Journal of Environmental Management 368 (2024) 122119

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Monetary policy impact on sustainability: Analyzing interest rates and corporate carbon emissions

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ARTICLE INFO

Keywords:
Interest rates
Carbon emissions
Paris agreement
Economic and policy uncertainty
Investor protection
Corporate governance

ABSTRACT

This study aims to investigate the impact of monetary policy on firms' carbon emissions. The primary focus is on the effect of increasing interest rates on the carbon footprint of companies, both prior to and following the implementation of the Paris Agreement in 2015. The results show that there is a positive relationship between interest rates and carbon emissions indicating that in the face of increasing interest rates, companies are more likely to choose short-term financial stability above long-term sustainability objectives. This positive relationship is less prevalent following the Paris Agreement suggesting that policymakers should continue to strengthen global climate initiatives as a pressure for companies to invest in green activities. Additional evidence suggests that the impact of interest rates on carbon emissions is particularly noticeable in situations characterized by elevated levels of economic and policy uncertainty, weak corporate governance quality, and poor investor protection. These results are robust to endogeneity concerns, alternative measures of interest rates, carbon emission, and alternative samples.

Disclaimer

The views and opinions expressed in this paper are those of the authors and do not reflect their respective institutions.

1. Introduction

Climate risk is largely mobilizing governments, shareholders, and civil society to reduce the adverse effects of climate change on the natural environment, human societies, and economies. Considering the recent evolution of the climate context driven by the remarkable speed of climate change, the pressure of international institutions (UN, IPCC, 2022), there is an increasing institutional pressure on firms to act on their climate impact to reduce carbon emissions (Haigh and Griffiths, 2009). Indeed, carbon emissions, predominantly in the form of greenhouse gases, are the principal contributor to the ongoing climate crisis, fuelling global warming and extreme weather events. Climate policies appear to be gaining the support of the stakeholders and the entire environment (Besio and Pronzini, 2014). Recognizing the urgent need to address climate change, the Paris Agreement (Conference of the Parties, COP, 2021), established in 2015 under the United Nations Framework Convention on Climate Change (UNFCCC), stands as a crucial global initiative. The agreement aims to limit global temperature increases to well below 2 °C above pre-industrial levels, with efforts to pursue a more ambitious target of 1.5 °C. The subsequent COP meetings have continued to emphasize the critical role of companies in the global effort to reduce carbon emissions that directly impact companies, compelling them to align their operations with more sustainable practices. Consequently, companies are facing increasing social and regulatory pressures to reduce their greenhouse gas (GHG) emissions.

Understanding the sources, drivers, and dynamics of carbon emissions is crucial to mitigate the adverse effects of climate change. The existing literature has explored numerous factors that could affect companies' carbon emissions. For instance, Azar et al. (2021) found that

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https://doi.org/10.1016/j.jenvman.2024.122119
Received 15 June 2024; Received in revised form 22 July 2024; Accepted 4 August 2024
Available online 12 August 2024

the "Big Three" (i.e., BlackRock, Vanguard, and State Street Global Advisors) have a positive effect on the reduction of firm's carbon emissions around the world, especially in later years where the three institutions become more committed to tackling Environmental, Social, and Governance concerns. Safiullah et al. (2022) showed that independent, long-term, domestic, and monitoring institutional ownership reduces carbon emissions by reducing energy consumption. Other studies examine corporate governance's effect by highlighting the board of directors' role in enhancing carbon performance (Konadu et al., 2022). Finally, the dynamic changes in the regulatory framework along with governmental pressures are key factors for the corporate leadership to proceed with investments in technology that minimizes its carbon emissions (e.g., Lopez et al., 2017; Ferrat, 2021 etc.).

While many studies have examined the driving factors of carbon emissions at the corporate level, the effect of macroeconomic factors is less explored. Previous studies have investigated, for instance, the impact of economic and policy uncertainty (EPU) (Jiang et al., 2019; Yu et al., 2021), oil price fluctuations (Wei et al., 2022); environmental regulations (Zhang et al., 2021); poverty (Khan, 2019) and inflation rate (Grolleau and Weber, 2024) on carbon emissions. However, the impact of monetary policy and particularly interest rates on firms' carbon emissions is yet to be explored.

The global economy has faced two exactly opposing monetary phases in the last two decades. In the aftermath of the global financial crisis, most industrialized economies came across negative interest rates as a new experiment in monetary policy adjustment to stimulate the receding economies. On the contrary and to maintain price stability, after the Covid-19 hit, major economies experienced unprecedented hikes in short-term interest rates. Indeed, to contain newborn inflationary pressures caused by the pandemic, Ukraine war-related supply disruptions, and energy price spikes, major central banks were compelled to shift from monetary easing to monetary tightening abruptly. In this context, it is more than evident that the monetary policy affects in various ways the real economy, though not all sectors symmetrically (e.g., Auer et al., 2021; Durante et al., 2022). Indeed, the significant risks associated with the "green mandate" of the Paris Agreement have ignited a contentious public discourse on the potential impact of a tight monetary policy on the rate of decarbonization. In particular, as a member of the ECB's Executive Board advocates, "as interest rates rise, investments in green technologies are becoming more expensive, something that eventually would jeopardize the pace of decarbonization".[1] The main concept stems from the fact that changes in macroeconomic policy, including monetary tightening, may put the so-called financial accelerator in motion (Bernanke et al., 1996). The main idea is that when an unfavorable event hits a company, for example, a rise in the interest rate, there is, beyond the direct impact on its earnings, an additional effect on the loss of retained earnings and the value of assets. Hence, decreasing the self-financing capacity will turn the company into a growing and more expensive external financing. Extensive research suggests that monetary policy affects the real economy via several transmission channels. Among all, the traditional interest rate and the credit channel of monetary policy are the most studied (Bernanke and Gertler, 1995) through which policies are transmitted until they affect investment.

In this respect, the literature examining the impact of the scale and scope of monetary policy and its contribution to green transition or, more specifically, on carbon emissions is a relatively new topic in academia. Research studies reveal that monetary policy can play a substantial role in combating climate change by prioritizing the support of climate change initiatives (e.g., Campiglio, 2016; Chan, 2020; Zeng et al., 2022 etc.). According to Jiang et al. (2019), changes in the real interest rate have an impact on industrial production, which in turn influences CO2 emissions in the opposite direction. Hence, expansionary (contractionary) monetary policies increase (decrease) CO2 emissions (e.g., Qingquan et al., 2020).

The until recently implemented unorthodox monetary strategy of ultra-low or even negative interest rates can impact carbon emissions through many channels that contribute to economic growth, like net exports and lowered national exchange rates to name a few (e.g., Chishti et al., 2021; Jianhui Ni and Ruan, 2023). More specifically, an expansionary monetary policy is a deteriorating environmental quality factor. Furthermore, a loose monetary strategy can have an indirect impact with an environmental footprint. Given that commercial banks are incentivized to expand lending in such an environment, it promotes technical advancements and encourages eco-friendly innovation, resulting in reduced carbon emissions (Wermuth et al., 2021). Consequently, this leads to a decrease in energy demand and a subsequent reduction in carbon emissions. In this line, Chan (2020), focusing on the close linkages between carbon emissions and macroeconomic policies, concluded that an increased interest rate disincentivizes or pauses producers from proceeding to new investments. Hence, a decrease in aggregate demand for goods and services leads to a decline in investment and consumption, with a subsequent effect on green transition. Indeed, higher interest rates lead to an increase in the cost of debt, making it more expensive for companies to invest in clean technologies or sustainable practices that reduce carbon emissions (e.g., Isiksal et al., 2019). Specifically, companies may be less likely to invest in long-term investments such as carbon-reducing projects during periods of high interest rates leading to increased carbon emissions. Our study aims to investigate the relationship between monetary policy and corporate carbon emissions. Particularly, our focus is on how interest rates affect a firm's carbon footprint before and after the Paris Agreement of 2015 for a panel of 2765 firms across 46 countries consisting of 12,647 observations from 2010 to 2021. It also highlights the effects of economic policy uncertainty, investor protection, strong governance and polluted industries in shaping this relationship.

We make several contributions to the ongoing literature on the drivers of carbon emissions (Yu et al., 2021; Wei et al., 2022; Zhang et al., 2021). Firstly, this study acknowledges the impact of monetary policy as an important factor affecting carbon emissions (e.g., Chishti et al., 2021), but the focus so far has been on the global economy. To the best of our knowledge, no published study has yet investigated the impact of contractionary monetary policies on carbon emissions at the firm level before and after the Paris agreement in 2015 involving a heterogeneous sample of multiple countries. We provide new evidence that rising interest rates will hinder companies from allocating funds to low-carbon initiatives. Second, this study enriches the relevant literature by examining the effect of macroeconomic indicators of carbon emissions, shedding additional light on the roles of economic policy uncertainty and investor protection (Jiang et al., 2019; Yu et al., 2021; Tee et al., 2023). This paper also relates to the literature on the economic consequences of interest rates that might reflect uncertainty about monetary policy. Johri et al. (2022) show that debt issuance declines when the world interest rate increases. Uribe and Yue (2006) find a significant effect of interest rates on emerging market fundamentals. Arora and Cerisola (2001) find that interest rates are a major determinant of sovereign spreads. Istrefi and Mouabbi (2018) find that interest rate uncertainty negatively influences the economy by affecting industrial production and unemployment. At a microeconomic level, Ghosh and Sensarma (2004) show that companies lower their long-term bank borrowings in favor of short-term borrowings post-monetary tightening. Luo et al. (2022) show that monetary policy uncertainty significantly reduces corporate risk-taking.

Finally, investigating the impact of interest rate policy on carbon emissions offers evidence that will provide better policy recommendations for governments and central banks to assess the consequences of policy implementation thoroughly and foster sustainable economic

[1] Speech on 10th January 2023 by Isabel Schnabel, Member of the Executive Board of the ECB, at the International Symposium on Central Bank Independence, Sveriges Riksbank, Stockholm.

growth. As Isiksal et al. (2019) conclude, policy makers should promote the stability of the real interest rates channel to reduce carbon emissions and encourage renewable energy investment by producing electricity using renewable sources. However, our paper differs from this perspective as we examine the real interest rate effect on corporate carbon emissions rather than considering emissions from the entire country's population. In addition, we do not solely focus on one country, but we expand our investigation to a vast number of countries with different characteristics, regulatory frameworks, and economic development.

