Disruptive Crises, Institutional Pressures, and Climate Action: Understanding Business Investment Decisions in Climate Technologies

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ABSTRACT

Climate technologies aim to reduce CO_2 emissions to mitigate the effects of global warming. In this paper, we analyze whether the disruptive events that we have been experiencing since 2020 (specifically, the coronavirus disease 2019 [COVID-19] pandemic and the war in Ukraine) act as drivers of firms' investment in climate technologies, and whether the institutional environment of the European Union (EU) also does so. For a sample of 5376 firms for the period 2016–2022, we find that firms' investment in climate technologies is higher in disruptive periods. Moreover, we find that this effect is smaller than the driving effect that the EU institutional environment has on firms' engagement in the fight against climate change and investment in climate technologies.

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1. Introduction

Global warming is one of the most pressing threats to humanity, with impacts manifesting in extreme weather events, loss of biodiversity, and significant risks to economic and social stability (Schipper et al., 2021; Busch et al., 2022). Significant reductions in greenhouse gas (GHG) emissions are essential to limit the rise in global temperatures and mitigate their negative impacts (Lee et al., 2015). Given their contribution to global emissions, businesses have a key role to play (Johnson et al., 2023). Nevertheless, the transition to a low-carbon economy requires a profound transformation of business models, with significant investments to reduce carbon footprints and improve long-term sustainability (Issa & Hanaysha, 2023; García-Sánchez et al., 2024b).

In this context, climate technologies have emerged as a key component in the fight against climate change, as they provide solutions to reduce, capture, and mitigate GHG emissions (Wang, 2017; Ebrahim, 2020). These technologies include low-carbon energy sources, energy efficiency solutions, energy storage and carbon capture and storage (CCS) systems, and advanced waste management (Wang et al., 2018; Hötte & Jee, 2022). The adoption of these innovative technologies by companies not only responds to the need to meet sustainability goals but also represents a strategic opportunity to improve competitiveness, access new markets, and ensure business resilience in an increasingly sustainability-oriented environment (Aibar-Guzmán et al., 2023a; García-Sánchez et al., 2024b). However, their implementation requires significant investments, the viability and profitability of which depend on several factors, such as the institutional environment and market stability (Ghisetti & Rennings, 2014).

In this scenario, the European institutional framework plays a crucial role in shaping the incentives and constraints for business investment in climate technologies (Matos et al., 2022). The European Union (EU) has adopted an ambitious approach to sustainability (García-Sánchez et al., 2023b; 2024c), with regulations such as the European Green Deal, the EU Sustainable Finance Strategy, the Corporate Sustainability Reporting Directive (CSRD), and the Carbon-Boundary

Adjustment Mechanism (CBAM), among others, that seek to align business strategies with decarbonization goals by establishing strict disclosure requirements, financial incentives, and penalty mechanisms for companies with high environmental impacts (Cifuentes-Faura, 2022). In this way, the European institutional environment acts as a pressure factor, facilitating the transition to more sustainable business models and influencing investment decisions in climate technologies (Wesseling et al., 2022).

However, the ability of companies to commit to these investments is also conditioned by the uncertainty they face in the economic and geopolitical environment (Cheikh & Zaied, 2023). In recent years, large-scale disruptive events have reshaped the business landscape and created new challenges for corporate sustainability (Zakeri et al., 2022; Su & Junge, 2023; García-Sánchez et al., 2025a). The coronavirus disease 2019 (COVID-19) pandemic had a severe impact on the global economy, disrupting supply chains and altering corporate strategic priorities (Bapuji et al., 2020; Agrawal et al., 2024). Subsequently, Russia's invasion of Ukraine triggered an unprecedented energy crisis in Europe, with a sharp rise in energy prices and a reconfiguration of supply and production strategies (Owjimehr et al., 2023; Wang et al., 2024). Both crises have not only profoundly altered economic and business dynamics, introducing uncertainty and volatility into markets (Allam et al., 2022; Nygaard, 2023), which may have diverted business attention and resources toward short-term goals at the expense of investment in sustainability and climate technologies (Khan et al., 2022; da Costa et al., 2023). They have also highlighted the need to strengthen business resilience and reduce reliance on fossil fuels (Schipper et al., 2021; Anastasia et al., 2023), particularly in Europe (Mišík & Nosko, 2022).

While numerous studies have analyzed the impact of the "perfect storm" in the economic environment resulting from the COVID-19 pandemic and the war in Ukraine, as well as the role of the European institutional environment on investment in GHG mitigation technologies and the transition to a low-carbon economy, these studies have adopted a macro perspective (e.g., Cheikh & Zaied, 2023; Hartley et al., 2023; You & Teirlinck, 2024). However, very few studies have focused their attention on firms (García-Sánchez et al., 2025a). As a result, how these two factors affect firms' investment in climate technologies remains an open research question. With these premises, this paper analyzes whether these recent disruptive events (i.e., the COVID-19 pandemic and the war in Ukraine) and the EU institutional environment have influenced business strategies to address climate change, in particular investments in climate technologies to reduce GHG emissions. For a sample of 5376 companies for the period 2016–2022, the results show that both disruptive events and the EU institutional environment have positively influenced companies' investments in climate technologies. However, the impact of the EU institutional environment is more determinant than that of disruptive events, suggesting that regulatory structure and political pressures play a more relevant role in promoting corporate sustainability.

