investments.

Table 4, Panels B and C show a similar pattern: actively managed pension funds tend to have a lower carbon footprint also when analyzing buckets of tracking error and industry active share respectively instead of active share. The main difference is that for tracking error the difference in mean carbon footprint between the highest and lowest bucket is not significant in every year, although it is significant in most years and for the overall change between 2010–2017. Next, we proceed with an investigation of the determinants of carbon footprints in a more general multivariate case.

4.2. Carbon footprint and active portfolio management

Table 5 presents our main estimates. Column (1) shows that a higher active share is negatively related to the carbon footprint of the stock portfolios. This suggests that pension funds that deviate from the market benchmark, shift their portfolio to firms that emit less carbon per unit of sales. We find a similar negative and statistically significant effects for tracking error and industry active share in Columns(2) and (3). Compared to an average carbon footprint of 272.1, the estimated effect sizes are also economically significant: a one standard deviation increase in active portfolio management is associated with a decrease in the carbon footprint of about 13.3 for active share, 17.6 for tracking error and 19.3 for industry active share.[10]

Next, in Column (4) we add the three measures of active portfolio management together and we add portfolio control variables. We notice that active share becomes insignificant in this specification, but tracking error and industry active share remain significant. Next we also add pension fund control variables in Column (5) and we notice that also tracking error becomes insignificant. Industry active share remains significant in Column (5), also when we add pension fund fixed effects in Column (6). This suggests that the effect of active portfolio management is mostly driven by within pension funds' industry allocations, which we analyze further below.

In terms of our control variables, in Table 5, Column (5) shows no significant relationship between previous stock portfolio excess returns and the carbon footprint. This finding is consistent with literature that finds that portfolios of firms with better social, governance and environmental scores do not show significant differences in risk-adjusted excess returns (e.g. Bauer et al., 2005; Cortez et al., 2009; Galema et al., 2008). Similarly, there is no link between the number of stocks held in the portfolio and the carbon footprint. Our results suggest that larger pension funds in our sample tend to have a higher carbon footprint. Interpreting the effect size in terms of semi-elasticity, a doubling in pension fund size is associated with an increase in the carbon footprint of about 11, which is modest compared to an average carbon footprint of 272. This finding is in line with Hoepner and Schopohl (2016) who find a negative relationship between pension fund size and the probability of signing the Principles for Responsible Investment (PRI). The size effect is inconsistent with the more general notion that larger pension funds are more concerned about corporate responsibility (Scholtens, 2006) and are more capable to screen stocks on environmental dimensions due to the monitoring cost involved with active management (Kempf and Osthoff, 2008; Sievanen et al., 2013). The overall strategic asset allocation towards shares is negatively associated with the carbon footprint once we include pension fund fixed effects. This is consistent with results found by Thistlethwaite (2015). Prior financial health indicators like the funding ratio or the total returns do not appear to be related to the carbon footprint. Finally, pension funds linked to a single company tend to have a significantly lower carbon footprint than industry-wide pension funds, although this effect is only significant at 10%. One potential explanation is that participants of the company pension funds can more directly influence the investment goals of their company's pension fund than participants from industry-wide pension funds.

To further test how industry active share affects the carbon footprint, we split active share variation in between- and within industry variation. Table 6 shows the results of this exercise. The sign and significance of control variables is mostly similar to that in Table 5. What stands out is that in Columns (1) to (5) only $\text{ActiveShareBetween}_{i,t}$ is statistically significant, whereas $\text{ActiveShareWithin}_{i,t}$ is never significant. Only in our most restrictive specification when we include pension fund fixed effects in Column (6), does the effect of $\text{ActiveShareBetween}_{i,t}$ become statistically insignificant. Together these findings suggest that pension funds appear to lower their carbon footprint mostly by deviating from the market benchmark in terms of their industry weights, instead of active deviations by divestments from the most carbon-intensive stocks within industries.

