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Addressing climate challenges through ESG-real estate investment strategies: An asset allocation perspective

Massimo Biasin [1], Andrea Delle Foglie [*], Emanuela Giacomini [1]

Department of Economics and Law, University of Macerata, Via Crescimbeni 14, Macerata, Italy

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A B S T R A C T

Real estate plays a major role in environmental impact, contributing to nearly 39 % of global emissions and significantly influencing climate change. Using a sample of European REITs (Real Estate Investment Trusts) and real estate companies, this study examines the risk-adjusted performance of real estate investments concerning their ESG (Environmental, Social, and Governance) performance, comparing the diversification benefits of conventional versus ESG real estate investments, with a specific focus on the environmental (E) aspects. The portfolios' asset allocation is designed using the Mean-Variance and the Risk Parity models. Simulations are run using a rolling-window technique, covering the entire sample period along with three different subsamples. According to our findings, high ESG score real estate portfolios perform similarly to the overall sector, while portfolios with environmental scores above the sample average offer enhanced diversification benefits. This finding is particularly significant, as such portfolios have the potential to generate positive externalities by reducing climate impact through lower emissions.

1. Introduction

Investors are growing interested in assessing whether firms are attentive to Environmental, Social, and Governance (ESG) issues, each encompassing key aspects of corporate responsibility. The Environmental pillar focuses on a company's impact on the planet, including its carbon emissions, which are a primary driver of climate change, alongside other factors like waste management, energy use, and natural resource conservation. The Social pillar evaluates how a firm manages relationships with its employees, customers, and communities, emphasising labour practices, diversity, human rights, and customer satisfaction. Lastly, the Governance pillar examines the company's leadership, executive pay, audits, internal controls, and shareholder rights, ensuring ethical conduct and accountability.

The Environmental component of ESG is particularly crucial in climate change, where carbon emissions are a primary driver. The real estate industry contributes approximately 39 % of global emissions, with manufacturing processes accounting for 11 % and asset and property management accounting for 28 % (Boland et al., 2022). Furthermore, the buildings and construction sectors alone account for nearly 36 % of final energy use globally (IEA, 2019), underscoring the substantial environmental impact of this industry.

Therefore, implementing real estate ESG strategies and, in particular, controlling for the environmental (E) component of buildings

* Corresponding author.
E-mail address: a.dellefoglie1@unimc.it (A. Delle Foglie).

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by addressing greenhouse gas emissions and energy demand, can make a crucial impact and advance low-carbon emissions consistently with public policies aimed at mitigating climate change by imposing mandatory energy efficiency standards (Ferentinos et al., 2021). Environmental building practices could reduce global carbon dioxide levels by up to 10 % by 2050 compared to current levels (IEA, 2022).

Based on this premise, this paper analyses the diversification benefits of investing in ESG real estate indexes compared to conventional ones from a multi-asset portfolio management perspective, with a specific emphasis on environmental strategies. We use Refinitiv ESG Score measures as screening criteria to assess the company's ESG performance and construct a set of novel ESG real estate indexes. We specifically focus on the environmental component (E) of the ESG score because of its links to emissions and energy consumption since real estate is expected to have a significant influence in this area (Boland et al., 2022). We adopt two asset allocation strategies: mean-variance and risk-parity, to assess the out-of-sample performance of portfolios with and without ESG-screened real estate indexes. Specifically, we consider the risk parity model since allocating portfolio weights considering the risk contribution rather than relying solely on expected returns ensures that each asset has an equal impact on the overall risk. This approach, also widespread in the asset management industry, aligns well with ESG and climate challenges considerations because it prevents a single high-risk or non-ESG asset from dominating the portfolio's risk profile, especially during market downturns when ESG asset classes seem to overperform (Pavlova and de Boyrie, 2022; Broadstock et al., 2021).

The results show that during an extended out-of-sample period spanning eight years (2014–2022), ESG real estate investments, especially those with a high level of environmental performance, positively contribute to macro-asset allocation. These strategies demonstrate better or comparable portfolio performances compared to unconstrained approaches. Interestingly, when we narrow the analysis to more recent periods (2018–2022), we observe a notable rise in the significance of real estate assets with high ESG scores, primarily environmental indexes. These assets outperform traditional real estate in terms of both returns and risk. This finding is consistent with the growing popularity of ESG investing, which has made investors more aware of the potential benefits of ESG-screened investments.

The remainder of this article is organised as follows: Section 2 offers a comprehensive review of the literature and background context. Section 3 presents the data and methodology used in the study. Section 4 reports and discusses the results. The article concludes with Section 5, which provides a final discussion and conclusions.

2. Background and theoretical framework

According to the 2021 Benchmark ESG Survey, 82 % of institutional investors consider ESG performance highly important when making investment decisions. Consistently, most literature supports the idea that sustainability is an opportunity as it generates positive environmental and social impact effects alongside higher financial returns (see, among others, Velte, 2017; Friede et al., 2015).[2] Therefore, besides regulatory obligations and societal considerations, a positive impact on financial risk-return would facilitate the flow of funds and further support investors' growing interest in asset allocation decisions towards ESG-screened real estate.