This research makes three contributions to the literature on sustainability. First, it broadens the understanding of the role of crises in shaping corporate sustainability (Cheikh & Zaied, 2023), demonstrating that they can act as catalysts for change. In doing so, this study contributes to a more nuanced understanding of how major shocks can influence the trajectory of corporate sustainability transitions. Second, it reinforces the importance of regulatory frameworks in the transition to more sustainable business models (Wesseling et al., 2022) and highlights the effectiveness of coercive pressure in accelerating investment in climate technologies (Zhou et al., 2019). As such, this work provides new insights into the factors driving the sustainable transformation of companies in line with the 2015 Paris Agreement. Finally, our study makes a broader contribution to theoretical literature by integrating insights from resource dependence theory, institutional theory, and the dynamic capabilities perspective to explain how firms respond to systemic disruptions and evolving regulatory environments. By linking disruptive events, institutional pressures, and investment decisions in climate technologies, the study provides a more comprehensive framework for understanding how firms adapt their strategies in conditions of heightened uncertainty and transition risk.

The remainder of the paper is structured as follows: After this introduction, the second section presents the theoretical framework and the development of the research hypotheses. The third section describes the empirical design, and the fourth and fifth sections report the basic and complementary results, which are discussed in the sixth section. The final section presents the main conclusions of the study.

2. Background, Literature Review, and Research Hypotheses

2.1. Climate Technologies and Their Application in Business

Climate technologies encompass a wide range of innovations designed to mitigate the impacts of climate change and facilitate the transition to a low-carbon economy (Wang, 2018; Ebrahim, 2020). These technologies are applied in different operational and strategic areas, effectively reducing GHG emissions and making more efficient use of natural resources (Li et al., 2022). While there are different classifications of climate technologies (e.g., Ghisetti & Rennings, 2014; Wang et al., 2018), following Aibar-Guzmán et al. (2023a), four main categories can be distinguished: green building technologies, clean technologies, eco-efficiency technologies (i.e., those that reduce resource consumption and use), and advanced waste management systems.

Green building technologies aim to reduce the environmental impact of buildings (Darko et al., 2017) by using environmentally friendly building materials, optimizing thermal insulation to improve energy efficiency, installing renewable energy systems (such as solar panels and geothermal energy), and developing smart buildings with automated energy consumption control systems (Hsieh et al., 2020; Chatterjee & Ürge-Vorsatz, 2021). Clean technologies aim to minimize the environmental footprint of industrial and operational processes, including CCS systems, renewable energy sources such as solar and wind power, the electrification of production processes, and improvements in machine efficiency through digitalization and automation (Erzurumlu & Erzurumlu, 2013; Wang, 2017). Eco-efficiency technologies are related to optimizing resource consumption and use and include initiatives such as reducing water and energy consumption, implementing more efficient production systems, and using recycled or sustainable raw materials (Kang & Lee, 2016; Wang et al., 2018). Finally, in the context of the transition to a circular economy, advanced waste management technologies aim at recycling and recovery, minimizing waste in production processes and reusing materials (Agovino et al., 2020; Aibar-Guzmán et al., 2023b).

2.2. Literature Review and Hypothesis Development

Following previous studies, this study uses resource dependence theory (RDT), dynamic capabilities theory (DCT), and institutional theory to develop the research hypotheses. RDT posits that organizations must adapt to their environment to secure access to critical resources to preserve their competitiveness and stability (Pfefer & Salancik, 1978). Thus, in a context of global crisis and uncertainty, firms will adjust their investment strategies according to changes in the structure of incentives and external threats (García-Sánchez et al., 2024a). From this perspective, recent disruptive events (such as the COVID-19 pandemic and the Russian invasion of Ukraine) have changed market conditions, which may encourage firms to invest in climate technologies in response to the need for operational resilience and energy diversification (Schipper et al., 2021; Zakeri et al., 2022).

However, DCT (Teece et al., 1997, p. 516) explains how companies can gain sustainable competitive advantages in highly volatile environments by integrating, creating, and reconfiguring internal and external resources. These "higher-order" capabilities allow companies to adapt, renew themselves, and influence their business environment (Teece, 2018). Therefore, to cope with systemic disruptions, companies must identify emerging risks and opportunities, exploit new technological possibilities, and adapt their operating models accordingly (Teece, 2007; 2023). From this perspective, investment in climate technologies can be seen as a strategic response through which companies can strengthen their long-term resilience and adaptability (Kyrdoda et al., 2023; Sahebalzamani et al., 2023; Opoku et al., 2025).

Finally, institutional theory argues that firms respond not only to economic incentives and access to resources but also to normative, mimetic, and coercive pressures imposed by their institutional environment (DiMaggio & Powell, 1983; Scott, 1995). In the EU context, climate regulation has set up an institutional framework that requires firms to adopt sustainable practices and demonstrate their commitment to sustainable development (Wesseling et al., 2022; García-Sánchez et al., 2023b). The coercive pressures arising from this regulation, combined with investor and societal expectations, may drive investment in climate technologies (García-Sánchez et al., 2020; Aibar Guzmán, 2023a).

