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Research article

Climate change and stock returns in the european market: An environmental intensity approach☆

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A R T I C L E I N F O

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A B S T R A C T

Climate change has become a risk that companies, governments and stakeholders must consider. Climate risk affects everything from people's health to the performance of companies. The European Union has approved various legislations and action plans to counteract the effects of climate change in a pioneering strategy. Companies can play a critical role in mitigating climate change and creating a more sustainable future by integrating environmental considerations into their decision-making processes. However, this integration may impact their performance. This paper aims to analyse the effect of climate change on the stock returns of European companies. The study sample consists of 265 companies listed in the Stoxx 600 index between 2015 and 2021 and the methodology used is the econometric method for panel data. The results show that carbon emissions have a negative effect on the performance of companies. Oppositely, a good rating in the environmental pillar has a positive impact on returns.

1. Introduction

There is no doubt about the incidence of human activity on climate change. Climate change and pollution not only pose risks for the future, but they are already having very visible effects on populations and time is running out (Cook and Heyes, 2022; Guaita Martínez et al., 2022; He et al., 2022; Wang et al., 2022). In an attempt to stop global warming or reduce its effects, many countries signed the Kyoto Protocol in 1997, whereby developed nations committed to reducing their Greenhouse Gas (GHG) emissions. However, the agreement did not become effective until 2005. Subsequently, in 2015, the Paris Agreement was approved (UNFCCC, 2015), an international and legally binding treaty, which for the first time included all countries in the fight against climate change. The main objective of the agreement was to keep the increase in global average temperature below 2 °C with respect to pre-industrial levels, and to try to limit it to a maximum of 1.5 °C.

The European Union (EU) is currently leading the fight against climate change and promoting the economic transition towards more sustainable investments, with various ongoing initiatives. The European Commission published the Action Plan on Sustainable Finance, with the aims of promoting sustainable and transparent investment, and ensuring that sustainability is included in risk management (European Commission, 2018). Different regulations have been derived from this plan, such as the regulation on Sustainability-related Disclosures in the Financial Services sector (European Parliament, 2019), the EU taxonomy for sustainable activities (also known as the Green Taxonomy) (European Parliament, 2020) and the Corporate Sustainability Reporting Directive (European Parliament, 2022).

Climate change has become an imperative threat that societies must address. Giglio et al. (2021) explain that the financial sector can play a crucial role in fighting against climate change and the associated risks. Therefore, a new problem arises: How can the financial sector help society and ecosystems in mitigating and adapting to climate change? Given the importance of the matter and the fact that the EU is clearly a pioneer in sustainability issues in general, and especially in sustainable finance, the purpose of this paper is to analyse the effect of climate risk on the stock returns of companies in the European financial market. Investors need to carefully assess the climate risk associated with the companies in which they invest, as well as the exposure of their portfolios to this risk.

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Climate change is a new type of risk for companies, known as climate risk. Reboredo and Ugolini (2022) define climate risk as the combination of physical risk and transition risk. The first comes from natural disasters and the unpredictability and intensity of weather events, and the second from the actions that companies must take in line with regulatory, technological and consumer preference changes to reduce their emissions and adapt their production processes to a green economy.

The effect of climate risk on financial markets and companies is a current issue and one that is widely debated in the literature (Giglio et al., 2021; Agliardi et al., 2023; Eurosif, 2023). There are different ways of approaching climate risk, and there is no clear consensus as to the variables and indicators that best define it. Among the most commonly used are carbon intensity (Bhat, 1999; In et al., 2019; Görgen et al., 2020; Bolton and Kacperczyk, 2021; Ilhan et al., 2021; Rodríguez-García et al., 2022), GHG emissions on the land, in the air, and in water bodies (Chang et al., 2020; Fang et al., 2021; Hsu et al., 2023), and the ESG ratings of major rating agencies (Garzón-Jiménez and Zorio-Grima, 2021; Zhang, 2022). Regarding carbon intensity, there is no one way to quantify it. Some authors use the sum of GHG emissions from Scope 1 and Scope 2 (in some cases also including those from Scope 3) standardised by the company's revenues (Garvey et al., 2018; In et al., 2019; Görgen et al., 2020; Bolton and Kacperczyk, 2021; Rodríguez-García et al., 2022; Trinks et al., 2022), while others standardise emissions using a company's market value (Ilhan et al., 2021), or its book equity (Hsu et al., 2023), or the reporting threshold of the European Pollutant Release and Transfer Register (Horváthová, 2012).

Most of the research on the impact of climate risk on the financial markets has focused on the USA (Bhat, 1999; Andersson et al., 2016; Albuquerque et al., 2019; In et al., 2019; Monasterolo and De Angelis, 2020; Yook and Hooke, 2020; Bolton and Kacperczyk, 2021; Ilhan et al., 2021; Garcia-Jorcano et al., 2022; Reboredo and Ugolini, 2022; Tang and Li, 2022; Hsu et al., 2023), and there is little research on the European financial market (Horváthová, 2012; Ennis et al., 2014; Oestreich and Tsiakas, 2015; Andersson et al., 2016; Monasterolo and De Angelis, 2020; Reboredo and Ugolini, 2022).