Recent studies indicate that ESG integration in portfolio management cannot only hedge against climate change risk (Engle et al., 2020) but also outperform strategies like screening or divestment, providing asymmetric benefits and potentially capturing a climate risk premium (Atz et al., 2021). Adopting ESG strategies in asset allocation reduces carbon footprints and aligns with the Paris Agreement's goal to limit global temperature increases to below 2 °C (Jinga, 2021). Moreover, Pedersen et al. (2021) argue that institutional investors may incorporate sustainability issues into their asset allocation processes to meet the specific requirements of ESG-motivated investors. However, ESG strategies could reduce the financial outcomes, and the unconstrained frontier would strictly dominate the efficient frontier for investors who screen out poor ESG stocks. Institutional investors, recognising the financial implications of climate risks, prefer risk management and engagement over divestment (Krueger et al., 2020). Moreover, considering ESG criteria, sustainable investing can outperform during positive market shocks and contribute to positive social impact by greening firms and shifting investment towards green entities (Pástor et al., 2020). Conversely, Amon et al., (2021) analysed several asset allocation strategies based on ESG weighting and found no significant difference in the financial performance but superior ESG performance of ESG-based strategies.

Moreover, the recent regulatory interventions aim to limit the negative environmental impact of buildings by reducing emissions and energy use intensity[3]. These industry-specific regulatory interventions may indicate sector risk-specific characteristics (Bolton et al., 2021), resulting in lower price synchronicity (Grewal et al., 2021) and contributing positively to diversification. The idiosyncraticity of real estate in terms of environmental footprint could steer investment and rental demand towards "sustainable" properties to the detriment of less efficient ones, resulting in a positive and negative transition risk, respectively, affecting asset prices and returns.

[2] Sustainable companies are often associated with lower capital constraints (Amel-Zadeh and Serafeim, 2018) and lower costs of capital (Dhaliwal et al., 2011). This encourages more investments in responsible endeavours (Hartzmark and Sussman, 2019), where ESG scores provide valuable information on risk and expected returns (Pedersen et al., 2019). Furthermore, companies that focus on ESG principles have historically outperformed their counterparts that are less sensitive to sustainable factors (Ouchen, 2022). Building on this argument, Hartzmark and Sussman (2019) provide evidence that sustainability is viewed positively in the market, as reflected in consistent and positive fund inflows towards sustainable firms and investment funds dedicated to responsible endeavours. Similarly, Pedersen et al. (2021) argue that institutional investors may incorporate sustainability issues into their asset allocation processes to meet the specific requirements of ESG-motivated investors.

[3] The European Union's action plan on sustainable finance, along with the related Non-Financial Reporting Directive (NFRD), Energy Efficiency and Energy Performance of Buildings Directives, and the EU Green Deal masterplan.

In turn, a positive diversification contribution of ESG and, particularly, Environmental real estate from a portfolio perspective would align investor decisions and public policies.

REITs and real estate companies represent an important percentage of institutional investors' portfolios (Andonov et al., 2013) and play a crucial role in the asset allocation process since they offer investors a well-documented diversification benefit (see, among others, Lee and Stevenson, 2005; Chiang and Ming-Long, 2007). At the same time, REITs and real estate companies' stakeholders are showing an increasing interest in sustainable issues. In this context, sustainability refers to a company's capability to invest in real estate projects in alignment with ESG (Environmental, Social, and Governance) practices. When selecting and assessing real estate assets, it becomes essential to consider a range of environmental and social factors. These include energy consumption, water usage metrics, waste generation, greenhouse gas emissions, place-making strategies, tenant satisfaction, health and well-being, as well as the project's overall impact on the community. Furthermore, in the context of REITs, ESG performance encompasses corporate sustainability, indicating a holistic approach to ethical, responsible, and sustainable business operations (Kempeneer et al., 2021). A recent strand of the literature consistently reveals a significant positive association between real estate companies' performance and their ESG performance score. Notable research supporting this includes findings by Cajias et al. (2014), Eichholtz et al. (2012), Brounen et al., (2021), Brounen and Marcato (2018), and Feng and Wu (2021).

While existing research underscores the positive impact of robust ESG practices on the financial performance of real estate firms, there remains a notable gap in understanding the implications of ESG-based investing in the real estate sector, particularly from a portfolio allocation standpoint. This paper aims to bridge this gap by conducting a comparative analysis of the risk-adjusted performance between multi-asset portfolios that invest in conventional real estate indexes and those that allocate to European ESG-focused real estate indexes. Covering the period from January 2006 to September 2022, our study provides crucial insights into the effectiveness of ESG-oriented investment strategies within the real estate sector.

Our findings contribute to several strands of the literature. First, the paper contributes to understanding how sustainable ESG real estate indexes, particularly those focusing on environmental strategies, can offer diversification benefits compared to conventional indexes in a multi-asset portfolio context. Second, focusing on the environmental component of the ESG score, the paper addresses the specific impact of environmentally sustainable real estate factors like emissions and energy consumption. This contributes to the literature on the environmental impact of real estate investments and their role in sustainable investing. Third, using Refinitiv ESG Score measures to construct novel ESG real estate indexes it offers a methodological contribution to the field, providing a new tool for assessing the ESG performance of real estate companies. Fourth, the paper's exploration of mean-variance and risk-parity asset allocation strategies in the context of ESG-screened real estate indexes adds to the literature on risk management and asset allocation. Notably, applying the risk parity model aligns with current ESG and climate challenges, offering insights into portfolio risk management in sustainable investing. Lastly, observing the increasing significance and outperformance of real estate assets with high ESG scores, particularly in more recent periods (2018–2022), contributes to the literature on the evolving trends in ESG investing. This finding aligns with investors' growing awareness and popularity of ESG-compliant investments.