The remainder of the paper is organized as follows. Section 2 presents the literature review and hypotheses. Section 3 describes the data and methodology, followed by Section 4, providing results and discussions. The last section concludes and provides policy implications.

2. Theoretical background

The main difficulty in this paper comes from two perspectives. First, there is a lack of formal theoretical work linking monetary policy to corporate carbon emissions. However, we are trying to link the monetary channels and neoclassical theories to achieve a straightforward and manageable framework. Second, the economic mechanism may be difficult to model. In this regard, we will need to employ a flexible empirical model to test our approach.

There are two opposing views on how interest rates could affect the carbon behavior of companies. The neoclassical view suggests that firms are more concerned about maximizing shareholder wealth and increasing firm performance (e.g., Stout, 2012). In a world of imperfection in capital markets and costly contract enforcement, adverse macroeconomic shocks, including monetary tightening, worsen agency problems between borrowers and lenders, limiting or making access to external finance more costly, thus negatively affecting firms' production and investment decisions. Bernanke et al. (1996) coined the term "financial accelerator" to describe that worsening credit market conditions may amplify adverse economic shocks. In other words, the notion of Financial Accelerator suggests that to the extent that shocks to the economy affect the net worth of borrowers, then the investment spending and production effects of the initial shock will be amplified. It is evident then that monetary policy significantly influences carbon emissions by affecting economic growth, interest rates, investment, and consumer spending (e.g., Ansuategi et al., 2015; Dafermos et al., 2018; etc.). Indeed, Aslam et al. (2021) and Jalil and Feridun (2011) demonstrate that monetary policy in China significantly influences economic development, which in turn indirectly affects carbon emissions.

In this sense, companies experiencing reduced profitability due to higher interest costs may cut expenditures on green technologies and sustainability measures (e.g., Isiksal et al., 2019). This view suggests that engaging in environmental initiatives is considered a misallocation of resources and an increase in costs, affecting firm performance and decreasing shareholders' wealth (Palmer et al., 1995). In addition, higher interest rates increase the cost of capital, making it more expensive for companies to finance investments and projects. As the cost of borrowing increases, firms may reduce capital-intensive projects, potentially affecting investments in environmentally friendly technologies and practices (Mahmoudian et al., 2023). In this line, rising interest rates may also increase a firm's financial distress (Kawai et al., 1996), impacting their ability to obtain credit and to invest in environmentally friendly initiatives. Companies facing higher interest expenses may prioritize short-term financial stability over long-term sustainability goals. This could reduce spending on environmental programs and initiatives, potentially leading to higher carbon emissions. Harrison and Berman (2016) show that corporate social responsibility activities are less likely to receive attention during difficult economic times due to cost reduction efforts. On the other hand, implementing a stringent monetary policy that increases interest rates impeded economic growth by reducing lending, investment, and consumption (Ansuategi et al., 2015), leading to a reduction in carbon emissions. Li and Zhang (2022) conducted a recent study that showed that just a 1% increase in policy rates reduced GDP growth by 0.3% and carbon emissions by 1.5% in the long term.

Furthermore, in order to efficiently and accurately assess firms' investment decisions under uncertainty in green technology, the Real Option model is put forward. The real options theory is a financial theory that extends the concept of financial options to real assets and investment decisions (Trigeorgis and Reuer, 2017). It provides a framework for analyzing and valuing strategic investment opportunities that companies may encounter. A real option is the right, without obligations, to defer, abandon, or adjust a project in response to the evolution of uncertainty (Dixit and Pindyck, 1994). By adopting the real options framework, companies can better capture the value of managerial flexibility and adapt to changing market conditions (Cesena et al., 2013). Analogous to a financial option, there is a value of delaying irreversible investment decisions until part of the uncertainty is resolved.[2] As interest rates rise, the present value of future cash flows associated with green projects decreases, potentially discouraging companies from pursuing environmentally friendly initiatives. Consequently, this could postpone investments aimed at reducing carbon emissions as companies weigh the financial implications of higher interest rates against the potential benefits of adopting sustainable practices. In other words, the firm owns a call option, which it may choose to exercise immediately or defer its exercise until a later date. This will result in a higher value on the option of waiting (Mc Donalds and Siegel, 1986).

The opposite view is based on the stakeholder theory (Friedman and Miles, 2002), stipulating that firms are not only pursuing the value maximization of shareholders' interest but are also committed to showing greater attention to their stakeholders' needs. It recognizes the importance of maintaining a balance between shareholders' and stakeholders' interests (Lin et al., 2017). In addition, by demonstrating a commitment to sustainability, companies can strengthen relationships with various stakeholders, including customers, suppliers, communities, and investors, building trust and cooperation among stakeholders (Koh et al., 2023). In challenging financial circumstances, companies that maintain or enhance their commitment to sustainability can strengthen their reputation and brand image and send a positive signal to their stakeholders. For instance, Yuan et al. (2022) show that during the economic policy uncertainty period, Chinese firms engage more in CSR activities to send a positive signal to their stockholders and that investors positively react to CSR engagement when EPU is high, resulting in increased firm value.

Companies that continue to reduce their carbon footprint demonstrate adaptability to changing market preferences. This adaptability can position them favorably in markets that increasingly prioritize environmental responsibility. This argument aligns with the resource-based view that encourages firms to invest in sustainable practices, including carbon emission reduction, to obtain a competitive advantage (Barney, 1995; Nidumolu et al., 2009). Companies may strategically allocate resources to develop and enhance green technologies even with high interest rates. These technologies can differentiate the firm in the market, potentially attracting investors and increasing firm value. Consequently, companies may continue to adapt and prioritize long-term competitive advantage by decreasing their carbon footprint over short-term financial pressures caused by high interest rates.

The preceding discussion leads to the two alternative hypotheses.

H1a. There is a positive relationship between interest rates and carbon emissions.

H1b. There is a negative relationship between interest rates and

[2] Please see Agaton (2021) for a review on utilizing the RO methods to CCS project valuation.

Table 1
Descriptive statistics.

	N	Mean	SD	p1	p25	p50	p75	p99
CO_2Total	12,647	12.7983	2.4945	6.3946	11.2070	12.8184	14.4261	18.0640
CO_2Direct	10,158	11.6737	3.1314	3.9703	9.5999	11.7427	13.8622	17.8894
CO_2Indirect	9,987	11.6423	2.2375	5.3214	10.4077	11.8828	13.1775	16.0127
RealInterest	12,647	2.2983	4.6501	−9.9247	0.7745	2.1561	3.3651	26.5821
Size	12,647	22.6425	1.4127	19.4685	21.6837	22.6161	23.5688	26.0365
CashRatio	12,647	0.1247	0.1160	0.0022	0.0445	0.0931	0.1653	0.5645
ROA	12,647	5.5892	7.8311	−18.8082	2.6049	5.2360	8.5912	26.3706
MTB	12,647	2.8853	3.2329	0.3053	1.0988	1.8691	3.3643	17.5139
Capex	12,647	5.5027	5.4311	0.0556	2.1648	4.1273	7.1761	25.7408
Leverage	12,647	0.2761	0.1577	0.0034	0.1620	0.2687	0.3751	0.6874
SalesGrowth	12,647	11.1007	126.5676	−38.2970	−1.6328	5.0063	13.5146	92.8977
PPE	12,647	0.3531	0.2462	0.0056	0.1442	0.3072	0.5306	0.9087
COD	12,647	0.0518	0.0559	0.0044	0.0266	0.0428	0.0615	0.2713
LnGDP	12,647	28.8448	1.5313	25.9650	27.8216	28.7784	30.4524	30.6944

Notes: This table reports descriptive statistics for a sample of 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions.

carbon emissions.

3. Research design

3.1. Data and sample description

We use data form different sources. We collect carbon emissions and firm-level corporate governance effectiveness data from the Thomson Reuters Asset 4 database. The country-level real interest rate, gross domestic product (GDP) and investor protection scores are all collected from the World Bank database. The country level of EPU is predicted by Baker et al. 's (2016) EPU database. Finally, the accounting and financial information used to estimate our control variables are collected from CompStat databases. After matching the dataset from these sources using firms' ISIN identifiers, a filtering process is performed on our matched dataset. We drop, first, firms with insufficient information on key variables. Second, we remove financial companies because different accounting standards govern them. The final sample consists of 2765 firms from 46 countries i.e., 12,647 observations from 2010 to 2021, setting 2021 the last available year in our sample.

Selecting a period ranging from 2010 to 2021, for empirical examination of the Paris accord provides a thorough perspective on the state of global climate policy before and after the accord. This timeframe allows us to analyze the initial effects of the agreement, place its implementation in the context of wider global events, and examine the changing scientific and technological environment that supports climate actions. Such a pattern is not that visible before 2010. Specifically, the chosen timeframe includes significant economic and political instances, such as the worldwide economic rebound after 2008, changes in key economies like the United States and China, and developing international relations, all of which impact the dynamics of climate policy. The period from 2010 to 2015, which preceded the Paris Agreement, is crucial for evaluating the starting conditions and patterns that the Paris Agreement aimed to tackle. During this time, there were important global climate policy advancements, such as the Copenhagen Accord (2009) and the Cancun Agreements (2010) among others, which paved the way for the Paris negotiations.

3.2. Carbon emissions

According to prior literature, our dependent variable, carbon emissions, is measured trough three measures (Bolton and Kacperczyk, 2021). The first measure, *CO_2Total*, as the natural logarithm of total carbon emissions calculated as the sum of direct and indirect carbon emissions. The second is the natural logarithm of direct carbon emissions (*CO2Direct*). The third measure is the natural logarithm on indirect carbon emissions (*CO_2Indirect*).