Building on the research of Garvey et al. (2018), In et al. (2019), Monasterolo and De Angelis (2020), Tripathi and Jham (2020) and Trinks et al. (2022), this study explores how climate-related risks influence financial markets. Furthermore, it aims to expand our understanding of the broader implications of the ESG scores. Derived from Horváthová (2012), Ennis et al. (2014), Albuquerque et al. (2019), Garzón-Jiménez and Zorio-Grima (2021), and Zhang (2022), this research also focuses on the effect of Environmental, Social, and Governance (ESG) factors on a company's stock returns with the aim of determining whether the market rewards or penalizes companies that receive positive or negative assessments in the ESG scores, and especially, in the environmental pillar score.

Therefore, this paper makes academic and practical contributions to the study of climate risk and its impacts on financial markets. From a practical perspective, it raises awareness among companies of the importance of managing climate risk and offers means of measuring it. Investors and portfolio managers can utilize these insights to gauge the exposure of their investments to climate risk and make more informed decisions to safeguard their portfolios against potential risk associated with environmental challenges. From a theoretical standpoint, this research supports the findings of previous studies by Garvey et al. (2018), In et al. (2019), Monasterolo and De Angelis (2020), Tripathi and Jham (2020) and Trinks et al. (2022), which indicate that the market values low exposure to climate risk. Furthermore, it introduces a specific variable, the environmental pillar score, to assess its relationship with companies' stock returns. The results also show that the control of carbon intensity and the environmental pillar score of the ESG score can be effective measures.

Based on the findings drawn from the analysis some recommendations can be presented in corporate practices: i) ESG awareness and ii) environmental risk management. Regarding the first, a better understanding of ESG factors can lead to more responsible decision-making and contribute to sustainable economic growth. Furthermore, by implementing measures to reduce carbon emissions and improve energy efficiency, companies can mitigate potential financial risks associated with environmental regulations and changing market demands.

The study is structured as follows: Section 2 contains a review of the literature on the link between climate risk and the financial markets. The methodology and hypotheses are described in Section 3, and the data is shown and explained in Section 4. The results are presented in Section 5 and the discussion of this analysis can be found in Section 6. The conclusions are drawn in Section 7.

2. Literature review

Existing research on the impact of climate risk on the financial markets has focused on analysing whether there is a risk premium in the high-carbon intensity portfolios (Görgen et al., 2020; Bolton and Kacperczyk, 2021; Reboredo and Ugolini, 2022; Tang and Li, 2022), or whether the low-carbon intensity portfolios perform better (Andersson et al., 2016; Garvey et al., 2018; In et al., 2019; Monasterolo and De Angelis, 2020; Tripathi and Jham, 2020; Yook and Hooke, 2020; Trinks et al., 2022). Other studies analyse the relationship between financial performance and the company's level of GHG emissions (Bhat, 1999; Chang et al., 2020; Fang et al., 2021; Hsu et al., 2023), or its ESG rating (Horváthová, 2012; Ennis et al., 2014; Albuquerque et al., 2019; Berg et al., 2021; Garzón-Jiménez and Zorio-Grima, 2021; Zhang, 2022).

The research on the existence of a risk premium in the high-carbon intensity portfolios has yielded non-homogeneous results. Bolton and Kacperczyk (2021), in the US market, and Tang and Li (2022), in the Chinese and US markets, find that there is a carbon premium. However, in a worldwide study, Görgen et al. (2020) conclude that there is no carbon premium and, furthermore, that investors are not aware of the climate risk of the companies they support. In their study of the European and North American markets, Reboredo and Ugolini (2022) also find that there is no transition risk premium, or in other words, that compensation is not required for companies that are more exposed to environmental regulatory changes.

Likewise, there is no consensus on how low-carbon portfolios perform. Garvey et al. (2018) and Trinks et al. (2022) find that at international level, low-carbon intensity portfolios perform better. Similarly, In et al. (2019) observe that US carbon-efficient portfolios perform better. Tripathi and Jham (2020) draw the same conclusion when analysing portfolios from the Indian market between 2006 and 2018. Monasterolo and De Angelis (2020) find that, at global level, the low-carbon indexes perform better, and that since the Paris Agreement the systematic risk of low-carbon portfolios had decreased. However, Andersson et al. (2016) find no differences in performance between sustainable and traditional indexes, noting that investors do not consider climate risk in their decision-making. More recently, Yook and Hooke (2020) analysed the S&P500 between 2004 and 2017, affirming that there are no differences in performance between carbon-free and traditional portfolios.

The results of the studies that relate the level of companies' GHG emissions and their returns are also divergent. For the US market, Bhat (1999) finds that GHG emissions negatively affect performance and market value. Fang et al. (2021) reach the same conclusion in their study focused on four Chinese cities, observing that the negative effect on performance has grown since the Paris Agreement. For their part, Hsu et al. (2023) analyse the US market, finding that companies that are high in GHG emissions perform better, while Chang et al. (2020) find that a change in emissions does not affect a company's performance, even though an increase in performance is accompanied by a corresponding increase in emissions.