2.2.1. Impact of Disruptive Events on Climate Technology Investment

In recent years, the global economy has been profoundly affected by disruptive events that have changed business dynamics and corporate strategy formulation (da Costa et al., 2023; Su & Junge, 2023; García-Sánchez et al., 2025a). Among these events, the COVID-19 pandemic was an unprecedented health and economic crisis that forced companies to reconfigure their strategies and operations in an environment of extreme uncertainty (Bapuji et al., 2020). Disruptions to global supply chains, falling demand in many sectors, and the need to adapt to remote working posed significant challenges to organizational stability and continuity (Agrawal et al., 2024). However, the crisis also acted as a catalyst for digital transformation and organizational resilience, accelerating the adoption of sustainable technologies and promoting a renewed focus on corporate sustainability (García-Sánchez & García-Sánchez, 2020; Schipper et al., 2021; Allam et al., 2022). In this sense, several studies have pointed out that the pandemic has raised awareness of global systemic risks, including the climate crisis, which has strengthened companies' commitment to the green transition and the reduction of their environmental impact (Schipper et al., 2021; Zakeri et al., 2022; Anastasia et al., 2023).

With many economies still recovering from the effects of the pandemic, Russia's invasion of Ukraine and subsequent war triggered a major geopolitical and economic crisis (Zakeri et al., 2022; da Costa et al., 2023). One of the most immediate effects was the disruption of energy markets, leading to soaring oil and gas prices and increasing pressure on Europe's energy security (Owjimehr et al., 2023). This energy crisis has prompted countries and companies to reduce their dependence on fossil fuels by investing in renewable energy sources and energy efficiency technologies, in line with the EU's strategic goals of decarbonization and energy autonomy (Cheikh & Zaied, 2023; Wang et al., 2024).

From an RDT perspective, these crises have reconfigured the structure of threats and opportunities faced by firms, prompting them to change their strategies to secure access to sustainable energy sources and low-emission technologies (García-Sánchez et al., 2023a). From the viewpoint of CDT, investment in climate technologies improves their ability to reduce their dependence on volatile fossil fuel markets and mitigates regulatory risks. It also aligns their innovation trajectories with the anticipated direction of the global energy transition. In this sense, disruptive crises may act as catalysts that accelerate organizational learning and the reallocation of resources toward technologies that support long-term sustainability and resilience (Kyrdoda et al., 2023; Sahebalzamani et al., 2023; Opoku et al., 2025). Finally, from the standpoint of institutional theory, these disruptive events have increased regulatory and societal pressures on firms to accelerate the transition to a more sustainable model (Agrawal et al., 2024). Increased public attention to the vulnerability of the energy system has led governments and investors to demand greater transparency and commitment to reducing carbon emissions (Ilhan et al., 2023; Subedi & Zoet, 2024). As a result, many companies have stepped up their investments in climate technologies not only as a survival strategy but also as a means of ensuring their legitimacy in a changing environment (Wesselin et al., 2022; Aibar Guzmán et al., 2023a).

Therefore, it is reasonable to expect that both recent disruptive events have stimulated business investment in climate technologies, both as an adaptation strategy and for competitive advantage. In this sense, the literature has shown that shocks can catalyze the adoption of climate technologies by aligning business interests with climate change mitigation objectives (Kuzenko et al., 2022; Mišík & Nosko, 2022; García-Sánchez et al., 2023a). Hence, the following hypothesis is proposed:

H1: Business investment in climate technologies is associated with disruptive events such as the pandemic and the invasion of Ukraine.

2.2.2. The Leading Role of the European Union in the Fight against Climate Change

The EU has positioned itself as a global leader in promoting sustainability and combating climate change (Cifuentes-Faura, 2022; García-Sánchez et al., 2023b; 2024c; 2025b; Rayner, 2023). Through an ambitious policy framework, the EU has set clear targets to achieve climate neutrality by 2050, promoting policies that encourage investment in clean technologies and GHG reductions (European Commission, 2021). Among the most prominent initiatives are the European Green Pact, which sets out a roadmap for a sustainable and competitive economy; the Sustainable Finance Disclosure Regulation (SFDR), which aims to improve transparency in sustainable investment; and the Corporate Sustainability Reporting Directive (CSRD), which extends non-financial reporting requirements for companies (García-Sánchez et al., 2023b; 2024c). In addition, mechanisms such as the Carbon Boundary Adjustment Mechanism (CBAM) aim to promote the uptake of climate technologies and ensure a just transition in the industrial sector (Bellora & Fontagné, 2023). This strong institutional framework has created both coercive and market pressures for companies to adopt more ambitious sustainability strategies and has promoted investment in climate technologies as a key element for the future competitiveness of European companies (Zhou et al., 2019; Wesseling et al., 2022; García-Sánchez et al., 2025b).

From the perspective of RDT, the EU regulatory framework provides financial incentives and reduces the uncertainty associated with sustainability investments, thereby facilitating firms' access to green capital and financing. Previous studies have shown that sound environmental regulation can accelerate the transition to sustainable business models by creating an environment that provides greater certainty for strategic decisions (Ghisetti & Rennings, 2014; Geissdoerfer et al., 2023). However, according to institutional theory, climate regulation in the EU acts as a source of coercive pressures forcing companies to incorporate sustainability criteria into their strategic decisions to comply with legal standards and avoid sanctions (Daddi et al., 2020; Wesseling et al., 2022; García-Sánchez et al., 2023b; 2024c; 2025b). In addition, the standardization of sustainability reporting has increased pressure from investors and other stakeholders for companies to adopt climate technologies that ensure alignment with decarbonization targets (Flammer et al., 2021).