3.3. Interest rates

Our study uses the real interest rate (*RealInterest*), which is measured as the lending interest rate adjusted for inflation as measured by the GDP deflator following Isiksal et al. (2019). The real interest rate is considered as more refined proxy than the nominal interest rate. The real interest rate reflects the alteration in purchasing power generated from an investment or given up by the borrower.

3.4. Baseline regression model

To examine the effect of interest rates on firms' carbon emissions, we use OLS regressions. The year, industry and country influence are controlled by the year, industry, and country fixed effects. We winsorize all variables at the 1% level. To clearly depict the relationships between the relevant variables in our research model, we estimate the following regression equation:

$$\begin{aligned} Carbon\ emissions_{i,j,t} = {} & \beta_0 + \beta_1 RealInterest_{j,t} + \beta_2 Size_{i,j,t} + \beta_3 CashRatio_{i,j,t} \\ & + \beta_4 ROA_{i,j,t} + \beta_5 MTB_{i,j,t} + \beta_6 Capex_{i,j,t} \\ & + \beta_7 Leverage_{i,j,t} + \beta_8 SalesGrowth_{i,j,t} + \beta_9 PPE_{i,j,t} \\ & + \beta_{10} COD_{i,j,t} + \beta_{11} LnGDP_{j,t} + Year\_FE \\ & + Industry\_FE + Country\_FE + \varepsilon_{i,j,t} \end{aligned} \tag{1}$$

Where *i, j, t* denote firm, country and year, respectively.

$Carbon\ emissions_{i,j,t}$ is one of three measures of firms' carbon emissions (i.e., *CO_2Total, CO2Direct, CO_2Indirect*).

The primary variable of interest is *$RealInterest_{j,t}$*. We should expect coefficient β_1 to be either positive or negative ($\beta_1 >< 0$) so as to formally inspect which of the two hypotheses holds.

We control for as many firm-level and country-level variables. *Size* is firm size proxied as the natural logarithm of total assets since larger firms may have different resource allocation strategies and environmental practices than smaller firms (Rajan and Zingales, 1995). Cash ratio (*CashRatio*) is computed as the ratio of cash and cash equivalent to total assets (Opler et al., 1999). The availability of cash influences a firm's ability to invest in sustainable initiatives. Return on assets (*ROA*) is proxied as the percentage of firm income scaled by total assets. Profitable firms may have the financial capacity to invest in sustainable practices. Market-to-book ratio (*MTB*), measured as the firm's market value scaled by the firm's book value. MTB captures the market's valuation of a firm relative to its book value. It may signal investor perceptions of the firm's environmental and sustainability practices. Capital expenditure (*Capex*), is computed as the percentage of the ratio of net investment expenditures to total assets. Capex as a percentage of total assets reflects a firm's investment in long-term projects. This

Table 2
Pearson correlation coefficients.

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
CO_2Total	1	1													
CO_2Direct	2	0.9303***	1												
CO_2Indirect	3	0.7817***	0.5997***	1											
RealInterest	4	−0.0058	0.0032	−0.0672***	1										
Size	5	0.5628***	0.4772***	0.5571***	−0.0011	1									
CashRatio	6	−0.2874***	−0.3039***	−0.2048***	−0.0040	−0.1539***	1								
ROA	7	−0.0392***	−0.0425***	0.0142	0.0479***	−0.0490***	0.1137***	1							
MTB	8	−0.1856***	−0.1866***	−0.0898***	0.0052	−0.1162***	0.2270***	0.3078***	1						
Capex	9	0.2246***	0.2242***	0.0961***	0.0268***	−0.0196**	−0.1181***	0.0602***	0.0120	1					
Leverage	10	0.1778***	0.1514***	0.0472***	0.0674***	0.1890***	−0.2926***	−0.1668***	0.0665***	0.0420***	1				
SalesGrowth	11	−0.0364***	−0.0256***	−0.0668***	0.0031	−0.0351***	0.0457***	0.0322***	0.0190**	0.0858***	−0.0203**	1			
PPE	12	0.4538***	0.4683***	0.2056***	−0.0098	0.0657***	−0.3667***	−0.1220***	−0.1770***	0.5022***	0.2592***	−0.0023	1		
COD	13	−0.0337***	−0.0119	−0.0566***	0.1063***	−0.1929***	0.0130	0.0479***	0.0273***	0.0185**	−0.1765***	0.0120	0.0446***	1	
LnGDP	14	0.1014***	0.0827***	0.1913***	−0.1060***	0.2412***	0.0677***	−0.0152*	0.1717***	−0.0253***	0.0400***	−0.0196**	−0.0844***	−0.0918***	1

Notes: This table reports Pearson correlation coefficients among our variables. The sample covers 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions. ***, **, and * are statistical significance at the 1%, 5% and 10% levels.

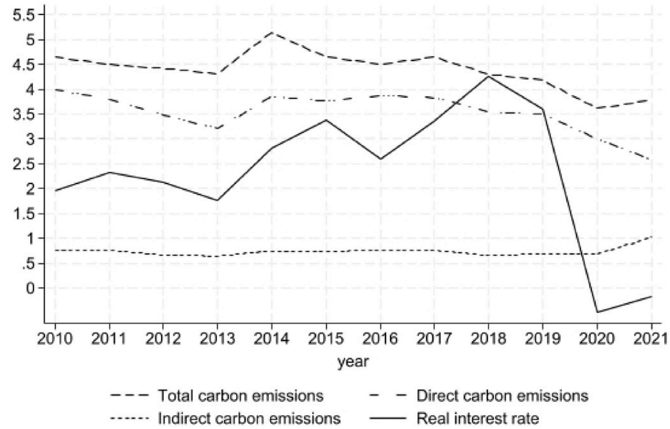

Fig. 1. Evolution of carbon emissions and real interest rates.

variable helps assess the extent to which firms commit resources to environmentally sustainable initiatives. Firm leverage (*Leverage*) proxied as the ratio of total debt to total assets. Leverage measures the extent to which a firm relies on debt. High leverage may influence a firm's ability to invest in sustainability due to financial constraints (Frank and Goyal, 2009; Kumar and Firoz, 2018). Firms' sales growth (*SalesGrowth*), computed as the difference between net sales revenues for the current and previous years scaled by the sales of the previous year multiplied by 100. Sales growth reflects the expansion of a firm's operations. Higher sales growth may be associated with increased carbon emissions (Kumar and Firoz, 2018). Firm long-term assets (*PPE*), measured as the property, plant and equipment assets scaled by total assets. It provides insights into a firm's commitment to sustainable

Table 3
Interest rate and carbon emissions.

	(1)	(2)	(3)
	CO_2Total	CO_2Direct	CO_2Indirect
RealInterest	0.0054**	0.0086***	0.0047
	(0.0021)	(0.0030)	(0.0028)
Size	0.5496***	0.5881***	0.5274***
	(0.0203)	(0.0294)	(0.0278)
CashRatio	−0.0529	−0.5346***	0.0365
	(0.0967)	(0.1395)	(0.1307)
ROA	−0.0002	0.0011	−0.0005
	(0.0008)	(0.0012)	(0.0012)
MTB	−0.0009	0.0020	0.0032
	(0.0027)	(0.0038)	(0.0036)
Capex	−0.0069***	−0.0034	−0.0079***
	(0.0016)	(0.0023)	(0.0022)
Leverage	−0.1806**	−0.0005	−0.2128**
	(0.0747)	(0.1083)	(0.1028)
SalesGrowth	0.0001	0.0001	0.0001**
	(0.0000)	(0.0001)	(0.0000)
PPE	0.6319***	0.4892***	0.9901***
	(0.0873)	(0.1311)	(0.1223)
COD	0.2177*	0.5278***	0.2865*
	(0.1158)	(0.1678)	(0.1562)
LnGDP	−0.5708***	−0.6372***	−0.2748***
	(0.0546)	(0.0822)	(0.0779)
Constant	16.6471***	16.5511***	7.3218***
	(1.5316)	(2.2981)	(2.1754)
Year_FE	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes
Observations	12,647	10,158	9987
R-squared	0.0864	0.0650	0.0615

Notes: This table reports the results on the effect of real interest rate on corporate carbon emissions. The sample covers 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions. Standard errors in parentheses. ***, **, and * are statistical significance at the 1%, 5% and 10% levels.

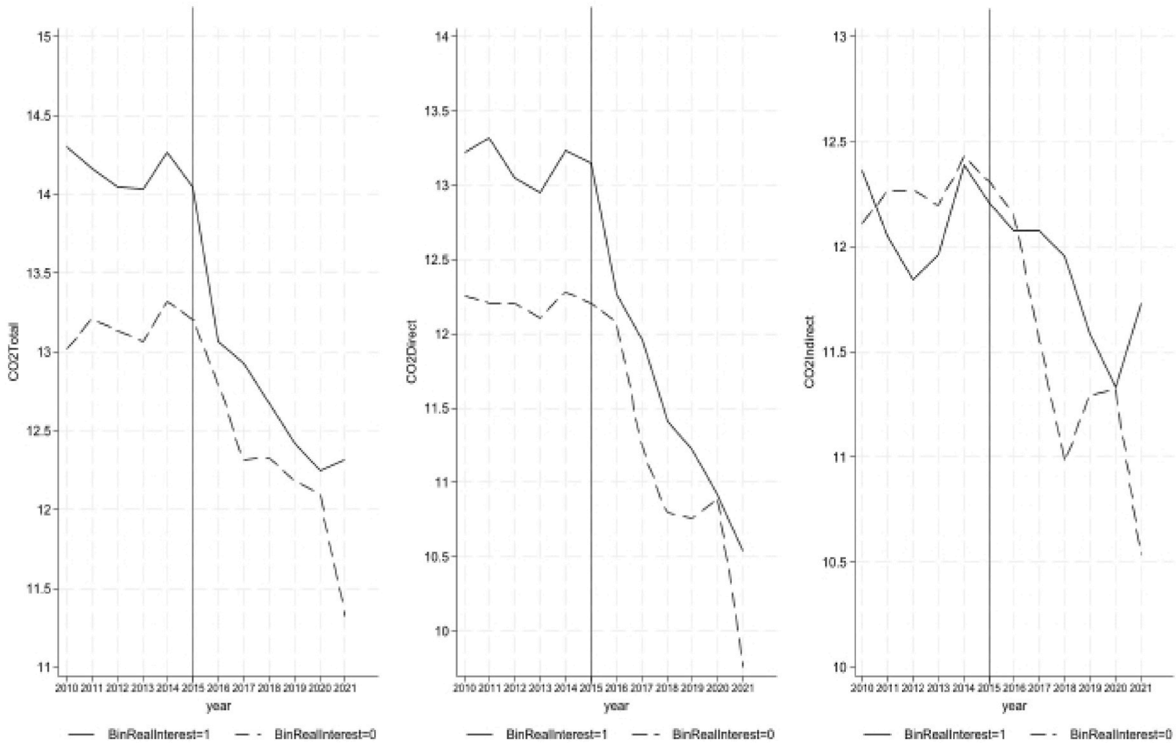

Fig. 2. Trends of total, direct and indirect emissions (in logarithm) for treated and control group.

practices (Wen et al., 2021). Firm cost of debt (*COD*) is computed as the interest expenditures scaled by total debt. It is relevant for understanding financial constraints that may affect sustainability investments (Faulkender and Petersen, 2006). Additionally, we control for the natural logarithm of GDP (*LnGDP*) as a country-level variable that may impact carbon emissions (Attílio et al., 2023).