Last, some studies find a positive relationship between ESG ratings and stock returns (Albuquerque et al., 2019; Garzón-Jiménez and

Zorio-Grima, 2021; Zhang, 2022), while others find no significant relationship between them (Horváthová, 2012; Ennis et al., 2014). It has also been noted that the relationship between ESG ratings and stock returns can vary depending on when the data was collected (Berg et al., 2021). Notably, in a worldwide study, Albuquerque et al. (2019) find that companies with a good ESG rating have a reduced systemic risk, are valued more highly, have less capital cost and are less susceptible to changes in economic cycles. Garzón-Jiménez and Zorio-Grima (2021) conclude that companies that disseminate more ESG information have a lower capital cost. Similarly, Zhang (2022) finds that companies with good ESG ratings and good ESG information disclosure perform better in the market. Berg et al. (2021) made a critical observation regarding the relationship between ESG ratings and stock returns, using data collected from Refinitiv. The authors found that before a methodological change was made by the rater, there was no significant relation between the ESG ratings and stock returns, whereas after the change, they found a strong relationship between them. This behaviour was also observed in the environmental and social pillars.

3. Methodology and hypotheses

To assess the possible existence of a climate risk premium, the panel data econometric model will be used. This methodology is selected because of its ability to examine the evolution of the group of companies over several years, controlling for individual effects (Martinez et al., 2016).

The model is defined as follows:

$$Y_{it} = \sum_{r=1}^{s} \beta_r \cdot X_{r,it} + \sum_{v=1}^{w} \beta_v X_{v,it} + \mu_i + \varepsilon_{it} \quad (1)$$

Where:

Y_{it} represents the stock return of company i in year t obtained from the annual variation in the price of each company's share

$X_{r,it}$ is the economic and financial variable r ($r = 1, \ldots, s$) for company i in year t.

$X_{v,it}$ is the variable related to climate risk and ESG factors v ($v = 1, \ldots, w$) for company i in year t.

μ_i is the individual unobservable heterogeneity that remains constant over time for each company.

ε_{it} is the random disturbance for which a zero mean and constant variance is assumed.

According to the theoretical framework regarding climate risk and stock returns, the economic and financial variables included in the model are volatility, the size of the company, fixed assets (PPE), and return on assets (ROA). The other group of variables are related to climate risk and the ESG factors: Scope 1 GHG emissions and Scope 2 GHG emissions, carbon intensity, ESG Combined Score, and each pillar score separately (Environmental, Social and Governance). Moreover, the effect of COVID-19 on a company's stock return is included in the analysis.

Therefore, the model is defined as follows:

$$\begin{aligned} Return_{it} &= \beta_1 Volatility_{it} + \beta_2 Size_{it} + \beta_3 PPE_{it} + \beta_4 ROA_{it} \\ &+ \beta_5 (Scope\ 1 + Scope\ 2) + \beta_6 Carbon\_Intensity_{it} \\ &+ \beta_7 ESGCombined_{it} + \beta_8 EnvPillar_{it} + \beta_9 SocPillar_{it} + \beta_{10} GovPillar_{it} \\ &+ \beta_{11} Carbon\_Intensity_{it} \cdot Covid19 + \mu_i + \varepsilon_{it} \quad (2) \end{aligned}$$

Volatility refers to the degree of variation or fluctuation in stock prices, it is, therefore, a measure of risk. In the present paper, this variable is obtained by annualising the daily volatility of the stock returns. A higher value indicates greater price fluctuations and increased uncertainty in the stock market, which can potentially impact stock returns.

The size of a company is obtained by applying the logarithm of the total amount of assets a company has in its accounting books. The logarithm is especially useful due to the wide range of disparity among the data.

The fixed assets are a subset of the assets that a company has, and they normally represent its properties, plants and equipment (PPE). The logarithm of total net amount of fixed assets is used in this study. A higher PPE value indicates that the company has more tangible assets, which might signal a stronger financial position.

Return on Assets (ROA) is a financial ratio that shows how much profit the company generates in relation to its total assets. A high ROA value indicates that the company is efficiently utilizing its assets to generate profits, while a low value of ROA may indicate profitability issues or inefficiency in asset utilization.

Regarding the variables related to climate risk, first, the sum of scope 1 and scope 2 emissions is included in the model. Scope 1 GHG emissions represent a company's direct emissions originating from sources that are controlled or owned by the business. This variable compiles the emissions of carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCS), perfluorocarbons (PFCS), sulfur hexafluoride (SF6) and nitrogen trifluoride (NF3). Meanwhile, scope 2 GHG emissions represent the indirect emissions of a company produced by the consumption of electricity, heat or steam. This category includes the same types of emissions as scope 1. Data from Scope 3 GHG emissions are excluded because the reporting on these emissions is currently poor given that there is no standard indicator to measure indirect emissions from the value chain (Garvey et al., 2018). These emissions are largely outside the company's direct control, which is why they were not included in this study.