3. Research design

3.1. Data and sample

We start our analysis by considering an investor whose asset menu comprises the most traditional asset classes: large-cap equity (MSCI Europe Index and EURO STOXX 50), mid-cap equity (MSCI Europe Mid Cap Index), small-cap equity (MSCI Europe Small Cap Index), bonds (Markit iBoxx EUR Sovereigns Eurozone and Markit iBoxx EUR Corporate Index) and real estate (Table 1).[4] As for the real estate asset class, we use the FTSE/EPRA Developed Europe Index, a market capitalization-weighted free-float adjusted index consisting of Europe's most heavily traded real estate stocks.

Following the methodology detailed in Appendix A, we construct three ESG Real Estate indexes, incorporating ESG into the portfolio by including or excluding assets based on their ESG scores. Specifically, (i) RE-ESG includes all entities with available ESG scores in a given year; (ii) RE-ESG25excludes those entities with ESG scores below the 25th percentile in a given year; and (iii) RE-ESG50 includes entities with ESG score above the sample mean in a given year. To measure a firm's environmental, social and governance performance, we use the Refinitiv database. ESG scores from Refinitiv are designed to transparently and objectively measure a company's relative ESG performance, commitment and effectiveness based on company-reported data in the public domain across three pillars: Environmental, Social and Governance (Refinitiv, 2022).[5] Specifically, the ESG Score is an overall company score based on the self-reported information in the environmental (E), social (S) and corporate governance (G) pillars, and it ranges from a minimum of zero to a maximum of 100, with higher values indicating more robust performance in sustainability practices.[6]

Furthermore, we create two environmental indexes: (i) RE-Env25, which includes those entities with an "E" score above the 25th percentile in a given year; (ii) RE-Env50, which includes those entities with an "E" score above the sample mean in a given year. The

[4] We select the asset classes according to the European Fund Categorization Forum guidelines provided by the European Fund and Asset Management Association (EFAMA).

[5] The Environmental pillar includes the categories: Resource use, Emissions, Innovation. The Social pillar includes the categories: Workforce, Human rights, Community, Product responsibility. The Governance pillar includes the categories: Management, Shareholders, CSR strategy.

[6] As outlined in the Refinitiv ESG score guideline (Refinitiv, 2022), the "*ESG scores are data-driven, accounting for the most material industry metrics, with minimal company size and transparency biases*."

Table 1
Asset classes description.

Asset class	Index	Index description	Variable name
Equities	MSCI Europe Small Cap Index (USD)	Small Cap companies across the 15 Developed Markets countries in Europe.	MSCIEUSC
	MSCI Europe Mid Cap Index (USD)	Mid Cap companies across the 15 Developed Markets countries in Europe.	MSCIEUMC
	MSCI Europe Index (USD)	Large and Mid-Cap companies across the 15 Developed Markets countries in Europe.	MSCIEU
	EURO STOXX 50 Index	50 largest companies among the 20 super sectors in terms of free-float market cap in Eurozone countries.	EUSTOXX50
Bonds	iBoxx EUR Sovereigns	Investment grade EUR-denominated bonds issued by Eurozone governments, exposure across the whole yield curve and minimum outstanding of EUR 1 bn per bond.	EUBONDSOV
	iBoxx EUR Corporates	Investment grade EUR-denominated bonds issued by Eurozone companies, exposure across the whole yield curve and minimum outstanding of EUR 1 bn per bond.	EUBONDCORP
Real Estate	EPRA Developed Europe Index	The FTSE EPRA/NAREIT Developed Europe Index is a Market Capitalization-Weighted Index consisting of Europe's most heavily traded real estate stocks. It has a base date of 31 December 1999 and a base of 1000.	FTSE/EPRA
Real Estate ESG Screened	RE-ESG	REITs and real estate companies are included in the EPRA Dev.Europe Index with available ESG scores in the Refinitiv databases.	RE-ESG
	RE-ESG25	REITs and real estate companies included in the EPRA Dev. Europe Index with available ESG scores in the Refinitiv databases, excluding those entities with ESG scores below the 25th percentile in the previous year.	RE-ESG25
	RE-ESG50	REITs and real estate companies included in the EPRA Dev. Europe Index with available ESG scores in the Refinitiv databases, excluding those entities with ESG scores below the mean ESG score in the previous year.	RE-ESG50
Real Estate Environmental Screened	RE-Env25	REITs and real estate companies included in the EPRA Dev. Europe Index with available ESG score in the Refinitiv databases excluding those entities with E score below the 25th percentile in the previous year.	RE-Env25
	RE-Env50	REITs and real estate companies included in the EPRA Dev. Europe Index with available ESG score in the Refinitiv databases excluding those entities with E score below the mean ESG score in the previous year.	RE-Env50

Note: Developed Markets countries in Europe include Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the UK.