4. Results and discussion

4.1. Descriptive statistics

The summary statistics for all samples are reported in Table 1. The mean value of total carbon emissions, direct carbon emissions, and indirect emissions are 12.7983, 11.6737, and 11.6423, respectively. These values are similar to the values reported by Azar et al. (2021). The mean value of real interest rate is 2.2983%.

Table 2 reports the Pearson's correlation. Table 2 shows that the correlations between all independent variables are <0.8. Indeed, collinearity is not a serious problem that we should treat.

Fig. 1 presents the evolution of the average values of total emissions, direct emissions, indirect emissions, and real interest rate across our studied period. We observe a decrease of total and direct carbon emissions after 2015, due to Paris agreement. The average of indirect emissions is stable throughout the study period. As for the real interest rate, we notice a high decrease between 2019 and 2020, due to the increase of inflation rate during the covid-19 period. Fig. 1 also shows that the carbon emissions (total and direct) and real interest rate evolves in the same direction in the period preceding the Paris agreement in 2015, providing some preliminary anecdotal evidence supporting the first hypothesis developed in the previous section.

4.2. Baseline regression

Table 3 reports the results on the effect of real interest rates on carbon emissions. It shows a positive and significant effect of real interest rate on total and direct carbon emissions, suggesting that firms in countries with high real interest rates emit more carbon. Our findings confirm our hypothesis H1a, suggesting that companies facing higher interest expenses may prioritize short-term projects over long-term sustainability projects. This reduces spending on environmental programs and initiatives, resulting in high carbon emissions. Our results contradict those of Attílio et al. (2023), who show that a monetary contraction in a country is associated with lower domestic emissions both in the short- and the long-run. While Attílio et al. (2023) focus on the impact of monetary contraction on CO2 emissions in four major regions (i.e., US, UK, Japan and the Eurozone), our study delves into the consequences of higher interest rates, emphasizing the potential trade-off between financial stability and sustainability goals for 46 countries. These differing outcomes highlight the nuanced relationship between monetary policy and environmental outcomes, emphasizing the need for a more granular understanding of the mechanisms at play.

However, our results are consistent with Harrison and Berman (2016) who show that, corporate social responsibility activities are less likely to receive attention during difficult economic times. The alignment of our results with Harrison and Berman's (2016) findings, indicating that corporate social responsibility activities are less prioritized during challenging economic periods, provides additional theoretical insights. The observed positive relationship between real interest rates and carbon emissions suggests that firms may, indeed, be compelled to relegate sustainability initiatives during times of economic difficulty. This could be attributed to the financial constraints imposed by higher interest rates, leading to a strategic shift in resource allocation away from environmental endeavors.

Furthermore, our results contribute to the broader theoretical discourse on the interplay between economic conditions, financial decision-making, and corporate sustainability. The positive effect of real interest rates on carbon emissions underscores the complex dynamics that firms navigate in balancing financial stability and environmental responsibility. The theoretical interpretation suggests that the impact of interest rates on corporate behavior extends beyond immediate financial

Table 4
Difference-in-difference based on the Paris Agreement in 2015.

Panel A. Role of Paris Agreement

	(1)	(2)	(3)
	CO_2Total	CO_2Direct	CO_2Indirect
BinRealInterest	1.0217***	0.4865***	−0.1164
	(0.0800)	(0.1095)	(0.0762)
Post2015	1.8097***	0.6920***	−0.0587
	(0.0652)	(0.0861)	(0.0658)
BinRealInterest*Post2015	−1.2294***	−0.4023***	0.1027
	(0.0923)	(0.1240)	(0.0876)
Control variables	Yes	Yes	Yes
Year_FE	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes
Observations	5695	4645	4555
R-squared	0.4607	0.5473	0.4822

Panel B. Role of Paris Agreement and polluted industries

	(1)	(2)	(3)
	CO_2Total	CO_2Direct	CO_2Indirect
BinRealInterest	0.3847***	0.3770***	0.0254
	(0.0534)	(0.0701)	(0.0481)
Post2015	1.4272***	0.6294***	0.0246
	(0.0555)	(0.0720)	(0.0541)
Polluted	0.4607***	1.0042***	0.0234
	(0.0601)	(0.0748)	(0.0522)
BinRealInterest*Post2015*Polluted	−0.6333***	−0.4629***	−0.1798***
	(0.0766)	(0.0987)	(0.0698)
Control variables	Yes	Yes	Yes
Year_FE	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes
Observations	5695	4645	4555
R-squared	0.4577	0.5555	0.4825

Panel C. Role of Paris Agreement and developed countries

	(1)	(2)	(3)
	CO_2Total	CO_2Direct	CO_2Indirect
BinRealInterest	0.4829***	0.3390***	−0.0263
	(0.0618)	(0.0833)	(0.0587)
Post2015	1.4823***	0.5950***	−0.0049
	(0.0575)	(0.0746)	(0.0560)
Developed	3.4939***	5.6441***	−2.3695*
	(1.1308)	(1.9905)	(1.3960)
BinRealInterest*Post2015*Developed	−0.7075***	−0.2980***	−0.0281
	(0.0878)	(0.1152)	(0.0813)
Control variables	Yes	Yes	Yes
Year_FE	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes
Observations	5695	4645	4555
R-squared	0.4564	0.5471	0.4821

Notes: This table reports the DiD approach results on the effect of Paris Agreement on the relationship between real interest rate and corporate carbon emissions. The sample covers 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions. Standard errors in parentheses. ***, **, and * are statistical significance at the 1%, 5% and 10% levels.

decisions, influencing the broader spectrum of sustainability practices.

The results pertaining to the control variables in our study not only contribute to the robustness of our findings but also align with existing literature, reinforcing the validity of our empirical approach. Previous research, particularly Safiullah et al. (2022) and Tee et al. (2023), bolsters the credibility of our model and provides additional insights into the determinants of carbon emissions. Firstly, the positive relationship observed between company size and carbon emissions is consistent with Safiullah et al. (2022), suggesting that larger companies tend to exhibit higher carbon emissions. This result may stem from the scale of operations and resource utilization in larger firms, underscoring the need for tailored sustainability measures in these organizations. Secondly, the positive association between the presence of long-term assets and carbon emissions aligns with Tee et al. (2023), indicating that firms with substantial long-term assets may engage in activities or processes that contribute to higher carbon emissions. The positive relationship between the cost of debt and carbon emissions is also in line with existing literature. Higher costs of debt may induce financial constraints, potentially diverting resources away from environmentally friendly initiatives. This is consistent with the notion that firms facing higher financial burdens may be less inclined to invest in sustainable practices.

On the other hand, the inverse relationships observed in our study are noteworthy. The negative associations between capital expenditure, leverage levels, and GDP with carbon emissions indicate that firms with higher capital expenditure, lower leverage, and operating in higher GDP environments tend to exhibit lower carbon emissions (Stern, 2011).

Table 5
The effect of EPU.

	(1)	(2)	(3)	(4)	(5)	(6)
	CO_2Total	CO_2Total	CO_2Direct	CO_2Direct	CO_2Indirect	CO_2Indirect
	High EPU	Low EPU	High EPU	Low EPU	High EPU	Low EPU
RealInterest	0.0094**	−0.0003	0.0071	0.0081	0.0146**	−0.0028
	(0.0047)	(0.0038)	(0.0060)	(0.0061)	(0.0058)	(0.0063)
Size	0.4790***	0.4765***	0.4421***	0.4560***	0.5022***	0.4041***
	(0.0362)	(0.0274)	(0.0460)	(0.0446)	(0.0441)	(0.0457)
CashRatio	−0.3827**	0.0294	−0.8414***	−0.5246**	−0.3065	−0.0657
	(0.1670)	(0.1262)	(0.2130)	(0.2114)	(0.2014)	(0.2162)
ROA	−0.0019	−0.0006	−0.0010	0.0011	0.0020	0.0007
	(0.0014)	(0.0012)	(0.0018)	(0.0019)	(0.0018)	(0.0020)
MTB	−0.0018	−0.0035	0.0027	−0.0037	−0.0006	−0.0049
	(0.0045)	(0.0041)	(0.0058)	(0.0063)	(0.0054)	(0.0066)
Capex	−0.0038	−0.0094***	−0.0029	−0.0088***	−0.0058	−0.0135***
	(0.0029)	(0.0020)	(0.0037)	(0.0033)	(0.0036)	(0.0034)
Leverage	−0.2591*	−0.2851***	0.0637	0.0221	−0.0380	−0.2049
	(0.1431)	(0.0967)	(0.1816)	(0.1605)	(0.1740)	(0.1648)
SalesGrowth	0.0001	−0.0000	0.0003**	−0.0000	0.0000	0.0001
	(0.0001)	(0.0000)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
PPE	0.6908***	0.7393***	0.3957*	0.5123**	0.6682***	0.9861***
	(0.1763)	(0.1180)	(0.2353)	(0.2092)	(0.2260)	(0.2153)
COD	0.2401	0.2416*	0.4158	0.4079*	0.7261***	0.1133
	(0.2109)	(0.1421)	(0.2911)	(0.2183)	(0.2709)	(0.2219)
LnGDP	−0.8323***	−0.3495***	−0.7064***	−0.2659**	−0.2565	−0.0723
	(0.1851)	(0.0735)	(0.2418)	(0.1250)	(0.2365)	(0.1276)
Constant	26.2221***	12.2915***	22.2291***	9.3614***	7.6558	4.5457
	(5.3906)	(2.1333)	(7.0434)	(3.6086)	(6.9000)	(3.6859)
Year_FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes	Yes	Yes	Yes
Chow-test	3.94 (0.0471)		1.41 (0.2347)		6.32 (0.0120)	
Observations	4626	5542	3997	4032	3923	3943
R-squared	0.0850	0.1055	0.0651	0.0589	0.0754	0.0701

Notes: This table reports the results on the effect of EPU on the relationship between real interest rate and corporate carbon emissions. The sample covers 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions. Standard errors in parentheses. ***, **, and * are statistical significance at the 1%, 5% and 10% levels.