Carbon Intensity is measured as the logarithm of the ratio between total Scope 1 and 2 emissions and the market capitalisation of the company. This variable represents the amount of emissions the company generates per monetary unit of its capitalization. When selecting companies, those with the lowest carbon intensity are preferable. Additionally, the "Carbon Intensity*COVID19" variable is introduced to investigate the impact of COVID-19 on the company's stock return. This coefficient obtained is the interaction term between "COVID" and "Carbon Intensity", representing how stock returns during the COVID-19 period are influenced by changes in the carbon intensity variable.

The ESG Combined Score is a score assigned by Eikon to a company, and is defined as the performance in the environmental, social and corporate governance pillars with an ESG Controversies overlay. This score ranges from 0 to 100. A higher ESG Combined Score implies that the company has a stronger overall ESG performance.

The Environmental Pillar Score measures the company's impact on the environment, assessing the effectiveness of its policies and actions in relation to environmental issue. This score reflects how well a company uses best management practices to avoid environmental risks and capitalize on environmental opportunities to generate long term shareholder value. Ranging from 0 to 100, a higher Environmental Pillar Score suggests that the company shows a strong commitment to environmental sustainability.

The Social Pillar Score measures a company's ability to build trust in workers, customers, suppliers and society in general. It serves as a reflection of the company's reputation and the health of its license to operate, which are crucial factors in determining its capacity to generate long-term shareholder value. This score ranges from 0 to 100. A higher Social Pillar Score indicates that the company exhibits strong social responsibility practices and prioritizes ethical behaviour and inclusive engagement with its stakeholders.

The Governance Pillar Score evaluates the systems and processes that a company applies to ensure company stakeholders' interests. It reflects a company's capacity, via its use of best management practices, to direct and control its rights and responsibilities through the creation of incentives, checks and balances to generate long-term shareholder value. Like the other pillars, the Governance Pillar Score ranges from 0 to 100.

A higher Governance Pillar Score indicates that the company demonstrates strong corporate governance practices.

Table 1 shows the authors that have included these variables in their works with the objective of determining whether there is a relation between sustainable variables and stock returns.

According to the theoretical framework of these variables, the following hypotheses are proposed for this study:

- *H1*: Higher emissions of Scope 1 and 2 decrease the company's stock returns.
- *H2*: Higher Carbon Intensity decreases company's stock returns.
- *H3*: An increase in the ESG Combined Score leads to an increase in the company's stock returns.
- *H4*: An increase in the Environmental Pillar Score leads to an increase in the company's stock returns.
- *H5*: An increase in the Social Pillar Score leads to an increase in the company's stock returns.
- *H6*: An increase in the Governance Pillar Score leads to an increase in the company's stock returns.
- *H7*: There exists and interaction between Covid-19 and carbon intensity that could potentially impact stock returns.

4. Data

The companies included in the analysis are selected from those listed on the Stoxx 600 index and for which data is available for all variables between 2015 and 2021. The data was sourced from Eikon/Datastream. The sample initially included the 600 companies in the Stoxx 600 index as of February 17th, 2023. In the screening process of the sample, companies with no data for one or more of the variables in the econometric model were removed, leading to the further elimination of 335 companies. The final sample corresponds to 265.

Table 2 shows the descriptive statistics and Table 3 the matrix of correlations.

A high correlation between the *Carbon_intensity* and *Scope1 + Scope2* variables and the *PPE* and *Scope 1 + Scope 2* variables can be observed. It is more appropriate to exclude total absolute emissions (Scope 1 + Scope 2) and maintain carbon intensity as this measure allows for a more accurate comparison between different sized companies (Ilhan et al., 2021) and the value of a company's fixed assets.

The final model used is as follows:

$$Return_{it} = \beta_1 Volatility_{it} + \beta_2 Size_{it} + \beta_3 PPE_{it} + \beta_4 ROA_{it} + +\beta_5 Carbon\_Intensity_{it} + \beta_6 ESGCombined_{it} + \beta_7 EnvPillar_{it} + \beta_8 SocPillar_{it} + \beta_9 GovPillar_{it} + \beta_{10} Carbon\_Intensity_{it} \cdot Covid19 + \mu_i + \varepsilon_{it} \quad (3)$$

Table 2
Descriptive statistics.

n = 1855	Mean	Std dev	Min	Max
Return	0.10	0.28	−0.76	2.35
Volatility	0.28	0.11	0.11	1.05
Size	9.90	1.71	4.22	14.78
PPE	7.53	2.10	−1.01	12.32
ROA	0.07	0.13	−0.13	2.49
Scope 1 + Scope 2	12.56	2.49	5.40	19.09
Carbon_intensity	3.03	2.31	−4.61	10.29
ESGCombined	65.73	14.30	23.78	94.16
EnvPillar	72.20	19.07	5.81	99.16
SocPillar	75.57	16.19	14.76	98.33
GovPillar	67.86	18.88	8.43	98.57
Carbon_intensity*COVID	0.78	1.75	−4.61	8.78

Where $i = 1,2, \ldots, 265$ companies and $t = 1,2, \ldots, 7$, years of study. Since all the data is available for each company, the panel data is balanced.