Environmental score (E) measures a company's impact on living and non-living natural systems, including the air, land and water, as well as complete ecosystems. It reflects how well a company uses best management practices to avoid environmental risks and capitalise on environmental opportunities to generate long-term shareholder value (Refinitiv, 2022). As for the ESG score, the E score ranges from 0 (worst) to 100 (best). Table 2 shows summary statistics for each asset class and the corresponding index selected or constructed for the asset allocation over the whole sample period. The RE-ESG and RE-ESG25 indexes outperformed the FTSE/EPRA Developed Europe Index, while the RE-Env25 presents the same performance for the entire sample. All the ESG-screened indexes show good returns except for the "higher screened" indexes (i.e., RE-ESG50 and RE-Env50) that underperform traditional real estate.

Finally, Table S1 in the Supplementary Material section shows asset class correlations. The stock market indexes and real estate are always highly positively correlated in this period, although the literature highlights that the correlation is not always consistent (Fisher and Sirmans, 1994; Benjamin et al., 2001; Geiger et al., 2016). Indeed, many investors hold equities and real estate in their portfolios to diversify their holdings and reduce risk. This leads to a positive correlation between the asset classes as investors allocate their capital across both markets. The real estate market includes public REITs stocks, and the stock market conditions can influence their performance (Kroencke et al., 2014). In addition, equities and real estate are considered long-term investments, and investors may choose to invest in one asset class or another based on their risk tolerance, investment goals, and personal preferences. Focusing on the correlations in two sub-sample periods (2014–2022 and 2018–2022) characterised by different macroeconomic and geopolitical conditions (e.g., the China–USA trade war, Covid-19, the Russia–Ukraine conflict, energy crisis, etc.), the positive relation between these asset classes remained strong.

3.2. Portfolio asset allocation methodologies

To evaluate the risk-adjusted performance contribution of ESG real estate within the macro-asset allocation process, we employ two distinct strategies:

- **Mean-Variance (MV).** Following Sharpe (2007), we use a quadratic program algorithm to solve the Mean-Variance optimisation (Markowitz, 1959) and find the portfolio that provides the maximum expected return for a given level of the standard deviation of

Table 2
Descriptive statistics.
This table provides summary statistics for each asset class over the whole sample period (January 1, 2006–September 30, 2022). "Mean" is the annualised time-series mean of weekly returns; "Std.Dev." is the associated annualised standard deviation. "Skew" and "Kurt" represent the return distribution's third and fourth moments. "Sharpe" denotes the annualised Sharpe ratios of the respective asset class. "JB" is the *p*-value (in %) of the Jarque–Bera statistic for testing and refusing the normality hypothesis of returns. For a detailed description of each asset class, please refer to Table 1.

	N.	Mean (%)	Std. Dev. (%)	Kurt	Skew	Sharpe	Min (%)	Max (%)	JB (%)
Equity									
MSCIEUSC	873	7.959	19.953	6.787	−1.257	0.282	−0.199	0.111	0.000
MSCIEUMC	873	6.343	19.886	7.435	−1.129	0.202	−0.200	0.131	0.000
MSCIEU	873	2.849	19.224	9.721	−1.271	0.027	−0.213	0.138	0.000
EUSTOXX50	873	1.850	21.802	6.734	−0.934	−0.022	−0.222	0.122	0.000
Bond									
EUBONDSOV	873	2.529	4.376	2.776	−0.267	0.046	−0.028	0.030	0.000
EUBONDCORP	873	2.317	3.553	13.037	−1.958	−0.004	−0.044	0.015	0.000
Real Estate - ESG									
FTSE/EPRA	873	4.150	21.538	6.726	−1.237	0.084	−0.200	0.108	0.000
RE-ESG	873	4.334	22.378	6.141	−1.081	0.090	−0.205	0.112	0.000
RE-ESG25	873	4.261	23.081	5.768	−1.012	0.084	−0.204	0.112	0.000
RE-ESG50	873	3.335	23.614	5.651	−0.963	0.043	−0.204	0.119	0.000
RE-Env25	873	4.150	23.066	5.856	−1.036	0.079	−0.204	0.112	0.000
RE-Env50	873	3.808	23.820	5.915	−0.943	0.062	−0.213	0.131	0.000

return, assuming that short selling is not allowed. Particularly, Sharpe (2007) assumes that the investors aim to maximise the expected utility of the return from the portfolio.[7]

- **Risk Parity (RP)**. The Risk Parity model (Clarke et al., 2013; Qian, 2005) represents a milestone in the Post-Modern Portfolio Theory attempting to bypass the portfolio optimisation methods, preferring a heuristic-solution-based risk distribution compared to the mean-variance based on the equal risk contribution. This approach provides stability to the asset allocation compared to the mean-variance strategy since it considers the risk contribution of a single component of the Marginal Risk Contribution (MRC) as a share of the portfolio total risk contribution and excludes any returns in the weight distribution.[8]

In order to investigate the performance contribution of ESG real estate to the macro-asset allocation, we compare the risk-adjusted performance of a portfolio that includes traditional real estate (RE portfolio) to five portfolios that invest in ESG-screened real estate. Specifically, the portfolios are (i) ESG, (ii) ESG-25, (iii) ESG50, (iv) Env25, and (v) Env50, which include, respectively, the RE-ESG index, the RE-ESG25 index, the RE-ESG50 index, the RE-Env25 index and the RE-Env50 index. Based on the models detailed in Appendix B, we perform three portfolio simulations (Simulation 1, 2 and 3) to capture the variation of sustainable real estate performance contribution through time. Furthermore, this allows us to consider different input data to forecast the portfolio performance in the out-of-sample, which is important because the rolling window technique is very responsive to input data changes (Zivot and Wang, 2003).