These findings contribute valuable insights to the ongoing discourse on the determinants of carbon emissions, shedding light on the role of investment decisions, financial structure, and economic context.

4.3. Difference-in-difference in carbon emissions and interest rates: The Paris Agreement effect

In this section, we focus on the Paris Agreement in 2015 as an exogenous shock to firms, bankers, and countries' decision-makers awareness of carbon emissions. Fig. 2 displays the mean levels of total, direct, and indirect emissions in logarithm for treated and control group pre- and post-Paris Agreement 2015. We define the treated and control groups based on a dummy variable that takes one if the value of real interest rates is above the sample median (*BinRealInterest*). The treated group includes firms in countries that have high real interest rates (above the sample median). The control group includes firms in countries with real interest rates below the sample median. The figure shows a higher level of total and direct emissions for firms in treated group, supporting our main findings. It also shows a significant decrease in carbon emissions after 2015. This decrease is more important for treated firms, suggesting that Paris Agreement has probably improved the awareness of firms in treated group to reduce carbon emissions more effectively. Also, Fig. 2 represents a visual examination of the parallel trend assumption of difference-in-difference methodology. It shows that carbon emissions of treated, and control group move in similar pattern pre- and post- Paris Agreement.

To empirically examine the role of Paris Agreement (2015), we combine the difference-in-differences methodology (DiD) with the propensity score matching approach, following Heckman et al. (1997). After defining treated and control groups based on the sample median of real interest rates, we employ a one-to-one matching method to match each firm in the treatment group to a firm in the control group, using the nearest neighbor matching technique with a maximum distance of 5%. The matching is based on the propensity scores estimated through logit regression in which the dependent variable is *BinRealInterest* and the independent variables are all control variables in Equation (1). We then run our difference-in-differences analysis on the final sample of all treated and control firm-year observations during 2010–2021, using the following equation:

$$\begin{aligned} Carbon\ emissions_{i,j,t} = {} & \beta_0 + \beta_1 BinRealInterest_{j,t} + \beta_2 Post2015 + \beta_3 BinRealInterest_{j,t} * Post2015 + \beta_4 Size_{i,j,t} + \beta_5 CashRatio_{i,j,t} + \beta_6 ROA_{i,j,t} + \beta_7 MTB_{i,j,t} \\ & + \beta_8 Capex_{i,j,t} + \beta_9 Leverage_{i,j,t} + \beta_{10} SalesGrowth_{i,j,t} + \beta_{11} PPE_{i,j,t} + \beta_{12} COD_{i,j,t} + \beta_{13} LnGDP_{j,t} + Year\_FE + Industry\_FE + Country\_FE \\ & + \varepsilon_{i,j,t} \end{aligned} \quad (2)$$

Table 6
The effect of investors protection.

	(1)	(2)	(3)	(4)	(5)	(6)
	CO_2Total	CO_2Total	CO_2Direct	CO_2Direct	CO_2Indirect	CO_2Indirect
	High IP	Low IP	High IP	Low IP	High IP	Low IP
RealInterest	−0.0047	0.0090***	0.0016	0.0083**	−0.0130**	0.0122***
	(0.0037)	(0.0033)	(0.0059)	(0.0040)	(0.0059)	(0.0040)
Size	0.4675***	0.5521***	0.5446***	0.5407***	0.4590***	0.4951***
	(0.0235)	(0.0365)	(0.0403)	(0.0432)	(0.0405)	(0.0426)
CashRatio	−0.1909*	−0.1359	−0.3832**	−0.5626***	−0.2281	0.1223
	(0.1094)	(0.1781)	(0.1874)	(0.2138)	(0.1880)	(0.2116)
ROA	0.0005	0.0005	−0.0016	0.0021	0.0010	−0.0009
	(0.0008)	(0.0017)	(0.0016)	(0.0018)	(0.0016)	(0.0020)
MTB	0.0028	0.0043	0.0087	−0.0009	0.0034	0.0087
	(0.0034)	(0.0046)	(0.0055)	(0.0055)	(0.0055)	(0.0055)
Capex	−0.0070***	−0.0058**	−0.0020	−0.0030	−0.0075**	−0.0088***
	(0.0017)	(0.0028)	(0.0028)	(0.0033)	(0.0030)	(0.0033)
Leverage	−0.0895	−0.5121***	0.1084	−0.2524	−0.3776***	−0.4015**
	(0.0835)	(0.1374)	(0.1428)	(0.1605)	(0.1443)	(0.1612)
SalesGrowth	−0.0001	0.0001	−0.0000	0.0002	0.0000	0.0002
	(0.0000)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
PPE	0.4382***	0.8562***	0.3537**	0.8130***	0.7823***	1.1160***
	(0.0959)	(0.1680)	(0.1781)	(0.2025)	(0.1817)	(0.2011)
COD	−0.0180	0.2193	0.3923*	0.4899**	−0.0855	0.3841*
	(0.1256)	(0.1999)	(0.2155)	(0.2325)	(0.2109)	(0.2308)
LnGDP	−0.5001***	−0.3965***	−0.2842*	−0.7058***	−0.2850*	0.1162
	(0.0825)	(0.1004)	(0.1468)	(0.1194)	(0.1478)	(0.1188)
Constant	16.7224***	11.3920***	7.6556*	19.3862***	9.5141**	−3.4605
	(2.3820)	(2.7610)	(4.2305)	(3.2830)	(4.2556)	(3.2678)
Year_FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes	Yes	Yes	Yes
Chow-test	7.60 (0.0059)		4.37 (0.0366)		9.36 (0.0022)	
Observations	6178	5853	4651	5017	4534	4956
R-squared	0.1105	0.0804	0.0693	0.0674	0.0606	0.0701

Notes: This table reports the results on the effect of investors protection on the relationship between real interest rate and corporate carbon emissions. The sample covers 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions. Standard errors in parentheses. ***, **, and * are statistical significance at the 1%, 5% and 10% levels.

Panel A of Table 4 presents the results for the samples in which firms with high interest rates are matched to low-interest rate firms. The coefficients of the interaction term (*BinRealInterest*Post2015*) are negative and significant when we use total and direct emissions as dependent variables, suggesting that the Paris agreement shock increases firms' focus on reducing carbon emissions. This aligns with the growing recognition of the Paris Agreement as a catalyst for heightened corporate awareness and commitment to environmental responsibility (Falkner, 2016), highlighting the potential success of global climate initiatives in fostering a transition towards more sustainable corporate practices.

Companies' response to Paris Agreement may be driven by potential mechanisms related, for instance, to their industry type (Safiullah et al., 2022), country regulation quality (Li et al., 2023), country technological advancement (Ahmad et al., 2020), and public awareness concerning carbon emissions (Jamali and Carroll, 2017). To examine if these mechanisms drive the effect of interest rates on carbon emissions after the Paris agreement, we used two variables. The first one is *Polluted* proxied as dummy variable that takes one if the firm operate in the sectors with first-digit Standard Industrial Classification codes "1," "2," and "4,". The second variable, *Developed,* is a dummy variable takes one if the firm is from a developed country, since developed countries have more stringent environmental regulation, are more technologically advanced and have greater awareness about sustainable development (Jamali and Carroll, 2017; Li et al., 2023). Then, we interact these variables with the interaction term between *BinRealInterest* and *Post2015,* following Safiullah et *al.* (2022).

The results reported in Panel B of Table 4 show that the coefficients of the triple interaction term (*BinRealInterest*Post2015*Polluted)* are all negative and significant, suggesting that firms from countries with high real interest rates that operate in polluted industries are more aware about carbon emissions reduction after the Paris agreement. Panel C of Table 4 shows also that the coefficients of the interaction term *(BinRealInterest*Post2015*Developed)* are negative and statistically significant, indicating that firms form developed countries that have higher real interest rates have reduced their carbon emissions more effectively after the Paris agreement in 2015.

4.4. Alternative evidence

4.4.1. The effect of EPU

According to the real options theory, firms are less incentivized to do sustainable actions during economic uncertainty due to the high volatility in the cash flow and the option value of waiting is higher during such periods (Pindyck, 1991; Dixit et al., 1994). Still, the lengthy and partially irreversible nature of such investments adds further ambiguity to the project and the corporate leadership may become more reluctant to promote green projects. Indeed, in this context, investing in green technology requires a significant amount of capital expenditure and has a lengthy period of time before the investment pays off (Kuo and Smith, 2018), which in some cases cannot be implemented without the government's support such as subsidies and advantageous tax incentives (Desheng et al., 2021; Latupeirissa and Adhariani, 2020). Hence, during high uncertainty periods and due to the substantial expenses involved, companies may delay future investment in green technologies until economic worries diminish (Tee et al., 2023).