4.3. The role of carbon footprint measurement and reporting

In this section we analyze how actively decarbonizing is connected to the measurement and reporting of carbon footprints by pension funds. This enables us to test whether the effect of active share is more pronounced for these pension funds. Because our findings suggest it is mostly industry active share that matters, we interact industry active share with indicator variables that become one when pension funds start measuring ($\text{FirstMeasuredDum}_{i,t}$) and reporting ($\text{FirstReportDum}_{i,t}$) their carbon footprint. We include pension fund fixed effects, time fixed effects and all control variables also included in Column (6) of Table 5 (not reported for the sake of brevity).

Column (1) of Table 7 shows that $\text{FirstReportDum}_{it}$ is negatively related to carbon footprint, but this effect is insignificant. In Column (2) the interaction between externally reporting the carbon footprint and industry active share is negative and significant. In economic terms, a one standard deviation increase in industry active share is associated with a decrease of the carbon footprint of 11.9 tonnes of CO_2 per million euros of sales on average, but for pension funds that also externally report their carbon footprint, active portfolio management is associated with a much larger drop in carbon footprint: 52.6 tonnes of CO_2 per million euros of sales on average.[11] In Column (2) the main effect of $\text{FirstReportDum}_{it}$ becomes significant and positive once we include the interaction. So an alternative interpretation would be that reporting is only associated with lower carbon footprint for pension funds whose industry active share is sufficiently high. In Columns (3) and (4) we find that the effects of starting to measure carbon emissions and its interaction with industry active share is similar to that of starting to report it.

To check the robustness of these results we perform two additional analyses. First, possibly some pension funds care more about socially responsible investment than others and therefore invest less in carbon-intensive industries. In that case our measurement and reporting dummies would simply pick up pension funds' social preferences. To test this we add in Column (5) an indicator variable that equals one starting in the quarter when a pension fund signs the Principles of Responsible Investment and zero before that. We add the interaction of this variable with industry active share in Column (6). We find that the indicator variable is significant in Column (5), suggesting socially responsible pension funds have a carbon footprint that is lower by 19.5 tonnes of CO_2 per million euros of sales. However, this effect is only significant at 10%. Its interaction with active share is insignificant, which suggests that responsible pension funds as a group are not deviating from the market portfolio more than others to reduce their carbon footprint.

Second, especially in the last couple of years there has been increased attention for carbon risk. To check whether our measurement and reporting dummies are picking up this trend, we add an indicator variable that is one for all pension funds in 2016 and 2017 and zero otherwise, while also keeping our general time fixed effects. We find a negative main effect of this 'recent period' variable in Columns (7) and (8), which is consistent with the negative trend in the carbon footprints identified earlier. However, the interaction of this variable with industry active share in Column (8) is statistically insignificant. This suggests that as a group pension funds have not started deviating from the market portfolio more to reduce their carbon footprint in the last two years of the sample.

[10] $-1.42 \times 9.34 = -13.3$, $-16.56 \times 1.06 = -17.6$ and $-3.01 \times 6.41 = -19.3$, respectively.

[11] $-1.86 \times 6.41 = -11.9$ and $11.9 + -6.34 \times 6.41 = -52.6$, respectively.

Table 6
Within- versus between-industry variation of active share.

	(1)	(2)	(3)	(4)	(5)	(6)
$ActiveShareWithin_{it}$	−0.0164		−0.0761	−0.0712	0.0381	−0.1518
	[0.422]		[0.420]	[0.432]	[0.386]	[0.434]
$ActiveShareBetween_{it}$		−1.6597***	−1.6626***	−1.7939*	−2.1267**	−0.9468
		[0.473]	[0.466]	[0.959]	[0.912]	[0.996]
$ExcessReturns_{it}$ in %				0.4660	0.1701	1.0193
				[1.338]	[1.413]	[1.373]
Number of stocks in $thousands_{it}$				−1.9239	−11.9255	6.0755
				[9.413]	[11.387]	[7.776]
log $TotalAssets_{it}$					11.3874**	−23.2998
					[4.940]	[46.699]
$ShareEquity_{it}$ in %					−0.5515	−1.1445*
					[0.677]	[0.667]
$FundRatio_{it}$					0.0486	−0.2577
					[0.354]	[0.795]
$TotalReturn_{it}$					1.1975	1.0396
					[0.886]	[0.770]
$IndustryWidePFDum_{i}$					−18.0138	
					[11.979]	
Constant	271.0489***	316.7979***	319.5002***	325.5780***	179.3388**	839.7266
	[15.781]	[14.171]	[15.181]	[36.804]	[79.922]	[684.468]
Observations	1199	1199	1199	1199	1153	1153
Adjusted R^2	0.424	0.478	0.477	0.477	0.537	0.717
Number of pension funds	44	44	44	44	41	41
Pension fund fixed effects	No	No	No	No	No	Yes