As a result, the EU institutional environment is expected to have stimulated business investment in climate technologies, and the following hypothesis is put forward:

H2: The EU institutional environment is associated with investment in climate technologies.

3. Empirical Design

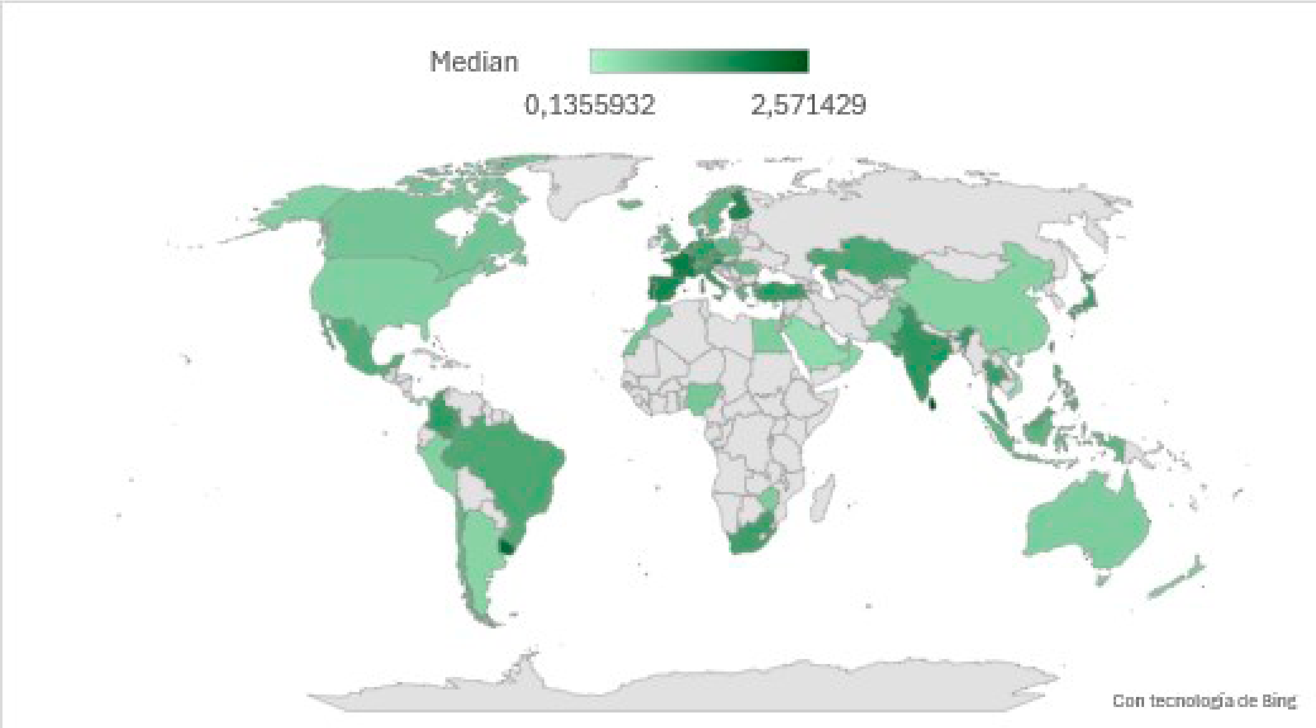
3.1. Sample

To meet the research objectives, we configured our initial population on the basis of large global companies. This criterion is commonly used in the literature, as it allows us to analyze the practices of companies that are more committed to sustainability owing to the availability of resources and capabilities they have and the fact that they are subject to greater environmental pressures (Aibar-Guzmán et al., 2023a; García-Sánchez et al., 2023a).