Accordingly, we expect that the effect of interest rate on carbon emissions is more pronounced in the presence of high EPU. To test this expectation, we split our sample into two sub-samples according to the level of EPU score predicted from Baker et al. 's (2016) database. Then,

Table 7
The effect of corporate governance effectiveness.

	(1)	(2)	(3)	(4)	(5)	(6)
	CO_2Total	CO_2Total	CO_2Direct	CO_2Direct	CO_2Indirect	CO_2Indirect
	Good CG	Poor CG	Good CG	Poor CG	Good CG	Poor CG
RealInterest	0.0025	0.0111***	0.0038	0.0101**	0.0001	0.0177***
	(0.0027)	(0.0036)	(0.0050)	(0.0040)	(0.0034)	(0.0054)
Size	0.6920***	0.4418***	0.4748***	0.7414***	0.6075***	0.4911***
	(0.0310)	(0.0262)	(0.0339)	(0.0496)	(0.0415)	(0.0372)
CashRatio	0.2307	−0.4114***	−0.8647***	−0.2493	0.3667*	−0.3468**
	(0.1465)	(0.1262)	(0.1635)	(0.2306)	(0.1948)	(0.1766)
ROA	−0.0001	0.0007	0.0016	0.0009	−0.0017	0.0021
	(0.0012)	(0.0011)	(0.0015)	(0.0020)	(0.0017)	(0.0017)
MTB	0.0046	0.0003	0.0033	0.0062	0.0087	0.0056
	(0.0049)	(0.0033)	(0.0042)	(0.0073)	(0.0063)	(0.0045)
Capex	−0.0027	−0.0094***	−0.0121***	0.0042	0.0008	−0.0179***
	(0.0022)	(0.0023)	(0.0031)	(0.0033)	(0.0028)	(0.0035)
Leverage	−0.1192	−0.2710**	−0.1580	0.1026	−0.2001	−0.1672
	(0.1067)	(0.1055)	(0.1373)	(0.1681)	(0.1433)	(0.1504)
SalesGrowth	0.0001*	−0.0001	0.0001	0.0001	0.0001**	−0.0001
	(0.0000)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
PPE	0.7252***	0.3833***	0.0987	0.6245***	1.0729***	0.7704***
	(0.1171)	(0.1326)	(0.1883)	(0.1859)	(0.1536)	(0.2070)
COD	0.3075**	0.0754	0.5052**	0.4830**	0.1930	0.4657*
	(0.1560)	(0.1712)	(0.2339)	(0.2381)	(0.1986)	(0.2521)
LnGDP	−0.2122***	−1.1205***	−0.8426***	−0.4621***	0.1130	−0.5023***
	(0.0742)	(0.1037)	(0.1390)	(0.1197)	(0.1017)	(0.1526)
Constant	2.7614	36.0672***	26.1661***	7.3884**	−5.8159**	15.4159***
	(2.0450)	(3.0249)	(4.0592)	(3.2531)	(2.7620)	(4.4600)
Year_FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes	Yes	Yes	Yes
Chow-test	9.69 (0.0019)		6.49 (0.0109)		10.95 (0.0009)	
Observations	6799	5848	4968	5190	5182	4805
R-squared	0.1125	0.0869	0.0732	0.0753	0.0862	0.0644

Notes: This table reports the results on the effect of corporate governance effectiveness on the relationship between real interest rate and corporate carbon emissions. The sample covers 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions. Standard errors in parentheses. ***, **, and * are statistical significance at the 1%, 5% and 10% levels.

we run our main regression for each sub-sample separately. The results of this test, reported in Table 5, show that the positive effect of the real interest rate on our three measures of carbon emissions is more pronounced in countries with high EPU. This result suggest that companies delay carbon emission reduction projects and prioritize short-term financial stability during periods of high interest rates coupled with high economic and political uncertainty.

4.4.2. *The effect of investors protection*

In countries where the investors' protection is strong, managers are more inclined to be more sustainable (Breuer et al., 2018; Oyewo et al., 2024). We expect that the positive effect of the real interest rate on carbon emissions is more pronounced in countries where the investors' protection is strong. We use the governance effectiveness index collected from the World Bank governance database. To examine the impact of investor protection on the relationship between interest rate and carbon emissions, we divide our sample into two groups according to the governance effectiveness index, and we run Equation (1) for each group separately. The results in Table 6 show that the positive effect of real interest rates is only prevalent in countries where investor protection is poor, pointing to a potential trade-off between financial stability and sustainability. The governance effectiveness index serves as a valuable metric, allowing for the identification of a nuanced relationship between interest rates and corporate environmental behavior. This finding aligns with Breuer et al. (2018), who argue that strong investor protection fosters a climate where managers are more motivated to adopt sustainable practices, thereby mitigating the environmental impact of financial decisions.

The observed positive effect of real interest rates on carbon emissions in countries with poor investor protection underscores the significance of institutional frameworks in influencing corporate behavior. Countries with weaker investor protection may face challenges in incentivizing managers to prioritize long-term sustainability over short-term financial stability, contributing to an intensified environmental impact under higher interest rates. This insight is consistent with prior research emphasizing the role of institutional factors in shaping corporate environmental responsibility (Cho and Patten, 2007). Policymakers and stakeholders in nations with lower governance effectiveness may find these results crucial for designing targeted interventions to promote sustainable practices in the face of financial constraints.

4.4.3. *The effect of corporate governance quality*

Prior research indicates that investing in green technology yields numerous enduring advantages, including the ability to establish a robust competitive edge for the firm (Alvarez et al., 2015), enhancing in this direction its reputation (e.g., Di Giuli and Kostovetsky, 2014; Bolton and Kacperczyk, 2021 etc.). In this line, according to stakeholders' theory, managers must manage a set of conflicting interests among different stakeholders. The presence of a sound corporate governance system may encourage managers to integrate the interests of different stakeholders into their strategies (Harjoto and Jo, 2011; Oyewo, 2023; Shahab et al., 2022). With this logic, we expect that strong corporate governance may cause managers to invest in carbon emission reduction even in the presence of high interest rates. To test our expectations, we split our sample into two groups according to the corporate governance score predicted by the Thomson Reuters Asset 4 database. The results, reported in Table 7, show that the positive effect of real interest rates on carbon emissions is prevalent only in firms with poor corporate governance. This observed prevalence of the positive effect in firms with poor corporate governance suggests that managers may face fewer incentives

Table 8
Polluted vs clean industries.

	(1)	(2)	(3)	(4)	(5)	(6)
	CO_2Total	CO_2Total	CO_2Direct	CO_2Direct	CO_2Indirect	CO_2Indirect
	Polluted	Clean	Polluted	Clean	Polluted	Clean
RealInterest	0.0081***	0.0013	0.0115***	0.0031	0.0046	0.0030
	(0.0031)	(0.0029)	(0.0043)	(0.0043)	(0.0045)	(0.0036)
Size	0.4880***	0.5925***	0.5573***	0.6053***	0.4586***	0.5770***
	(0.0342)	(0.0250)	(0.0485)	(0.0368)	(0.0505)	(0.0312)
CashRatio	−0.1636	−0.0265	−0.3967	−0.6312***	−0.1044	0.0972
	(0.1805)	(0.1122)	(0.2581)	(0.1625)	(0.2689)	(0.1373)
ROA	−0.0018	0.0009	0.0002	0.0021	−0.0003	−0.0004
	(0.0014)	(0.0010)	(0.0019)	(0.0016)	(0.0021)	(0.0014)
MTB	−0.0115**	0.0037	−0.0060	0.0038	−0.0045	0.0068*
	(0.0056)	(0.0031)	(0.0080)	(0.0043)	(0.0084)	(0.0037)
Capex	−0.0070***	−0.0063***	−0.0075**	0.0001	−0.0130***	−0.0034
	(0.0024)	(0.0021)	(0.0036)	(0.0030)	(0.0038)	(0.0026)
Leverage	−0.4282***	−0.0297	−0.1550	0.1362	−0.2953	−0.1517
	(0.1257)	(0.0917)	(0.1823)	(0.1329)	(0.1917)	(0.1136)
SalesGrowth	−0.0000	0.0001	−0.0001	0.0001	0.0001	0.0001**
	(0.0001)	(0.0000)	(0.0002)	(0.0001)	(0.0002)	(0.0000)
PPE	0.1180	1.1859***	−0.1447	1.3254***	0.5406***	1.4539***
	(0.1308)	(0.1189)	(0.1916)	(0.1840)	(0.2019)	(0.1503)
COD	0.1482	0.1976	0.4492*	0.4605*	0.1714	0.2977
	(0.1713)	(0.1575)	(0.2392)	(0.2377)	(0.2454)	(0.1987)
LnGDP	−0.4694***	−0.6400***	−0.6408***	−0.5850***	−0.2211*	−0.2887***
	(0.0821)	(0.0731)	(0.1221)	(0.1116)	(0.1278)	(0.0950)
Constant	15.9051***	17.1600***	18.4245***	13.8142***	7.6145**	6.4603**
	(2.2891)	(2.0654)	(3.3869)	(3.1422)	(3.5426)	(2.6738)
Year_FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes	Yes	Yes	Yes
Chow-test	6.92 (0.0086)		7.11 (0.0077)		1.07 (0.3008)	
Observations	5445	7202	4481	5677	4303	5684
R-squared	0.0626	0.1238	0.0493	0.0964	0.0373	0.1079

Notes: This table reports the results on the effect of polluted industries on the relationship between real interest rate and corporate carbon emissions. The sample covers 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions. Standard errors in parentheses. ***, **, and * are statistical significance at the 1%, 5% and 10% levels.

or constraints to prioritize long-term environmental sustainability over short-term financial stability in the absence of robust governance structures. This aligns with the agency theory perspective, where the alignment of managerial and shareholder interests is crucial for strong governance and, by extension, for sustainable decision-making (Jensen and Meckling, 2019; Shleifer and Vishny, 1997).