5. Results

To determine whether the model is fixed effects or random effects, Hausman's test was applied (Table 4). The null hypothesis of this test states that there is no significant correlation between the individual effects of each company and the estimators. If the null hypothesis is accepted, the random effects model is used. Otherwise, the fixed effects model is used. The test indicates that the null hypothesis is not accepted. Therefore, the fixed effects model is used. Furthermore, an evaluation of multicollinearity within the independent variables was applied through the calculation of the Variance Inflation Factor (VIF). High VIF values (5–10) can indicate potential issues with multicollinearity. The results, as reported in Table 5, show that the VIF values range from 1.064 to 2.776, which are within acceptable limits, reassuring that concerns regarding multicollinearity are not of significant magnitude. The results of the panel model are presented in Table 6.

In terms of the model's goodness-of-fit, an R^2 of 0.16 is obtained. Although this value might appear low, it is consistent with the findings of other studies in the research field. Horváthová (2012) and Trinks et al. (2022) also reported R^2 values around 0.15 and 0.27 in their econometric models using panel data. Consequently, it can be concluded that

Table 1
Relationship between literature and variables used in this analysis.

Variable	Authors
Volatility	Görgen et al. (2020)
Size	Albuquerque et al. (2019), In et al. (2019), Görgen et al. (2020) and Trinks et al. (2020, 2022)
PPE	Görgen et al. (2020), Trinks et al. (2020), Bolton and Kacperczyk (2021) and Hsu et al. (2023)
ROA	Garvey et al. (2018), In et al. (2019), Trinks et al. (2020) and Reboredo and Ugolini (2022)
Scope 1 and Scope 2	Garvey et al. (2018), In et al. (2019), Bolton and Kacperczyk (2021), Trinks et al. (2022) and Zhang (2022)
Carbon_intensity	Ilhan et al. (2021)
ESGCombined	Albuquerque et al. (2019), Berg et al. (2021), Garzón-Jiménez and Zorio-Grima (2021) and Zhang (2022)
Each pillar (E-S-G)	In et al. (2019), Berg et al. (2021) and Agliardi et al. (2023)
Carbon_intensity*COVID	Song et al. (2021)

Table 3
Matrix of correlations.

	Volatility	Size	PPE	ROA	Scope1+Scope2	Carbon_intensity	ESGCombined	EnvPillar	SocPillar	GovPillar	Carbon*COVID
Volatility	1										
Size	0.068	1									
PPE	0.034	0.559	1								
ROA	−0.107	−0.369	−0.229	1							
Scope1 + Scope2	−0.002	0.303	0.777	−0.185	1						
Carbon_intensity	0.072	0.027	0.556	−0.174	0.887	1					
ESGCombined	−0.090	−0.007	0.075	−0.033	0.121	0.091	1				
EnvPillar	0.041	0.492	0.410	−0.182	0.297	0.123	0.442	1			
SocPillar	0.002	0.410	0.461	−0.179	0.385	0.194	0.506	0.596	1		
GovPillar	0.079	0.215	0.197	−0.025	0.181	0.137	0.358	0.161	0.253	1	
Carbon*COVID	0.317	0.057	0.249	−0.079	0.313	0.324	0.017	0.111	0.154	0.213	1

Table 4
Test of hausman.

chisq = 251.64
df = 10
p-value <2.2e-16

Table 5
VIF values of independent variables.

Volatility	1.064002
Size	2.530752
PPE	2.776351
ROA	1.238333
Carbon_intensity	1.949929
ESGCombined	1.948830
EnvPillar	2.043466
SocPillar	2.068989
GovPillar	1.299548
Carbon intensity*COVID	1.099819

Table 6
Data panel results.

Volatility	−0.648***
	(0.068)
Size	−0.040
	(0.035)
PPE	0.056***
	(0.020)
ROA	0.274*
	(0.146)
Carbon_intensity	−0.165***
	(0.013)
ESGCombined	0.001
	(0.001)
EnvPillar	0.002*
	(0.001)
SocPillar	−0.002**
	(0.001)
GovPillar	−0.001*
	(0.001)
Carbon intensity*COVID	0.00002
	(0.00002)
Observations	1855
R2	0.16104
F Statistic	30.3274*** df (= 10: 1580)

Note: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

the model's explanatory power is comparable to that of other studies included in the academic literature.

All economic-financial variables are significant, except for the size of the company's assets. Regarding the rest of the variables, there is a positive relationship between the volume of fixed assets and stock returns. The positive coefficient (0.111) indicates that, on average, a higher level of property, plant and equipment may have a positive impact on the outcome. Investors might interpret higher PPE as a sign of future growth potential. Moreover, a positive relationship with ROA is observed. The coefficient (0.274) suggests that on average firms with higher profitability, have higher stock returns. Regarding volatility, the negative and highly significant coefficient (−0.648) indicates that on average stocks with higher standard deviation (risk) have lower returns.