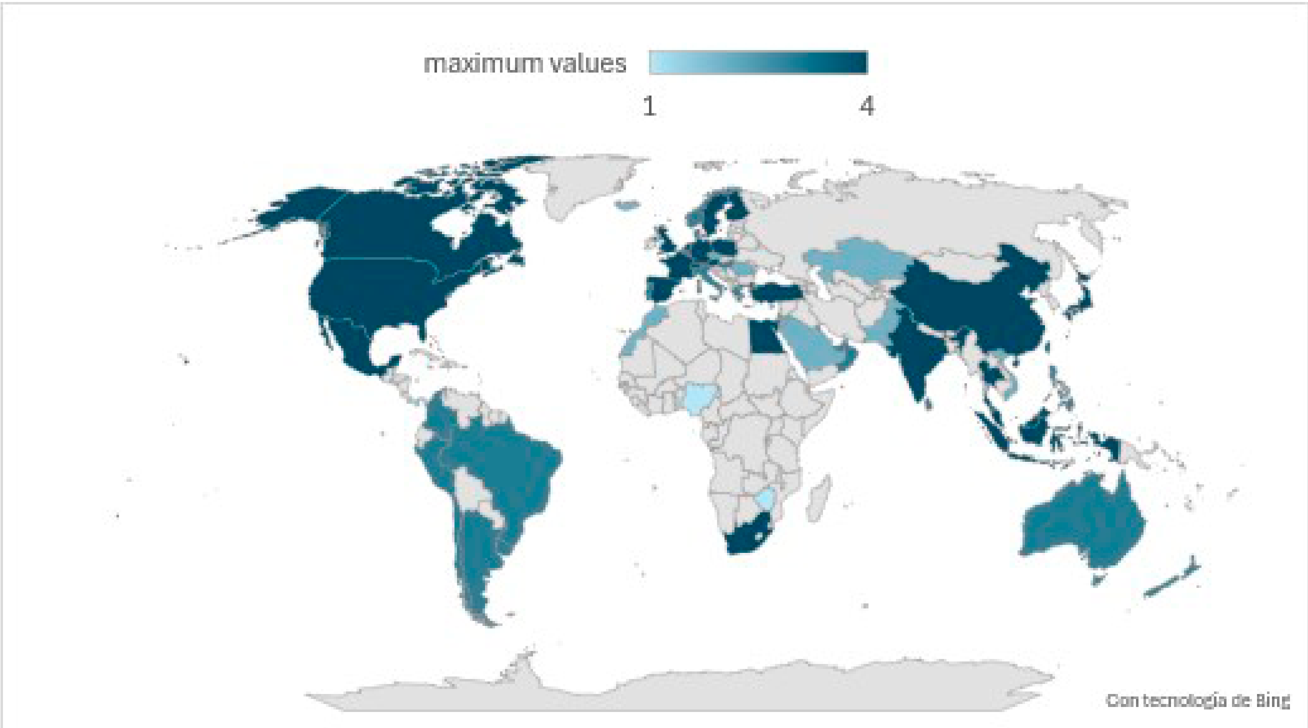
In this respect, the initial population was configured on the basis of the number of large companies for which economic-financial and environmental, social, and governance (ESG) information is available in the Refinitiv database. This database contains corporate information on more than 15,000 companies headquartered in 76 countries. Regarding the period of analysis, the years 2016–2022 were selected, considering the impact that the Paris Agreement, as a legally binding international treaty, may have on companies' climate change strategies.

Based on the availability of the information needed to estimate the models presented below, the final sample corresponds to 5376 companies (37,632 observations). The headquarters of these companies are in 65 different geographical areas, which favors the study of institutional impacts (You & Teirlinck, 2024). In this respect, Fig. 1 provides the sample description based on business investments in climate technologies according to the average (Panel A) and maximum (Panel B) values of the business environment analyzed in each country.

Fig. 1. ClimateTECH by geographic zones.



Panel A. Mean values.



Panel B. Maximum values.

3.2. Model and Variables

Equation 1 is designed to test the research hypotheses regarding the effect of disruptive events and the European institutional framework on climate technology investment at the firm level. In this respect, the proposed hypotheses were accepted for . Given the ordinal nature of the ClimateTECH score, Equation 1 is estimated using an ordinal regression for panel data. Endogeneity is controlled by using a lag in the independent and control variables.

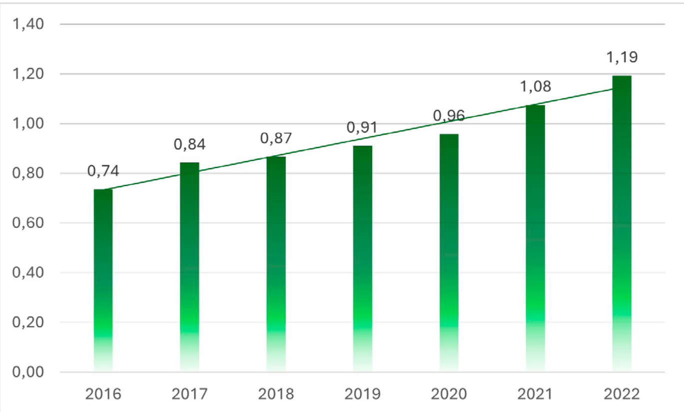
(Equation 1)

According to Aibar-Guzmán et al. (2023a), the ClimateTech variable corresponds to a score that takes values between 0 and 4. This score is made up of the sum of four dichotomous variables that indicate whether or not the company has invested in environmentally friendly technology in buildings (buildingTECH), clean technologies (cleanTECH), reduction of consumption and use of resources (resourceTECH), and waste management (wasteTECH).

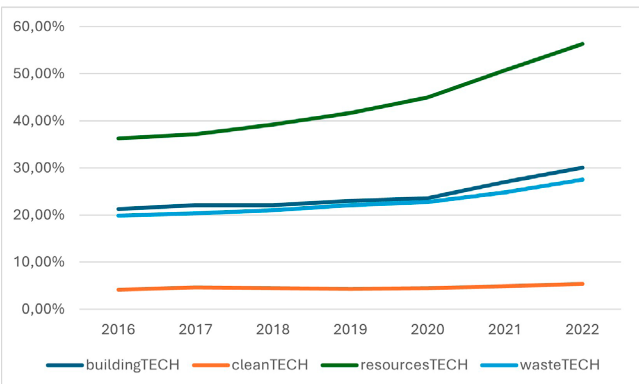
Figure 2 presents the dynamic evolution of the overall climateTECH score and its sub-components. As can be seen, on average, companies have invested in a climate technology project to mitigate the effects of global warming, which is particularly related to investments in initiatives to reduce the consumption and use of various resources (resourceTECH).

Fig. 2. Dynamic evolution of climateTECH.

Panel A. Evolution of the score climateTECH.



Panel B. Evolution of the components of climateTECH.