4.4.4. *Polluted vs clean industries*

It could be argued that the nature of the activity sector may drive our main results. Some industries are more concerned about carbon emissions reduction, i.e., oil and gas industries (Benkraiem et al., 2022). To mitigate such concerns, we divide our sample into subsamples of polluted and clean industries in this section. Polluted industries include firms belonging to the sectors with first-digit Standard Industrial Classification codes "1," "2," and "4,". The results in Table 8 show that the effect of real interest rate is positive and significant only in polluted industries, underscoring the sectoral heterogeneity in the impact of financial decisions on environmental outcomes. Industries with higher pollution potential may face unique challenges in aligning financial priorities with sustainable practices, necessitating targeted approaches to address carbon emissions in these sectors. This sector-specific understanding contributes to the broader discourse on sustainable finance and environmental policymaking, emphasizing the need for nuanced strategies that account for the diversity of industries in the global economic landscape.

4.5. *Robustness tests*

4.5.1. *Alternative measure of interest rates*

To test the robustness of our main conclusion, we use the change of real interest rate from t-1 to t as an alternative measure following Sharpe and Suarez (Sharpe and Suarez, 2021). We use the variation to examine the effect of the increase (decrease) of interest rates on the level of carbon emissions. The results of this test, reported in Table 9, show a positive effect of real interest rate variation on total and direct carbon emissions and an insignificant effect on indirect emissions.

4.5.2. *Alternative measure of carbon emissions*

In this section, we use an alternative proxy of carbon emissions. Carbon intensity is proxied by total carbon emissions, direct carbon emissions and indirect carbon emissions scaled by each firm's total assets. The results reported in Table 10 using this alternative measure are the same as those reported in Table 3.

4.5.3. *Alternative sample*

We examine the relationship between interest rates and carbon emissions for manufacturing firms' sub-sample because the latter are the most concerned about carbon emission reduction. Manufacturing companies include all companies with Standard Industrial Classification (SIC) codes between 1000 and 3999. The results reported in Table 11 are very similar to our main results, suggesting a positive and significant effect of real interest rate on total and direct carbon emissions.

4.5.4. *Endogeneity and selection bias*

Our findings may suffer from endogeneity concerns. Firms from countries with high real interest rates may have distinctive characteristics that could impact carbon emissions. For instance, high interest rates may mitigate corporate growth, which is likely to affect carbon emissions. In other words, the positive impact of real interest rates on carbon emissions might be due to the specific characteristics of firms

Table 9
Alternative measure of interest rate.

	(1)	(2)	(3)
	CO_2Total	CO_2Direct	CO_2Indirect
ΔRealInterest	0.0160***	0.0166**	0.0030
	(0.0053)	(0.0078)	(0.0074)
Size	0.5427***	0.5674***	0.5211***
	(0.0207)	(0.0297)	(0.0279)
CashRatio	−0.1042	−0.6519***	−0.0071
	(0.0975)	(0.1392)	(0.1298)
ROA	−0.0001	0.0018	−0.0015
	(0.0009)	(0.0013)	(0.0012)
MTB	−0.0015	0.0001	0.0023
	(0.0028)	(0.0039)	(0.0036)
Capex	−0.0056***	−0.0031	−0.0074***
	(0.0016)	(0.0023)	(0.0022)
Leverage	−0.1496*	0.0318	−0.2202**
	(0.0773)	(0.1108)	(0.1045)
SalesGrowth	0.0001	0.0001	0.0001**
	(0.0000)	(0.0001)	(0.0000)
PPE	0.5365***	0.4664***	0.9945***
	(0.0919)	(0.1353)	(0.1282)
COD	0.3089**	0.6906***	0.2247
	(0.1282)	(0.1857)	(0.1706)
LnGDP	−0.4928***	−0.5480***	−0.2125***
	(0.0549)	(0.0843)	(0.0796)
Constant	14.6627***	14.5504***	5.7521***
	(1.5358)	(2.3523)	(2.2194)
Year_FE	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes
Observations	11,953	9693	9515
R-squared	0.0832	0.0637	0.0625

Notes: This table reports the results on the effect of real interest rate on corporate carbon emissions using alternative measure of real interest rate. The sample covers 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions. Standard errors in parentheses. ***, **, and * are statistical significance at the 1%, 5% and 10% levels.

Table 10
Alternative measure of carbon emissions.

	(1)	(2)	(3)
	CO_2TotalIntensity	CO_2DirectIntensity	CO_2IndirectIntensity
RealInterest	0.0041*	0.0084***	0.0048*
	(0.0021)	(0.0030)	(0.0028)
Size	−0.4244***	−0.3884***	−0.4497***
	(0.0202)	(0.0293)	(0.0277)
CashRatio	−0.0887	−0.5762***	−0.0139
	(0.0962)	(0.1389)	(0.1305)
ROA	0.0004	0.0017	0.0002
	(0.0008)	(0.0012)	(0.0012)
MTB	0.0048*	0.0080**	0.0091**
	(0.0027)	(0.0038)	(0.0036)
Capex	−0.0057***	−0.0022	−0.0067***
	(0.0016)	(0.0023)	(0.0022)
Leverage	−0.2006***	−0.0194	−0.2246**
	(0.0744)	(0.1078)	(0.1026)
SalesGrowth	0.0001	0.0001	0.0001**
	(0.0000)	(0.0001)	(0.0000)
PPE	0.6042***	0.4836***	0.9833***
	(0.0869)	(0.1306)	(0.1220)
COD	0.2407**	0.5572***	0.3143**
	(0.1152)	(0.1671)	(0.1558)
LnGDP	0.1144**	0.0890	0.4447***
	(0.0543)	(0.0819)	(0.0777)
Constant	8.5892***	7.5576***	−1.4622
	(1.5245)	(2.2890)	(2.1709)
Year_FE	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes
Observations	12,647	10,158	9987
R-squared	0.1118	0.0746	0.1026

Notes: This table reports the results on the effect of real interest rate on corporate carbon emissions using alternative measure of carbon emissions. The sample covers 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions. Standard errors in parentheses. ***, **, and * are statistical significance at the 1%, 5% and 10% levels.

that arise from high real interest rates, rather than the real interest rate itself. Furthermore, the studied relationship may be affected by simultaneity and omitted variables concerns. For example, economic growth may influence simultaneously corporate carbon emissions and the demand for loans, affecting real interest rates. We then use the Generalized Method of Moments (GMM) approach to address the simultaneity and omitted variables concerns. We also use the PSM to mitigate the endogeneity related to the heterogeneity of firms' specific characteristics.

GMM approach: We include the lagged dependent as an instrumental variable. We employ two tests to justify the choice of the instrument variables: the Sargan test and the Arellano and Bond test. These tests valid the late carbon emissions level as instrument variables. The results of GMM regression reported in Table 12 remain qualitatively the same.

PSM approach: to run PSM, we divide our sample into two groups: firms in countries with high real interest rates (treatment group) and those with low real interest rates (control group). These groups must show no observable differences in corporation characteristics. In the first step of PSM, we estimate the propensity scores for the treatment and control groups using a logit regression, in which the dependent variable is binary and takes one if the real interest rate is above its sample median. The independent variables are all control variables in Equation (1). In the second step, we match, using the estimated propensity scores, each firm in the treatment group with a firm in the control group with similar characteristics. The matching process is based on the nearest neighbor matching technique with a maximum distance of 5%. Similar to our main finding, the result of the PSM approach, reported in Table 13, shows a positive effect of the real interest rate on carbon emissions.

5. Conclusion

The Paris Agreement (Conference of the Parties, COP, 2021), established in 2015 under the United Nations Framework Convention on Climate Change, has triggered several participant countries to announce specific carbon reduction plans in an attempt to move away from fossil fuels. An inquiry that often arises is how a nation finances its endeavors to reduce carbon emissions, and what is the role of those obliged to make a U-turn in the mixture of energy use in their production? However, implementing ambitious carbon reduction plans carries significant challenges for central bankers worldwide since it places the conduct of monetary policy at the forefront of the issue. Indeed, the influence of monetary policy on carbon emissions is significant as it affects economic growth, interest rates, investment, and consumer spending (Aglietta et al., 2015). Within prevailing high inflationary conditions, monetary policy formulation to address climate change objectives is further complicated, as increasing interest rates can impede economic growth and investment in environmentally friendly technologies. In this respect, companies should recognize the impact of interest rates on their carbon emissions and consider incorporating environmental sustainability goals into their long-term strategies. The purpose of this paper is then to investigate how interest rates shape corporate carbon emissions.

Based on an international sample of 12,647 observations from 2010 to 2021, the results show that the relationship between interest rates and firms' carbon emissions is positive and significant. This result suggests that when facing interest rates rising, companies are more inclined to prioritize short-term financial stability over long-term sustainability goals. The results also show that this relationship is less prevalent after the Paris Agreement, suggesting that climate policies are essential in impacting firms' sustainable practices. Additional evidence shows that

Table 11
Alternative sample.

	(1)	(2)	(3)
	CO_2Total	CO_2Direct	CO_2Indirect
RealInterest	0.0096***	0.0088*	0.0034
	(0.0030)	(0.0045)	(0.0038)
Size	0.5463***	0.6341***	0.5226***
	(0.0274)	(0.0433)	(0.0364)
CashRatio	0.0976	−0.4598**	0.0218
	(0.1264)	(0.1993)	(0.1678)
ROA	−0.0019	−0.0017	−0.0029*
	(0.0013)	(0.0020)	(0.0017)
MTB	−0.0021	0.0017	0.0083
	(0.0040)	(0.0061)	(0.0051)
Capex	−0.0126***	−0.0091***	−0.0144***
	(0.0023)	(0.0035)	(0.0031)
Leverage	−0.2010**	−0.0684	−0.2541*
	(0.1022)	(0.1625)	(0.1363)
SalesGrowth	0.0002	0.0002	0.0003**
	(0.0001)	(0.0002)	(0.0002)
PPE	0.7818***	0.3674**	0.7257***
	(0.1151)	(0.1847)	(0.1552)
COD	0.2433*	0.4857**	0.2092
	(0.1364)	(0.2064)	(0.1712)
LnGDP	−0.6359***	−0.6213***	−0.3412***
	(0.0693)	(0.1151)	(0.0970)
Constant	18.7264***	15.4152***	9.8945***
	(1.9443)	(3.1942)	(2.6931)
Year_FE	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes
Observations	6672	5160	5096
R-squared	0.0979	0.0653	0.0680

Notes: This table reports the results on the effect of real interest rate on corporate carbon emissions using alternative sample. The sample covers 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions. Standard errors in parentheses. ***, **, and * are statistical significance at the 1%, 5% and 10% levels.