Regarding the variables related to climate risk, the results show that all of them are significant except for ESGCombined, a result that coincides with the work of Horváthová (2012) and Ennis et al. (2014). The lack of significance of the ESGCombined in the regression model is explained by the fact that the social and governance pillars have a negative relationship with performance, offsetting the environmental effect. Measures to improve social and governance aspects may require additional spending, affecting profitability. However, it is confirmed that a good rating in environmental issues is statistically significant and

Table 7
Summary of the hypotheses and coefficient effect for non-financial variables (climate risk and ESG factors)*.

	Hypotheses	Coefficient effect
Carbon Intensity	–	–
ESG Combined Score	+	*
Environmental Pillar Score	+	+
Social Pillar Score	+	–
Governance Pillar Score	+	–
Carbon Intensity * Covid	*	*

* The Scope 1+ Scope 2 variable has not been included in this table due to its high correlation with the rest of the variables. Therefore, hypothesis H1 cannot be verified.

is positively (0.002) associated with higher performance.

Regarding carbon intensity, it is observed that it has a negative and highly significant relationship with stock return, suggesting that on average companies with high carbon emissions have a lower stock returns, a result that coincides with those found by Garvey et al. (2018), In et al. (2019) and Trinks et al. (2022). This could be due to several factors, such as a negative image of the company, affecting its sales, or direct sanctions on its emissions, thereby increasing its costs. In any case, this result highlights the importance of adequately managing the environmental impact of companies to maintain good financial performance.

6. Discussion

Table 7 is a summary of the hypotheses and the effects found for each non-financial variable on stock returns. (+) indicates a positive relation with stock returns, meaning that higher values of the explanatory variables increase the value of stock returns; (−) implies the opposite relationship; and (*) denotes that the variable is not significant in the model.

It can be observed that the findings confirm hypothesis *H2*, suggesting a negative relationship between carbon intensity and stock returns, corroborating the results of previous studies by Garvey et al. (2018), In et al. (2019) and Trinks et al. (2022). Therefore, on average, companies with a higher carbon intensity tend to yield lower stock returns, highlighting the potential financial benefits of environmental practices. The effect of the interaction of COVID-19 with carbon intensity is not statically significant (hypothesis *H7*).

Contrary to initial expectations based on hypothesis *H3*, there is not a significant relationship between stock returns and the ESG Combined Score (Horváthová, 2012; Ennis et al., 2014). This finding is in line with the research of Berg et al. (2021), suggesting that older ESG data may not have had a meaningful influence on stock returns. However, this result differs from that found by Zhang (2022), who asserts that there is a positive relationship. This discrepancy might be due to differences in the dataset periods and the measurement of the ESG scores, as suggested by Berg et al. (2021) in their study.

The Environmental Pillar Score (hypothesis *H4*) was found to have a positive relationship with stock returns. This result reinforces the increasingly recognised role of strong environmental performance in generating higher returns, consistent with the findings of In et al. (2019) and Berg et al. (2021).

Last, the findings relating to the Social Pillar Score and the Governance Pillar Score (Hypotheses *H5* and *H6*) contradicted both our initial predictions and those of Berg et al. (2021) and In et al. (2019), who found that companies with good social and governance scores outperformed other companies in the stock market. However, this negative relationship is in line with other studies such as Abdi et al. (2020, 2022), who also found a negative impact derived from the possible costs of launching social policies. These costs seem to be an extra financial burden and are not immediately returned, at least in the short term.

7. Conclusions

The aim of this study was to examine the effect of climate risk on the financial performance of companies. Climate risk was measured using carbon intensity, the environmental pillar score and the ESGCombined score. The data of 265 European companies on the Stoxx 600 index was used.

Companies can play a critical role in mitigating climate change and creating a more sustainable future by integrating environmental considerations into their decision-making processes. However, this integration may impact their performance.

The analysed model shows that on average companies with higher carbon emissions have lower stock returns, a result that can be explained by regulatory pressure, investors' growing concern about environmental impact and the transition towards a low-carbon economy. This suggests that companies must seriously consider reducing their carbon emissions and adopt sustainable measures in their business model.

The ESG metric is not a good indicator as a measure of climate risk as it assesses the sustainable performance of a company in environmental, social and governance terms. The results suggest that a higher score in the environmental pillar is associated with companies' improved financial performance. However, higher scores in the social and governance aspects could negatively impact companies' stock returns. These findings suggest that the ESG Combined score is not an appropriate measure for assessing climate risk.

The present study was based on a specific sample of European companies and may not be representative of the global market, which implies a limitation in the generalisability of the results. Another limitation is the reliance on a single database for acquiring sustainability data, including Scope 1 and Scope 2 GHG emissions, ESG Scores and individual pillar scores. As stated by recent research (Berg et al., 2022), there is often a low correlation between ESG ratings from different providers (Refinitiv, Sustainalytics, MSCI, among others), suggesting substantial variability in how these metrics are assessed. Consequently, the findings of this paper may be specific to the methodology employed by the Eikon database and could differ if alternative databases were used.