This table reports main effects of estimating Eq. (1). All explanatory variables are lagged by one period and explained in the notes of Table 1. All estimations include year-quarter fixed and pension fund fixed effects. Standard errors are clustered at the pension fund level and are reported in parentheses.

*** Corresponds to the 1% level of significance.

** Corresponds to the 5% level of significance.

* Corresponds to the 10% level of significance.

Table 7
The effect of measuring and reporting on pension fund portfolio carbon footprint.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$ActiveShareInd_{it}$	−2.8560***	−1.8624**	−2.9612**	−1.9376***	−2.8872**	−3.0892**	−2.9700**	−2.3927***
	[1.047]	[0.700]	[1.145]	[0.692]	[1.102]	[1.393]	[1.164]	[0.762]
$FirstReportDum_{it}$	−29.7070	47.7924**						
	[18.865]	[19.964]						
$FirstReportDum_{it}$ × $ActiveShareInd_{it}$		−6.3408***						
		[1.177]						
$FirstMeasuredDum_{it}$			−5.8633	56.2649***				
			[12.919]	[20.149]				
$FirstMeasuredDum_{it}$ × $ActiveShareInd_{it}$				−5.6930***				
				[1.648]				
PRI Dum_{it}					−19.5172*	−22.6634		
					[11.476]	[20.954]		
PRI Dum_{it} × $ActiveShareInd_{it}$						0.2801		
						[1.991]		
2016–2017 Dum_t							−136.8040***	−105.5188*
							[43.617]	[54.080]
2016–2017 Dum_t × $ActiveShareInd_{it}$								−1.7962
								[1.832]
Observations	1153	1153	1153	1153	1153	1153	1153	1153
Adjusted R^2	0.745	0.764	0.742	0.759	0.745	0.744	0.742	0.745
Number of pension funds	41	41	41	41	41	41	41	41

This table reports results of estimating Eq. (1). All explanatory variables are lagged by one period and explained in the notes of Table 1. All estimations include year-quarter fixed effects, pension fund fixed effects. In addition, estimation contain the following control variables whose coefficients are omitted for the sake of brevity: $ExcessReturns_{it}$, Number of $stocks_{it}$, log $TotalAssets_{it}$, $ShareEquity_{it}$, $FundRatio_{it}$ and $TotalReturn_{it}$. Standard errors are clustered at the pension fund level and are reported in parentheses.

*** Corresponds to the 1% level of significance.

** Corresponds to the 5% level of significance.

* Corresponds to the 10% level of significance.

4.4. Performance analyses

The final question we ask is whether pension fund performance is affected when pension funds actively manage their portfolio and have a lower carbon footprint. For that purpose we run monthly portfolio performance regressions. Comparable to the procedure followed by Cremers and Petajisto (2009), each quarter we sort pension funds' value-weighted equity portfolios into active share quartiles and then further into carbon footprint quartiles and average their returns. We do the same for tracking error quartiles and industry active share quartiles. Eq. (2) shows how we regress excess returns for each of the equally-weighted portfolios on the four-factor model of Carhart (1997). Because we have an international sample of stocks, we use the Fama-French global three factors augmented with the global momentum factor.[12]

An important consideration concerns the market benchmark. Fig. 1 shows that the international benchmark of Fama-French starts underperforming both the MSCI ACWI and our market benchmark, starting from mid-2014 onwards. So the Fama-French market factor seems less appropriate to evaluate the performance of the universe of stocks held by the pension funds in our sample. The MSCI ACWI is highly correlated with our market benchmark and only slightly underperforms it. To be conservative and to be consistent with our previous analyses, we use our market benchmark returns and subtract returns on the risk-free rate provided by Fama-French to generate our market risk factor.