4. Results

4.1. Simulation 1: full sample period (January 2006–September 2022)

The first portfolio optimisation process considers the full sample periods (i.e. 873 weekly returns) with a rolling window of 436 weeks (out-of-sample period).[9] Performance results and portfolio statistics are summarised in Table 3. MV and RP optimisation results show that investing in ESG-screened real estate indexes improves the portfolio risk-adjusted performance. When we compare the ESG portfolio to the RE portfolio, the Sharpe (Sortino) ratio increases from 0.185 to 0.208.[10] Selecting highly ESG-screened real estate indexes further improves the portfolio risk-adjusted performance (ESG25 and ESG50). Interestingly, the benefits of sustainable real estate investments are maximised when constructing the environmental portfolios (Env25 and Env50) with a MV optimisation strategy; however, we do not find a positive effect of the real estate environmental indexes when we use the RP strategy. Regarding downside risk, the ESG-screened indexes positively benefit asset allocation with both the MV and RP optimisation processes.[11]

Looking at the RP asset marginal weight contribution (Appendix A – Table A1) for ESG, ESG25 and ESG50 portfolios, the weight of ESG-screened real estate assets never surmounts the 5.5 %. It is unsurprising, as the RP aims to equalise each asset class's total risk

[7] MV strategy has some limitations, such as the issue of concentration and the issue of estimation error (Chan et al., 1999; Roncalli, 2013), that may lead to unstable or suboptimal portfolios and high turnover if the portfolio is frequently rebalanced to account for changes in the estimates.
[8] See, among others, (Allen, 2010; Anderson et al., 2012; Bruder and Roncalli, 2012; Choueifaty and Coignard, 2008; Foresti and Rush, 2010; Levell, 2010; Lohre et al., 2012; Maillard et al., 2010; Meucci, 2007, 2009).
[9] Figs. 1–3 in the Supplementary Material section show the cumulative returns of the various portfolios over the respective out-of-sample period.
[10] Sharpe Ratio: (0.208 − 0.185) / 0.185.
[11] With RP the maximum drawdown reduces by 5bp with respect to the portfolio that invests in the FTSE/EPRA index.

Table 3
Simulation 1: Portfolio Performance – 873 weekly returns (January 2006–September 2022)
This table summarises the portfolio's out-of-sample performance. "Return" denotes the annualised time-series cumulative return; "Std. Dev." shows the associated annualised standard deviation; "Sharpe Ratio" represents the annualised Sharpe ratio (risk-free is set to zero given the negative Euro short-term rate until September 30, 2022); "Max Drawdown" (MDD) is the maximum observed loss from a peak to a portfolio trough before a new peak is attained. The "Calmar Ratio" is a risk-adjusted indicator that considers MDD as a risk-adjusted risk indicator; "Downside Risk" was estimated by annualising the lower partial moment of the time-series return to calculate the "Sortino Ratio".

In-sample $w = 437$ – out-of-sample $w = 436$							
Mean-variance							
Portfolio	**Return (%)**	**Std. Dev. (%)**	**Sharpe ratio**	**Max drawdown (%)**	**Calmar ratio**	**Downside risk**	**Sortino ratio**
RE	3.144	16.960	0.185	−38.465	0.082	4.741	0.663
ESG	3.593	17.266	0.208	−38.315	0.094	4.728	0.760
ESG25	3.465	17.224	0.201	−38.327	0.090	4.715	0.735
ESG50	3.883	17.300	0.224	−38.315	0.101	4.703	0.826
Env25	3.827	17.296	0.221	−38.315	0.100	4.703	0.814
Env50	3.767	17.293	0.218	−38.315	0.101	4.703	0.801
Risk Parity							
RE	1.575	0.085	0.185	−24.896	0.063	4.842	0.325
ESG	1.147	0.052	0.220	−19.514	0.058	4.805	0.240
ESG25	1.072	0.052	0.207	−19.466	0.055	4.792	0.224
ESG50	0.984	0.052	0.188	−19.521	0.050	4.805	0.205
Env25	0.843	0.069	0.122	−20.347	0.041	4.742	0.178
Env50	0.529	0.072	0.073	−24.896	0.022	4.742	0.111

contribution (TRC), allocating a lower weight to high-volatility assets. Vice versa, the RE-Env25 and RE-Env50 indexes represent, on average, respectively, about 12.7 and 13.6 % of the portfolio asset allocation, with peak values in the range of about 50/52 %, suggesting that these asset classes had a lower marginal risk contribution during the sample timespan, but that, in some periods, the environmentally screened real estate assets were preferred to equities or bonds.[12] According to the literature, these three portfolios could be more balanced in concentration and diversification terms, as confirmed by the average weight level achieved by each asset class (Hoesli et al., 2004; Umar and Olson, 2022; Lekander, 2015).

4.2. Simulation 2: sample period (January 2014–September 2022)

The second simulation focuses on recent periods, specifically from January 1, 2014, to September 30, 2022 (i.e. 456 weekly returns), with a rolling window of 353 weeks (out-of-sample period). We started in 2014 because of the introduction of Agenda 2030 and the COP21 Paris Agreement, representing the starting point for the European regulatory pathway in sustainability. While we expect a positive effect of ESG becoming more popular after 2014, we acknowledge that during the 2014–2022 periods, financial markets experienced periods of high market volatility.