The independent variables DisrT and EU correspond to dichotomous variables that take values 0 and 1 to identify disruptive events and the European institutional environment, respectively. More specifically, following García-Sánchez et al. (2024b; 2024d; 2025a), the DisrT variable, with a value of 1, identifies the disruptive effects occurring in the period 2020–2022, mainly related to the uncertainty generated by the COVID-19 pandemic and the energy and economic consequences stemming from the war in Ukraine. According to García-Sánchez et al. (2023b; 2024c), the EU variable takes the value 1 for companies headquartered in EU Member States due to the institutional impact of European regulation on the environmental and social practices of the affected companies.

In addition, to avoid bias in the results, the empirical model synthesized in Equation 1 includes a vector of 15 variables that allow us to control for the main business and corporate governance characteristics of the analyzed company, as well as the sector of activity, the specificities of each country and the year analyzed.

Table 1 presents the description and descriptive statistics of the variables used to test the research hypotheses.

Table 1. Variable description

Variable	Definition	Mean/ Frequency
ClimateTECH	Score using values from 0 to 4 to indicate the level of investment in climate technologies	0.98
buildingTECH	Dichotomous variable taking the value 1 if the company has invested in green building technologies	24.79%
cleanTECH	Dichotomous variable taking the value 1 if the company has invested in clean technologies	4.74%
resources-TECH	Dichotomous variable taking the value 1 if the company has invested in eco-efficiency technologies for resource optimization	45.13%
wasteTECH	Dichotomous variable taking the value 1 if the company has invested in advanced waste management systems	23.33%
DisrT	Dichotomous variable taking the value 1 for the period 2020–2022	50.52%
EU	Dichotomous variable taking the value 1 for EU companies	13.85%
logTA	Log of total assets as a proxy for company size	21.91
Leverage	Debt ratio	17.69%
ROA	Return on assets	1.30%
WC	Working capital	0.78
Dividend	Annual dividend policy	1.29
logInves	Log of annual investment	19.14

StrInv	Percentage of shares held by strategic investors	39.40%
BoActivity	Board activity measured by number of annual meetings	9.48
BoFem	Percentage of female directors	19.66%
BoIndep	Proportion of independent directors	60.58%
Duality	Dichotomous variable taking the value 1 if the CEO is the chairman of the board of directors	33.46%
CSRCommitte	Dichotomous variable taking the value 1 if the company has established a CSR committee	50.41%

4. Basic and Robust Results

4.1. Descriptive Analysis

Table 2 presents the bivariate correlations between the variables used to estimate Equation 1 and test the research hypotheses. The analysis of the coefficients does not indicate a problem of multicollinearity.

Table 2. Correlation matrix

		1	2	3	4	5	6	7
1	ClimateTECH	1						
2	buildingTECH	0.65***	1					
3	cleanTECH	0.32***	0.05***	1				
4	resourcesTECH	0.83***	0.33***	0.12***	1			
5	wasteTECH	0.77***	0.24***	0.12***	0.56***	1		
6	DisrT	0.08***	0.05***	0.01*	0.11***	0.04***	1	
7	EU	0.18***	0.06***	0.02***	0.22***	0.13***	0.04***	1
8	logTA	0.45***	0.36***	0.09***	0.37***	0.30***	−0.04***	0.03***
9	Leverage	0.08***	0.08***	0.02***	0.06***	0.05***	−0.04***	−0.01*
10	ROA	0.01**	0.01	0.00	0.01**	0.01	0.00	0.00
11	WC	0.13***	0.10***	0.04***	0.09***	0.10***	0.01	−0.02***
12	Dividend	0.04***	0.03***	0.00	0.03***	0.03***	−0.01	0.00
13	logInves	0.42***	0.28***	0.14***	0.37***	0.30***	−0.05**	0.07**
14	StrInv	−0.01	0.00	−0.01**	0.00	−0.01***	0.01***	0.04***
15	BoActivity	0.06***	0.02***	0.02***	0.07***	0.04***	0.07***	0.08***
16	BoFem	0.18***	0.14***	0.01***	0.17***	0.11***	0.17***	0.30***
17	BoIndep	−0.03***	0.06***	0.01	−0.09***	−0.04***	0.01**	−0.05***
18	Duality	−0.01***	0.04***	0.02***	−0.05***	−0.02***	−0.03***	−0.08***
19	CSRCommitte	0.54***	0.30***	0.11***	0.52***	0.41***	0.13***	0.11***
		8	9	10	11	12	13	14
8	logTA	1						
9	Leverage	0.11***	1					
10	ROA	0.03***	0,00	1				
11	WC	0.22***	−0,02***	0,00	1			

12	Dividend	0.02***	0,00	0,01***	0,01	1		
13	logInves	0.73***	0,07***	0,01	0,19***	0,02***	1	
14	StrInv	0.00	−0,01***	0,00	0,00	−0,01	−0,01**	1
15	BoActivity	0.10***	−0,01**	−0,03***	0,01*	−0,01**	0,05***	−0,01*
16	BoFem	0.05***	0,05***	0,01*	−0,03***	0,01*	0,09***	−0,01
17	BoIndep	−0.06***	0,14***	0,01	−0,03***	0,01**	−0,03***	−0,07***
18	Duality	0.02***	0,07***	0,00	0,04***	0,03***	0,10***	−0,03***
19	CSRCommitte	0.37***	0,05***	0,01**	0,08***	0,02***	0,32***	0,01**
		15	16	17	18	19		
15	BoActivity	1						
16	BoFem	0.03***	1					
17	BoIndep	−0.07***	0,31***	1				
18	Duality	−0.11***	−0,02***	0,13***	1			
19	CSRCommitte	0.06***	0,17***	−0,05***	−0,07***	1		

n = 5376 firms (37,632 observations). *t* = 2016–2022
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