Table 12
GMM regression.

VARIABLES	(1)	(2)	(3)
	CO_2Total	CO_2Direct	CO_2Indirect
Lagged dependent variable	0.4914***	0.4386***	0.3273***
	(0.0899)	(0.0688)	(0.0971)
RealInterest	0.0073***	0.0099***	0.0091***
	(0.0015)	(0.0025)	(0.0021)
Size	0.1266***	0.1405***	0.0856
	(0.0442)	(0.0527)	(0.0552)
CashRatio	−0.4236***	−0.4977***	−0.3619**
	(0.1268)	(0.1455)	(0.1523)
ROA	0.0003	0.0000	−0.0006
	(0.0009)	(0.0010)	(0.0011)
MTB	−0.0082***	−0.0046	−0.0057
	(0.0031)	(0.0044)	(0.0038)
Capex	0.0017	0.0042	0.0041
	(0.0020)	(0.0026)	(0.0039)
Leverage	−0.1445	−0.1509	−0.1644
	(0.0993)	(0.1347)	(0.1413)
SalesGrowth	0.0007***	0.0006***	0.0005***
	(0.0001)	(0.0001)	(0.0001)
PPE	0.1166	−0.0723	0.2149
	(0.1361)	(0.1540)	(0.1720)
COD	−0.0887	0.0949	−0.0882
	(0.0993)	(0.1520)	(0.1115)
LnGDP	−0.0556	−0.0230	−0.0936
	(0.0564)	(0.0792)	(0.0770)
Constant	5.3944***	4.2589*	8.6996***
	(1.9974)	(2.2262)	(2.3081)
Year_FE	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes
Sargan (p-value)	0.3112	0.2046	0.0893
AR1 (p-value)	0.0001	0.0011	0.0057
AR2 (p-value)	0.7995	0.6001	0.2756
Observations	7187	5441	5297

Notes: This table reports the GMM approach results on the effect of real interest rate on corporate carbon emissions. The sample covers 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions. Standard errors in parentheses. ***, **, and * are statistical significance at the 1%, 5% and 10% levels.

the positive effect of interest rates on carbon emissions is more pronounced under high economic and policy uncertainty, weak corporate governance quality and poor investor protection. The results are robust to endogeneity concerns, alternative measures of interest rates, carbon emission, and alternative samples.

These results have several implications for policymakers, companies and investors. Policymakers and international organizations should continue to strengthen global climate initiatives to encourage sustainable practices. Indeed, international efforts to address climate change may be influencing corporate behavior. For example, governments can introduce green financing initiatives, such as green bonds or subsidies for renewable energy projects, coupled with low-interest rates to spur investment in sustainable sectors with low carbon footprint. Especially the transition of carbon-intensive industries to an eco-friendlier production might be more vulnerable to changes in interest rates. As such, regulators should assess the exposure of financial institutions to carbon-intensive sectors and adjust capital requirements accordingly. This can help mitigate systemic risks arising from the transition to a low-carbon economy. Policymakers can also implement more stringent monetary policies, especially in periods of high uncertainty, offering attractive interest rates as incentives for companies committed to investing in green activities to reduce their carbon footprint. Especially, when inflation surges, central bankers should contemplate implementing more targeted interventions to encourage firms to engage in climate-aligned behavior. These results are also crucial for managers who must identify and manage the risks of prioritizing short-term financial stability over long-term sustainability. Companies may benefit from strengthening corporate governance structures and improving transparency in reporting sustainability metrics.

A special attention should be paid to the role of Central Banks in developing economies. Their level of independence and transparency can be rather crucial. Central banks evaluate climate-related risks and integrate them into their assets and portfolios. Subsequently, they may effectively convey these potential dangers and redirect funding towards environmentally sustainable development. However, developing countries encounter much more significant challenges in their energy transitions since they must strike a delicate equilibrium between economic expansion and the shift towards less carbon-intensive economies. Hence, global actions do not share a common starting point. This heterogeneity between developed and developing countries conveys the wrong message in the effort of lowering carbon emissions. The specific nature of both central banks and governments actions to address climate change will thus be contingent upon the outcome of different trade-offs in each unique national situation. Policymakers should take under consideration this issue and implement the necessary mechanisms to converge such differences probably at U.N. level.

This study is not without limitations. For instance, in the methodological part, the effect of interest rates on carbon emissions may not be immediate. Investment decisions in carbon-intensive sectors or green technologies take time to materialize and influence emission levels. However, our long-term data can capture these delayed effects adequately. In addition, different economic sectors respond differently to changes in interest rates, that is why we paid special attention to polluted industries in our estimation. Further, economic agents, including firms and households, may respond to interest rate changes in ways that are not fully understood or anticipated by existing models. As Wu et al. (Wu et al., 2023) point out, several variables, including

Table 13
PSM approach.

	(1)	(2)	(3)
	CO_2Total	CO_2Direct	CO_2Indirect
BinRealInterest	0.1419***	0.1892***	−0.0408
	(0.0472)	(0.0593)	(0.0408)
Size	0.9687***	0.9367***	0.8301***
	(0.0177)	(0.0218)	(0.0150)
CashRatio	0.4766**	0.5618**	−2.0052***
	(0.1973)	(0.2654)	(0.1874)
ROA	0.0214***	0.0118***	−0.0011
	(0.0030)	(0.0037)	(0.0025)
MTB	−0.0568***	−0.0697***	0.0296***
	(0.0072)	(0.0095)	(0.0066)
Capex	−0.0076**	−0.0213***	0.0116***
	(0.0039)	(0.0052)	(0.0033)
Leverage	−1.2053***	−2.1931***	−2.1415***
	(0.1326)	(0.1532)	(0.1085)
SalesGrowth	−0.0007***	−0.0018***	−0.0005***
	(0.0002)	(0.0003)	(0.0001)
PPE	2.7725***	4.9627***	1.9131***
	(0.1104)	(0.1332)	(0.0903)
COD	1.2504***	−0.3991	−0.6200**
	(0.2008)	(0.3850)	(0.2977)
LnGDP	−1.2860***	−2.3037***	0.5461**
	(0.2633)	(0.3353)	(0.2399)
Constant	26.5656***	56.0753***	−20.7217***
	(7.0644)	(9.0934)	(6.5091)
Year_FE	Yes	Yes	Yes
Industry_FE	Yes	Yes	Yes
Country_FE	Yes	Yes	Yes
Observations	5695	4645	4555
R-squared	0.4237	0.5440	0.4821

Notes: This table reports the PSM approach results on the effect of real interest rate on corporate carbon emissions. The sample covers 12,647 firm-year observations from 2010 to 2021. See the appendix for variables definitions. Standard errors in parentheses. ***, **, and * are statistical significance at the 1%, 5% and 10% levels.

investment responses, consumption patterns, and economic structure, influence the magnitude and timing of impacts. Further investigation is needed, particularly regarding the different impacts experienced by developed and developing economies and the integration of monetary policy with other climate policies. This approach will hopefully accelerate the decarbonization process.

CRediT authorship contribution statement

Dimitris Anastasiou: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Antonis Ballis:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Assil Guizani:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Christos Kallandranis:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Faten Lakhal:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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.

Appendix

Appendix
Variables' definitions

Variables Names	Measures
Dependent variables	
Total carbon emission (CO_2Total)	The log of total carbon emissions (in tones)
Direct carbon emission (CO_2Direct)	The log of total direct carbon emissions (in tones)
Indirect carbon emission (CO2Direct)	The log of total indirect carbon emissions (in tones)
Key variables	
Real interest rate (RealInterest)	The lending interest rate adjusted for inflation as measured by the GDP deflator.
Variation of real interest rate (ΔRealInterest)	The difference between real interest rate for the current and previous years scaled by the real interest rate of the previous year.
High real interest rate (BinRealInterest)	Dummy variable that takes one if real interest rate is above its sample median.
Polluted industries (Polluted)	Dummy variable that takes one if first-digit Standard Industrial Classification codes is "1," "2," and "4,".
Developed countries (Developed)	Dummy variable that takes one if the firm comes from developed countries: Australia, Austria, Belgium, Canada, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hong Kong, Iceland, Ireland, Italy, Japan, Korea (south), Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovakia, Slovenia, Spain, Sweden, Switzerland, Taiwan, United kingdom, and United states.
Economic and policy uncertainty (EPU)	The economic policy uncertainty index constructed by Baker et al. (2016) including the following components: the coverage of policy-related economic uncertainty by different newspapers, the number of federal tax expirations, and disagreements among economic forecasts.
Investors protection (IP)	The governance effectiveness predicted from the World Bank database which refers to the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.
Corporate governance effectiveness (CG)	The corporate governance quality score predicted from Thomson Reuters Asset 4 database, including management quality, shareholders' rights, and corporate social responsibility strategy

(continued on next page)

Appendix (*continued*)

Variables Names	Measures
Control variables	
Firm size (Size)	The natural logarithm of total assets
Cash holdings (CashRatio)	The ratio of cash and cash equivalent to current liability
Return on assets ratio (ROA)	The ratio of net income over total assets
Market-to-book ratio (MTB)	The firm's market value scaled by firm's book value
Capital expenditure (Capex)	The ratio of net investment expenditures to total assets
Firm leverage (Leverage)	The ratio of long-term debt over total assets
Sales growth (SalesGrowth)	The difference between sales for the current and previous years scaled by the sales of the previous year
Firm long-term assets (PPE)	The property, plant and equipment assets scaled by total assets
Firm cost of debt (COD)	The interest expenditures scaled by total debt
Gross domestic product (LnGDP)	The log of GDP

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