For future lines of research, it is proposed to use other measures of carbon intensity widely accepted in the literature and proposed in the studies by Garvey et al. (2018), In et al. (2019), Görgen et al. (2020), Bolton and Kacperczyk (2021) and Trinks et al. (2022), among others.

CRediT authorship contribution statement

Maria-Glòria Barberà-Mariné: Conceptualization, Writing – review & editing, Supervision. **Laura Fabregat-Aibar:** Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Andreu-Michael Neumann-Calafell:** Investigation, Data curation, Writing – original draft, Writing – review & editing. **Antonio Terceño:** Conceptualization, Writing – review & editing, Supervision.

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.

Data availability

Data will be made available on request.

References

Abdi, Y., Li, X., Càmara-Turull, X., 2020. Impact of sustainability on firm value and financial performance in the air transport industry. Sustainability 12 (23), 1–22. https://doi.org/10.3390/su12239957.

Abdi, Y., Li, X., Càmara-Turull, X., 2022. Exploring the impact of sustainability (ESG) disclosure on firm value and financial performance (FP) in airline industry: the moderating role of size and age. Environ. Dev. Sustain. 24 (4), 5052–5079. https://doi.org/10.1007/s10668-021-01649-w.

Agliardi, E., Alexapoulos, T., Karvelas, K., 2023. The environmental pillar of ESG and financial performance: a portfolio analysis. Energy Econ. 120, 106598 https://doi.org/10.1016/j.eneco.2023.106598.

Albuquerque, R., Koskinen, Y., Zhang, C., 2019. Corporate social responsibility and firm risk: theory and empirical evidence. Manag. Sci. 65 (10), 4451–4469. https://doi.org/10.1287/mnsc.2018.3043.

Andersson, M., Bolton, P., Samama, F., 2016. Hedging climate risk. Financ. Anal. J. 72 (3) https://doi.org/10.2469/faj.v72.n3.4.

Berg, F., Fabisik, K., Sautner, Z., 2021. Is History Repeating Itself? the (Un)predictable Past of ESG Ratings (708/2020; Finance).

Berg, F., Kölbel, J.F., Rigobon, R., 2022. Aggregate confusion: the divergence of ESG ratings. Rev. Finance 26 (6), 1315–1344. https://ssrn.com/abstract=3438533.

Bhat, V.N., 1999. Does it pay to be green? Int. J. Environ. Stud. 56 (4), 497–507. https://doi.org/10.1080/00207239908711219.

Bolton, P., Kacperczyk, M., 2021. Do investors care about carbon risk? J. Financ. Econ. 142 (2), 517–549. https://doi.org/10.1016/j.jfineco.2021.05.008.

Chang, C.L., Ilomäki, J., Laurila, H., McAleer, M., 2020. Causality between CO2 emissions and stock markets. Energies 13 (11), 1–14. https://doi.org/10.3390/en13112893.

Cook, N., Heyes, A., 2022. Pollution pictures: psychological exposure to pollution impacts worker productivity in a large-scale field experiment. J. Environ. Econ. Manag. 114, 102691 https://doi.org/10.1016/J.JEEM.2022.102691.

Ennis, C.J., Montaser, T., Don Idoko, I., Idamu, S., Munir, A., Court, R., Gharfalkar, M., 2014. Exploring the links between carbon emissions performance, share price, and disclosure. In: Green Technology and Sustainable Development (GTSD) 2014 Conference. https://doi.org/10.13140/2.1.3564.1927.

European Commission, 2018. March 8). Sustainable Finance: Commission's Action Plan for a Greener and Cleaner Economy. Press Release. https://ec.europa.eu/commission/presscorner/detail/en/IP_18_1404.

European Parliament, 2019. Regulation (EU) 2019/2088 of the European Parliament and of the Council of 27 November 2019. On Sustainability-Related Disclosures in the Financial Services Sector. European Parliament.

European Parliament, 2020. Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020. On the Establishment of Framework to Facilitate Sustainable Investment, and Amending Regulation (EU) 2019/2088. European Parliament.

European Parliament, 2022. Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022. Amending Regulation (EU) 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as Regards Corporate Sustainability Reporting. European Parliament.

Eurosif, 2023. Eurosif Report on Climate-Related Data: the Investors' Perspective.

Fang, Z., Xie, J., Peng, R., Wang, S., 2021. Climate finance: mapping air pollution and finance market in time series. Econometrics 9 (4), 1–15. https://doi.org/10.3390/econometrics9040043.

Garcia-Jorcano, L., Jimenez-Martin, J.A., Robles, M.D., 2022. Carbon dioxide risk exposure: Co2Risk. Climate Risk Manag. 36 https://doi.org/10.1016/j.crm.2022.100435.

Garvey, G.T., Iyer, M., Nash, J., 2018. Carbon footprint and productivity: does the "E" in ESG capture efficiency as well as environment? J. Invest. Manag. 16 (1), 59–69. www.joim.com.

Garzón-Jiménez, R., Zorio-Grima, A., 2021. Effects of carbon emissions, environmental disclosures and CSR assurance on cost of equity in emerging markets. Sustainability 13 (2), 1–11. https://doi.org/10.3390/su13020696.