Table 4 reports the results of Simulation 2.[13] The MV strategy shows a negative performance contribution of the ESG and environmental real estate portfolios. However, the RP portfolio shows that environmentally screened real estate portfolios (Env25 and Env50) outperform traditional real estate (RE). Thus, REITs and real estate companies with higher environmental scores significantly improve risk-adjusted performance when an investor uses a strategy like RP designed to help investors maintain a portfolio with significant risk diversification benefits.

Finally, the RP asset marginal weight contribution (Table A1) and the Env25 and Env50 portfolios show that the contribution of the real estate and environmentally screened asset classes is crucial to maintaining good portfolio diversification and performance. In both cases, the environmentally friendly real estate achieved an average of 8.6 (4.8) % with a maximum value of 68.6 (67.3) %.

Our findings suggest that even during market downturns, investors could prefer environmentally screened real estate assets to maintain a good level of diversification and return without affecting volatility and incurring large overall drawdowns.

4.3. Simulation 3: sample period (January 2018–September 2022)

Finally, we narrow the input time series data with a rolling time window that relies on 104 weeks in-sample (January 1, 2018–January 1, 2020) and an out-of-sample period of 144 weeks. These time series correspond to a high volatility period and allow us to test better the effect of strategies such as the risk parity model, resulting in a more resilient Simulation 2.

The results of this simulation are reported in Figs. 7–9 of the Supplementary Material section and Table 5. As in Simulation 2, the MV strategy indicates poor performances of ESG-screened real estate indexes; however, the results are enhanced when applying the RP approach. Even if the overall performance is still negative, the results of highly environmentally screened real estate portfolios (i.e. Env25 and Env50) are marginally better than for ESG-screened real estate allocations and almost equal to traditional real estate

[12] The detailed asset marginal weight contributions are available on request.
[13] Figs. 4–6 in the Supplementary Material section chart the cumulative returns.

Table 4
Simulation 2 portfolio performance – 456 weekly returns (January 2014–September 2022).
This table summarises the portfolio's out-of-sample performance. "Return" denotes the annualised time-series cumulative return; "Std. Dev." shows the associated annualised standard deviation; "Sharpe Ratio" represents the annualised Sharpe ratio (risk-free is set to zero given the negative Euro short-term rate until September 30, 2022); "Max Drawdown" (MDD) is the maximum observed loss from a peak to a portfolio trough before a new peak is attained. The "Calmar Ratio" is a risk-adjusted indicator that considers MDD as a risk-adjusted risk indicator; "Downside Risk" was estimated by annualising the lower partial moment of the time-series return to calculate the "Sortino Ratio".

In-sample weeks = 104 – out-of-sample weeks = 353							
Mean-variance							
Portfolio	**Return (%)**	**Std. Dev. (%)**	**Sharpe ratio**	**Max drawdown (%)**	**Calmar ratio**	**Downside risk**	**Sortino ratio**
RE	−1.813	16.031	−0.113	−32.255	−0.056	4.801	−0.378
ESG	−2.317	16.363	−0.142	−32.680	−0.071	4.785	−0.484
ESG25	−2.086	16.204	−0.129	−32.555	−0.064	4.754	−0.439
ESG50	−2.558	15.825	−0.162	−32.082	−0.080	4.801	−0.533
Env25	−2.677	16.249	−0.165	−32.700	−0.082	4.816	−0.556
Env50	−2.934	16.262	−0.180	−33.963	−0.086	4.770	−0.615
Risk Parity							
RE	2.409	0.133	**0.181**	−22.156	0.109	4.747	0.507
ESG	−0.127	0.052	−0.024	−19.697	−0.006	4.840	−0.026
ESG25	−0.219	0.053	−0.042	−19.785	−0.011	4.855	−0.045
ESG50	−0.278	0.053	−0.053	−19.776	−0.014	4.870	−0.057
Env25	3.422	0.130	**0.264**	−20.222	0.169	4.622	0.714
Env50	3.309	0.131	**0.253**	−20.924	0.109	4.638	0.507

Table 5
Simulation 3 portfolio performance – 247 weekly returns (January 2018–September 2022).
This table summarises the portfolio's out-of-sample performance. "Return" denotes the annualised time-series cumulative return; "Std. Dev." shows the associated annualised standard deviation; "Sharpe Ratio" represents the annualised Sharpe ratio (risk-free is set to zero given the negative Euro short-term rate until September 30, 2022); "Max Drawdown" (MDD) is the maximum observed loss from a peak to a portfolio trough before a new peak is attained. The "Calmar Ratio" is a risk-adjusted indicator that considers MDD as a risk-adjusted risk indicator; "Downside Risk" was estimated by annualising the lower partial moment of the time-series return to calculate the "Sortino Ratio".