4.2. Basic Results

Table 3 presents the results of the estimation of Equation 1. To ensure the robustness of our results, sequential estimation models are included. Thus, the first column presents the results of the estimation of Equation 1 including the control variables. Columns 2 and 3 include the independent variables DisrT and EU in isolation. The fourth row presents the results for the inclusion of all the variables proposed for the estimation of the empirical model designed to test the hypotheses.

Table 3. Main results

	ClimateTECH			
	Ordered regression for Equation 1			
	Coeff. (SD)	Coeff. (SD)	Coeff. (SD)	Coeff. (SD)
DisrT		0.77***		0.80***
		(0.04)		(0.04)
EU			1.85***	2.04***
			(0.15)	(0.15)
logTA	1.23***	1.15***	1.29***	1.22***
	(0.05)	(0.05)	(0.05)	(0.05)
Leverage	−0.29	0.02	−0.42*	−0.10
	(0.22)	(0.23)	(0.22)	(0.22)
ROA	1.78***	2.44***	1.85***	2.54***
	(0.30)	(0.31)	(0.30)	(0.31)
WC	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Dividend	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
logInves	0.21***	0.29***	0.17***	0.24***
	(0.04)	(0.04)	(0.04)	(0.04)
StrInv	0.04*	0.05**	0.06***	0.07***
	(0.02)	(0.02)	(0.02)	(0.02)
BoActivity	0.01*	0.00	0.01*	0.00
	(0.00)	(0.0)	(0.00)	(0.00)
BoFem	0.04***	0.03***	0.04***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)
BoIndep	0.00	−0.00	0.00	−0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Duality	−0.08	−0.05	−0.06	−0.03
	(0.08)	(0.08)	(0.08)	(0.08)
CSRCommitte	2.04***	1.84***	2.04***	1.83***
	(0.06)	(0.07)	(0.06)	(0.07)
Industry	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Log likelihood	−20,042.40	−19,852.56	−19,962.77	−19,760.35

n = 5376 firms (37,632 observations). *t* = 2016–2022. Coeff., coefficient; SD, standard deviation
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Focusing on the results reflected in the last column, we observed that the impact of the DisrT variable on the climateTECH score was positive and significant at the 99% confidence level. Specifically, These results allowed us to contrast the research hypothesis H1, which posits that business investment in climate technologies was driven by the disruptive events represented by the COVID-19 pandemic and the invasion of Ukraine, thus strengthening the evidence obtained by Kuzenko et al. (2022), Mišík & Nosko (2022), and García-Sánchez et al. (2023a).

Regarding the impact of the European institutional framework on investment in climate technologies to combat global warming, we observed that the coefficient and was significant at the 99% confidence level. This evidence supports hypothesis H2, which states that the EU institutional environment promotes investment in climate technologies by firms, and confirms the results of Damert et al. (2017), Aibar-Guzmán et al. (2023a), García-Sánchez et al. (2023a), and You and Teirlinck (2024).

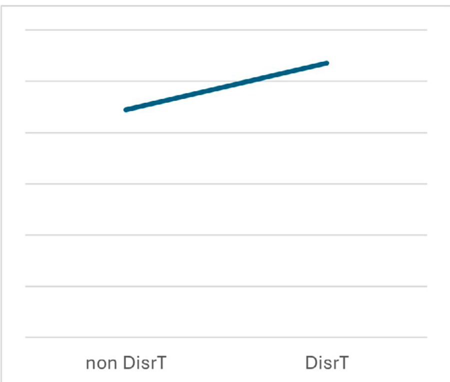
Comparing the impact of the two explanatory factors, we found that the effect of , confirming that the impact of institutional pressure on the fight against climate change is greater than the impact of the disruptive events analyzed.

In addition, the analysis of the effect of the control variables showed that investment in climate technologies is characteristic of companies that have a greater volume of resources and capabilities due to their size and a more expansive investment policy, as well as those that achieve a higher annual profitability. This situation is also associated with the presence of strategic investors in the shareholding structure and more diverse and specialized boards of directors.

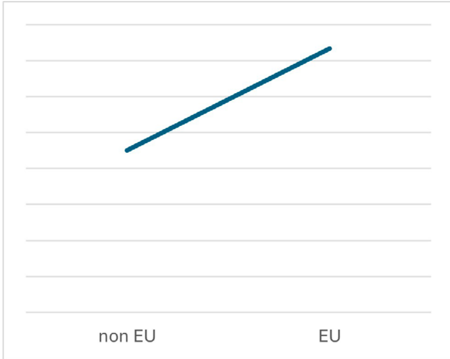
Figure 3 provides a visual representation of the observed relationships for investment in climate technologies in pre-disruption and disruptive periods and in European and non-European institutional settings, confirming the results discussed above.

Fig. 3. ClimateTECH in different scenarios.

Panel A. Pre-disruption and disruptive periods.



Panel B. EU versus non-EU settings.