Table 8 shows the results of the portfolio performance regressions. Regardless of whether we create buckets based on active share, tracking error or industry active share, there does not seem to be a pattern that indicates over- or underperformance depending on the buckets for active portfolio management and the carbon footprints. Given that Cremers and Petajisto (2009) find significant outperformance of higher active share quartiles compared to lower active share quartiles, this might be somewhat surprising. However, as noted previously, pension funds are on average relatively close to the market benchmark (i.e. the average active share is rather low). Apparently their deviations from the market benchmark are not sufficiently large to generate significant differences in risk-adjusted performance. Similarly, differences in carbon footprints are not related to differences in financial performance of the pension funds.

In results available upon request we also use the MSCI ACWI as market benchmark. In this case, the individually sorted portfolios tend to outperform, likely because the MSCI ACWI slightly underperforms the stocks in our sample. However, we detect no significant pattern based on active share and carbon footprint quartiles. This is also witnessed by the fact that none of the High-Low difference portfolios provide significant risk-adjusted returns, neither in terms of active share quartiles, nor in terms of carbon footprint quartiles. Overall these results are consistent with Andersson et al. (2016) and Trinks et al. (2018): Pension funds with high active share and a low carbon footprint do not suffer in terms of financial performance.

Table 8
Equally-weighted alphas for pension funds.

Carbon footprint quartiles	Low	2	3	High	All	High–Low
Panel A: active share quartiles						
High	0.33	1.09	0.17	0.13	0.43	−0.20
	(0.81)	(0.36)	(0.83)	(0.90)	(0.53)	(0.91)
3	−0.85	0.25	−0.11	0.32	−0.10	1.18
	(0.17)	(0.66)	(0.86)	(0.65)	(0.83)	(0.14)
2	−0.70	−0.64	−0.88	0.14	−0.52	0.85
	(0.07)	(0.19)	(0.09)	(0.76)	(0.14)	(0.06)
Low	−0.48	0.08	−0.32	−0.04	−0.19	0.44
	(0.38)	(0.86)	(0.48)	(0.92)	(0.65)	(0.25)
All	−0.42	0.19	−0.29	0.14	−0.09	0.56
	(0.41)	(0.70)	(0.53)	(0.78)	(0.82)	(0.36)
High–Low	0.81	1.01	0.48	0.17	0.62	
	(0.57)	(0.34)	(0.50)	(0.87)	(0.25)	
Panel B: tracking error quartiles						
High	0.49	0.83	−0.36	−0.77	0.05	−1.27
	(0.69)	(0.42)	(0.65)	(0.40)	(0.94)	(0.43)
3	−0.88	0.29	0.18	−0.05	−0.12	0.83
	(0.12)	(0.59)	(0.75)	(0.94)	(0.79)	(0.31)
2	−0.32	−0.52	−0.32	−0.15	−0.33	0.17
	(0.62)	(0.33)	(0.56)	(0.77)	(0.46)	(0.76)
Low	−0.37	−0.59	−0.13	0.14	−0.24	0.51
	(0.38)	(0.23)	(0.76)	(0.76)	(0.53)	(0.21)
All	−0.27	0.00	−0.16	−0.21	−0.16	0.06
	(0.59)	(0.99)	(0.72)	(0.67)	(0.70)	(0.91)
High–Low	0.86	1.42	−0.23	−0.91	0.28	
	(0.49)	(0.14)	(0.76)	(0.30)	(0.61)	
Panel C: industry active share quartiles						
High	−0.17	−0.34	−0.13	0.50	−0.03	0.67
	(0.89)	(0.67)	(0.84)	(0.63)	(0.95)	(0.70)
3	0.09	−0.80	−0.57	−0.12	−0.35	−0.21
	(0.91)	(0.27)	(0.34)	(0.86)	(0.51)	(0.79)
2	−0.46	−0.09	−0.14	−0.03	−0.18	0.43
	(0.27)	(0.85)	(0.74)	(0.96)	(0.62)	(0.48)
Low	−0.16	0.13	−0.02	−0.04	−0.02	0.12
	(0.79)	(0.81)	(0.97)	(0.92)	(0.96)	(0.81)
All	−0.18	−0.27	−0.21	0.08	−0.15	0.25
	(0.74)	(0.60)	(0.58)	(0.88)	(0.72)	(0.67)
High–Low	−0.01	−0.47	−0.11	0.55	−0.01	
	(1.00)	(0.48)	(0.84)	(0.57)	(0.98)	