In-sample w = 104 – out-of-sample w = 144							
Mean-variance							
Portfolio	**Return (%)**	**Std. Dev.(%)**	**Sharpe ratio**	**Max drawdown (%)**	**Calmar ratio**	**Downside risk**	**Sortino ratio**
RE	−11.354	19.961	−0.569	−32.255	−0.352	4.824	−2.354
ESG	−11.448	20.204	−0.567	−32.680	−0.350	4.786	−2.392
ESG25	−11.362	20.158	−0.564	−32.555	−0.349	4.824	−2.355
ESG50	−10.915	19.373	−0.563	−31.191	−0.350	4.824	−2.262
Env25	−11.459	20.186	−0.568	−32.699	−0.350	4.824	−2.375
Env50	−12.028	20.316	−0.592	−33.451	−0.360	4.824	−2.493
Risk Parity							
RE	−3.408	0.228	−0.150	−30.781	−0.111	4.882	−0.699
ESG	−5.352	0.065	−0.820	−19.087	−0.280	5.169	−1.035
ESG25	−5.394	0.065	−0.826	−19.150	−0.282	5.204	−1.037
ESG50	−5.446	0.065	−0.834	−19.163	−0.284	5.239	−1.040
Env25	−3.358	0.230	−0.146	−30.391	−0.111	4.807	−0.699
Env50	−3.416	0.226	−0.151	−30.609	−0.111	4.845	−0.705

portfolios. Thus, the results confirm the positive contribution of the environmentally screened assets in relative terms (the weight contributions achieve a maximum value of 44.2 and 46.8 % of the asset allocation, respectively). However, focusing on an even narrower time horizon, the "market effect" did not allow us to appreciate the positive contribution of real estate assets toward environmental and sustainability goals.

5. Conclusions

The real estate sector plays a pivotal role in environmental sustainability, particularly within the ESG framework, given its contribution of nearly 39 % to global emissions. This significant impact necessitates a more profound understanding among investors regarding how ESG-screened and environmentally friendly real estate can enhance the diversification of investment portfolios. This paper contributes to the existing body of literature by exploring how investing in publicly listed real estate that adheres to ESG criteria impacts the risk-adjusted performance of portfolios. Using a novel set of ESG-real estate indexes, this study demonstrates that ESG and especially environmental-screened real estate investments positively contribute to portfolio diversification compared to traditional real estate. Additionally, the risk-parity approach reveals that portfolios incorporating environmentally screened real estate investments achieve comparable or even superior performance to unconstrained mixed portfolios, particularly during market downturns. These results suggest that investors increasingly recognise the comprehensive benefits of investments compliant with ESG criteria, in line with the ongoing development and implementation of regulatory and reporting frameworks. From this viewpoint, our analysis offers valuable insights for institutional investors and policymakers by determining whether investing in European ESG real estate investment vehicles is an effective diversification strategy.

The significance of our findings extends beyond pure financial performance, as they underscore the crucial role of sustainable and environmentally friendly real estate investments in addressing climate change. Integrating ESG considerations, especially environmental aspects, into real estate investment strategies could have a tangible impact on mitigating climate risk. By prioritising energy efficiency, renewable energy integration, and sustainable design, Environmental-screened real estate investments contribute to reducing carbon footprints, mitigating climate change, and advancing climate goals. By demonstrating leadership in sustainability and responsible investment practices, ESG real estate portfolios can influence the industry and inspire broader adoption of climate-friendly strategies. Ultimately, their significance lies in their ability to contribute to the transition to a low-carbon economy and create more sustainable and resilient built environments. By demonstrating the potential benefits of investing in ESG real estate investment vehicles as part of a diversification strategy, we highlight the opportunities for aligning investment decisions and the related flow of funds with climate goals and promoting sustainable development. This evidence also seems to confirm, from a financial perspective, the positive externalities of public policies to counter climate change caused by the real estate sector. Lastly, introducing regulatory interventions at the industry level adds to the urgency of exploring this topic (e.g., Lee and Yik, 2004).

CRediT authorship contribution statement

Massimo Biasin: Conceptualization, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. **Andrea Delle Foglie:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. **Emanuela Giacomini:** Conceptualization, Project administration, Data curation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.frl.2024.105381.

Appendix A. Index methodology

To construct our ESG Real Estate indexes, we follow the methodology used by EPRA to construct the FTSE/EPRA Developed Europe Index (see Giacomini et al., 2015). Therefore, given the different times of entry in the stock market of each constituent, we review the constituents quarterly. We obtained the list of constituents of the NAREIT/EPRA Developed Europe Index on the EPRA website, and we used the ISIN code to match the constituent's data with the ESG scores from Refinitiv. While EPRA accurately selects only firms in the real estate sector, using the Industry Classification Benchmark classification (FTSE EPRA NAREIT, 2023), we further ensure that all constituents of the index have the first two digits of their Standard Industrial Classification (SIC) code equal to 65 (Real Estate) or a SIC code equal to 6798 (Real Estate Investment Trusts). Of 202 constituents, 142 have at least one ESG score available over the 2006–2022 sample period. Although the Refinitiv database has a history dating back to 2002, our dataset starts from 2006 due to a lack of information on ESG scores before this date.

We collect weekly data for each company regarding the total return and market capitalisation from Refinitiv Eikon, resulting in 873 weekly observations. Using the subsample of constituents with available ESG scores, we create an index of total returns for the entire sample by weighting the total return of each component in week t by its market capitalisation at the end of week $t-1$. The weight of the index ($w_{i,t}^{v}$) for each firm in weeks t is, therefore:

$$w_{i,t}^{v} = \frac{\left(mcap_{i,t-1}^{v}\right)}{\sum_{i=1}^{N_t}\left(mcap_{i,t-1}^{v}\right)}$$

where $mcap_{i,t-1}^{v}$ is the equity market capitalization of firm i at the end of the week $t-1$. The total return (Ret_t^V) on our index in week t is defined as:

$$Ret_t^V = \sum_{i=1}^{N_t} w_{i,t}^{V} ret_{i,t}^{V}$$

A common way of incorporating ESG into a portfolio is by restricting the feasible investments among the assets with the highest ESG scores or vice versa by excluding assets with weak ESG scores.