Giglio, S., Kelly, B., Stroebel, J., 2021. Climate finance. Annual Rev. Financial Econom. 13, 15–36. https://doi.org/10.1146/annurev-financial-102620.

Görgen, M., Jacob, A., Nerlinger, M., Riordan, R., Rohleder, M., Wilkens, M., 2020. Carbon Risk. https://doi.org/10.2139/ssrn.2930897.

Guaita Martínez, J.M., Puertas, R., Martín Martín, J.M., Ribeiro-Soriano, D., 2022. Digitalization, innovation and environmental policies aimed at achieving sustainable production. Sustain. Prod. Consum. 32, 92–100. https://doi.org/10.1016/j.spc.2022.03.035.

He, X., Luo, Z., Zhang, J., 2022. The impact of air pollution on movie theater admissions. J. Environ. Econ. Manag. 112, 102626 https://doi.org/10.1016/J.JEEM.2022.102626.

Horváthová, E., 2012. The impact of environmental performance on firm performance: short-term costs and long-term benefits? Ecol. Econ. 84, 91–97. https://doi.org/10.1016/j.ecolecon.2012.10.001.

Hsu, P.-H., Li, K., Tsou, C.-Y., 2023. The pollution premium. J. Finance 78 (3), 1343–1392. https://doi.org/10.1111/jofi.13217.

Ilhan, E., Sautner, Z., Vilkov, G., 2021. Carbon tail risk. Rev. Financ. Stud. 34 (3), 1540–1571. https://doi.org/10.1093/rfs/hhaa071.

In, S.Y., Park, K.Y., Monk, A., 2019. Is "Being Green" Rewarded in the Market?: an Empirical Investigation of Decarbonization and Stock Returns.

Martinez, L.B., Teruel, M., Terceño, A., 2016. Determinantes de spreads soberanos durante la reciente crisis financiera: el caso Europeo. Cuad. Adm. 29 (53) https://doi.org/10.11144/Javeriana.cao29-53.dssd.

Monasterolo, I., De Angelis, L., 2020. Blind to carbon risk? An analysis of stock market's reaction to the Paris Agreement. Ecol. Econ. 170 (April 2020), 1–19. https://doi.org/10.1016/j.ecolecon.2019.106571.

Oestreich, A.M., Tsiakas, I., 2015. Carbon emissions and stock returns: evidence from the EU emissions trading scheme. J. Bank. Finance 58, 294–308. https://doi.org/10.1016/j.jbankfin.2015.05.005.

Reboredo, J.C., Ugolini, A., 2022. Climate transition risk, profitability and stock prices. Int. Rev. Financ. Anal. 83, 1–20. https://doi.org/10.1016/j.irfa.2022.102271.

Rodríguez-García, M. del P., Galindo-Manrique, A.F., Cortez-Alejandro, K.A., Méndez-Sáenz, A.B., 2022. Eco-efficiency and financial performance in Latin American countries: an environmental intensity approach. Res. Int. Bus. Finance 59. https://doi.org/10.1016/j.ribaf.2021.101547.

Song, H.J., Yeon, J., Lee, S., 2021. Impact of the COVID-19 pandemic: evidence from the U.S. restaurant industry. Int. J. Hospit. Manag. 92 https://doi.org/10.1016/j.ijhm.2020.102702.

Tang, J., Li, J., 2022. Carbon risk and return prediction: evidence from the multi-CNN method. Front. Environ. Sci. 10, 1–12. https://doi.org/10.3389/fenvs.2022.1035809.

Trinks, A., Ibikunle, G., Mulder, M., Scholtens, B., 2022. Carbon intensity and the cost of equity capital. Energy J. 43 (2) https://doi.org/10.5547/01956574.43.2.atri.

Trinks, A., Mulder, M., Scholtens, B., 2020. An efficiency perspective on carbon emissions and financial performance. Ecol. Econ. 175 (106632), 1–12. https://doi.org/10.1016/j.ecolecon.2020.106632.

Tripathi, V., Jham, J., 2020. Corporate environmental performance and stock market performance: Indian evidence on disaggregated measure of sustainability. J. Corp. Account. Finance 31 (3), 76–97. https://doi.org/10.1002/jcaf.22444.

UNFCC, 2015. The Paris Agreement. United Nations Climate Change. In: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

Wang, C., Lin, Q., Qiu, Y., 2022. Productivity loss amid invisible pollution. J. Environ. Econ. Manag. 112, 102638 https://doi.org/10.1016/J.JEEM.2022.102638.

Yook, K., Hooke, J., 2020. A study of "fossil free" equity portfolio performance. J. Invest. ESG Special Issue 2020, 70–80. https://doi.org/10.3905/joi.2019.1.110.

Zhang, S.Y., 2022. Are investors sensitive to climate-related transition and physical risks? Evidence from global stock markets. Res. Int. Bus. Finance 62, 101710. https://doi.org/10.1016/j.ribaf.2022.101710.