This table reports annualized four-factor alphas based on Eq. (2) using monthly portfolio regressions. Pension funds are sorted based on their active share and subsequently within each active share quartile they are sorted on carbon footprint quartiles. Portfolios are rebalanced each quarter. The table shows annualized alphas in percentages, followed by p-values (in parentheses) based on White's standard errors. For each panel Active Share, Tracking error and Industry active share, the rows labeled High-Low indicate the performance differential between high and low quartiles, and rows labeled All indicate returns averaged over all quartiles of Active share, Tracking error and Industry active share. Similarly, the column High-Low indicates the performance differential between high and low carbon footprint quartiles and the column All indicates portfolios averaged over all carbon footprint quartiles.

5. Conclusion

In this paper we study whether more actively managed pension fund portfolios have a lower carbon footprint. We combine Dutch pension funds' security-by-security equity holdings—obtained from supervisory data—with securities' carbon levels, returns and measures of active portfolio management.

Pension funds are actively managing their stock portfolios to reduce their carbon footprint. We find that pension funds with a higher active share have lower carbon footprints. On top of this, actively managed pension funds that measure and report their carbon footprint accomplish greater reductions in their carbon emissions. This decarbonization effect appears to be mostly driven by divestments from firms in industries associated with high carbon emissions. For investors, divesting from certain industries appears to be an effective way to reduce carbon footprints.

We find no evidence of pension funds reducing their carbon footprint by divesting from the most carbon-intensive firms within each industry. As argued by Andersson et al. (2016), in the long-run a within-industry divestment strategy could support the transition towards a low-carbon economy because it creates more competition within industries. In addition, it could result in more diversified portfolios than divestment based on simple between-industry screening and exclusion of firms. We also find no evidence that pension fund variation in active shares and carbon footprints creates systematic differences in risk-adjusted performance. One possible explanation is that even pension funds with the highest active shares in our sample do not deviate from the market portfolio excessively such that these deviations are too small to affect risk-adjusted performance. Consistent with Trinks et al. (2018), we also find no variation in excess return performance when sorting stock portfolios by their carbon footprint. This suggests that active decarbonization does not impair investors' financial performance.

Conceptually, divesting from carbon-intensive industries is an

[12] See also http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/index.html.

important starting point, but this type of portfolio management may only have limited impact on the transition towards a low-carbon economy. If pension funds want to create global environmental impact to address climate change, they could benefit from having more concentrated portfolios that are more actively managed. A well-managed smaller portfolio could be obtained with minimal tracking error (Andersson et al., 2016). Smaller portfolios might enable better active ownership and monitoring of firms to ensure their contribution to the goals set forth in the Paris Agreement.

An important limitation facing both our research and investors attempting to reduce the carbon footprint of their portfolios is the quality and availability of carbon emissions data. Our carbon footprint variable is based solely on data covering Scope 1 (direct emissions) and Scope 2 (indirect emissions resulting from companies' energy purchases). Scope 3 emissions covering third-party emissions tied to firms' sales (suppliers and consumers) are not accounted for. Currently, these Scope 3 emissions are not systematically measured, even though they can represent a significant share of total emissions for some firms and industries. For instance, for car manufacturers we only take into account the carbon emissions of the car production process, whereas consumers driving the cars create a large share of the emissions currently not accounted for. There is a wider call to increase the transparency and quality of firm level CO_2 emissions (Gupta and Mason, 2016; Liesen et al., 2015; Thistlethwaite, 2015). Especially because climate change poses a risk to investors, it is not unimaginable that regulators at some point will mandate all publicly listed firms to measure and report their carbon emissions. As better emissions data become available, investors could more accurately decarbonize portfolios and future research could better track their progress. For now, the data currently at our disposal indicates that pension funds are actively decarbonizing their portfolios.

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