Table A.1
Summary of risk parity asset marginal weight contribution.

	Simulation 1		Simulation 2		Simulation 3	
	Mean (%)	Variance (%)	Mean (%)	Variance (%)	Mean (%)	Variance (%)
FTSE/EPRA	28.24	2.127	6.57	0.91	2.231	0.858
RE-ESG	4.379	0.258	5.79	0.00	2.964	0.031
RE-ESG50	4.202	0.001	5.44	0.00	2.915	0.03
RE-ESG25	4.209	0.001	5.53	0.00	3.042	0.03
RE-Env50	12.695	4.334	4.76	1.93	1.192	0.446
Re-Env25	13.618	3.844	8.64	4.55	0.746	0.258

Appendix B. Empirical model

Mean-Variance

For the empirical model, we consider a portfolio $X = (x1; x2; \ldots; xn)$ of n risky assets, excluding leverage, short selling, minimum investment weight, sector neutrality or liquidity threshold. Let be $R = (r1; r2; r3; \ldots.; rn)$ the vector returns of a n asset resulting in $\sum_{i=1}^{n} x_i = 1 = x^T e$ with $e = (1, 1, 1, \ldots, 1)^{\mathrm{T}}$, Rp the expected return of the portfolio and σ_p^2 the variance of the portfolio: $R_p = \sum_{i=1}^{n} r_i x_i = x^T R$; $\sigma_p^2 = \sum_{i=1}^{n}\sum_{j=1}^{n} x_i x_j \sigma_{i,j} = x^T \Omega x$ where Ω is the matrix of covariances: $\Omega = \begin{pmatrix} \sigma_{1,1} & \cdots & \sigma_{1,n} \\ \vdots & \ddots & \vdots \\ \sigma_{n,1} & \cdots & \sigma_{n,n} \end{pmatrix}$. We solve this optimization problem using the MATLAB Optimization Toolbox™, which provides functions for finding parameters that minimize or maximize objectives while satisfying constraints.

According to Clarke et al. (2011), we consider the diversification ratio as $D_P = \frac{w'\sigma}{\sqrt{w'\Omega w}}$ where σ is an N-by-1 vector of asset volatilities and Ω is the matrix of covariances. D_P is equal to the Sharpe ratio if the σ replaces the expected excess returns vector. This substitution gives the optimal maximum diversification weight vector as $w_{MD} = \left(\frac{\sigma_{MD}^2}{\sigma_A}\right)\Omega^{-1}\sigma$ where σ_A is the weighted average asset risk. To solve this second optimization problem, we use again the MATLAB Optimization Toolbox™ applying the *fmincon* functions, which provide an SQP-based nonlinear programming solver, finding the minimum of a constrained nonlinear multivariable function of a problem (Byrd et al. 2000; Waltz et al., 2006; Giuzio, 2017; Mussafi and Ismail, 2021).

Risk Parity

For the empirical model, according to Richard and Roncalli (2019), we defined a portfolio $X = (x1; x2; \ldots; xn)$ of n risky assets, excluding leverage, short selling, minimum investment weight, sector neutrality or liquidity threshold. We assume the $MRC_i(x) = \frac{(\Omega x)_t}{\sqrt{x^T\ \Omega x}}$ and the $TRC_i(x) = x_i \frac{(\Omega x)_t}{\sqrt{x^T\ \Omega x}}$, where Ω is the covariance matrix. Since the ERC aims to build a risk-balanced portfolio considering the asset allocation in terms of risk contribution (risk budgeting), we consider risk budget b and the vector of risk in the percentage of the total risk $b = (b_1, b_2, \ldots, b_n)$, where $b_i = b_j = 1/n$, the $TRC_i(x) = TRC_j(x)$ and the $x_i \frac{(\Omega x)_t}{\sqrt{x^T\ \Omega x}} = x_j \frac{(\Omega x)_t}{\sqrt{x^T}}$ so it is easy to show that the $\sum_{i=1}^{n} TRC(x) = nTRC_i(x)$ and the $TRC_i(x) = \frac{\sigma(x)}{n}$. Thus, the risk parity can be solved as the following optimization problem: $X = arg\ \min f(x)$, where $f(x) = \sum_{i=1}^{n}\sum_{i=1}^{n} (TRC_i(x) - TRC_j(x))^2$, and $f(x) = \sum_{i=1}^{n}\sum_{i=1}^{n} (x_i\ (\Omega x\ )_i\ -\ x_i(\Omega x)_j)^2$, $\sum_{i=1}^{n} x_i = 1$ *and* $x \geq 0$. Considering the Euler decomposition of the portfolio risk measure $X = arg\ \min \sum_{i=1}^{n}\left(x_i(\Omega x)_i - \frac{\sigma_p(x)}{n}\right)^2$. It is equivalent to solving a nonlinear equation with n unknown variables (Delle Foglie and Pola, 2021).

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