4.3. Robustness Check

To address potential endogeneity concerns, specifically the possibility of selection bias whereby firms with an existing commitment to sustainability might invest more in climate technologies regardless of external shocks, we employed a propensity score matching (PSM) methodology (Rosenbaum & Rubin, 1983).

This analysis aims to create a quasi-experimental setting by matching firms with a strong sustainability commitment—the treated group—with a control group of firms that possess statistically similar observable characteristics but lack such commitment. We estimated the propensity scores using a logistic regression that incorporates baseline covariates associated with the previous control variables. We then used the nearest-neighbor matching algorithm without replacement to pair the observations.

After ensuring that the covariate balancing condition was satisfied, we re-estimated our baseline models using this matched sample. The results, reported in the first column of Table 4, demonstrated that the positive relationship between EU, DisrT, and climate technology investments remained statistically significant. This rigorous robustness check alleviated concerns that our findings were purely driven by historical sustainability commitments, thereby reinforcing the conclusion that institutional pressures and disruptive crises act as independent catalysts for these investments.

Additionally, the last two columns of Table 4 present the results of a subsample analysis based on firms' advancement and energy strategy, as proposed by García-Sánchez (2023; 2025b). While the findings are similar to those of previous models, it is evident that EU institutional pressures and disruptive events have a lesser impact on firms with more ambitious energy strategies.

Table 4. Robustness analysis

	climateTECH		
	Ordered regression for Equation 1		
		Energy strategy	
	PSM	Low	High
	Coeff.	Coeff.	Coeff.
	(SD)	(SD)	(SD)
DisrT	0.79***	1.84***	0.44***
	(0.04)	(0.13)	(0.04)
EU	2.00***	2.14***	1.06***
	(0.14)	(0.35)	(0.15)
logTA	1.10***	1.12***	0.80***
	(0.04)	(0.10)	(0.05)
Leverage	0.21	1.64***	−0.16
	(0.19)	(0.44)	(0.26)
ROA	1.83***	2.78***	1.23***
	(0.25)	(0.58)	(0.36)
WC	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
Dividend	0.00	0.17***	0.00
	(0.00)	(0.06)	(0.00)
logInves	0.29***	−0.13	0.16***
	(0.04)	(0.08)	(0.05)
StrInv	−0.07***	−0.03	−0.08***
	(0.02)	(0.06)	(0.02)
BoActivity	0.00	0.02	−0.01
	(0.00)	(0.01)	(0.01)
BoFem	0.02***	0.05***	0.01***
	(0.00)	(0.01)	(0.00)
BoIndep	0.00	0.01	0.00
	(0.00)	(0.00)	(0.00)
Duality	0.00	0.11	0.11
	(0.07)	(0.18)	(0.08)
CSRCommitte	2.38***	2.24***	1.42***
	(0.06)	(0.16)	(0.08)
Industry	Yes	Yes	Yes
country	Yes	Yes	Yes
Year	Yes	Yes	Yes
Log likelihood	−23,322.54	−4248.38	−15,329.52

PSM analysis: n = 3763 firms (26,314 observations); t = 2016–2022. Energy strategy analysis: n = 5376 firms (37,632 observations); t = 2016–2022. Coeff., coefficient; SD, standard deviation
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

4.4. Heterogeneity Analysis

Although our baseline results suggest a generally positive correlation between institutional pressures, disruptive events, and investments in climate technology, this effect may not be consistent for all types of firms. To gain a more nuanced understanding of this dynamic, we conducted a heterogeneity analysis examining how firm-level characteristics shape this strategic response. Following prior literature (e.g., García-Sánchez et al., 2023a; 2024a), our analysis focused on two critical dimensions: firm size and financial capacity. We hypothesized that larger firms and those with greater financial capacity are better equipped to withstand the impact of these factors and maintain or increase their long-term climate investments. Table 5 presents the results of the subsample analyses based on these firm characteristics. These results confirm our hypothesis, showing that the effect of the independent variables is consistent across the subsamples.

Table 5. Heterogeneity analysis

	climateTECH			
	Ordered regression for Equation 1			
	Firm size		Financial capacity	
	High	Low	High	Low
	Coeff.	Coeff.	Coeff.	Coeff.
	(SD)	(SD)	(SD)	(SD)
DisrT	0.82***	0.64***	0.89***	0.56***
	(0.04)	(0.11)	(0.04)	(0.07)
EU	2.03***	2.15***	2.12***	1.50***
	(0.15)	(0.48)	(0.15)	(0.30)
logTA	1.20***	0.26	1.17***	0.64**
	(0.05)	(0.21)	(0.05)	(0.11)
Leverage	0.15	−0.08	0.27	−0.20
	(0.20)	(0.83)	(0.21)	(0.52)
ROA	1.65***	2.66***	1.86***	1.20*
	(0.26)	(0.98)	(0.28)	(0.66)
WC	0.00	0.00	0.00*	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Dividend	0.00	−0.06	0.00	0.01
	(0.00)	(0.05)	(0.00)	(0.03)
logInves	0.23***	0.85***	0.17***	0.61***
	(0.04)	(0.12)	(0.04)	(0.08)
StrInv	0.00	−0.15***	−0.05**	−0.16***
	(0.03)	(0.04)	(0.02)	(0.04)
BoActivity	0.00	0.01	−0.01	0.01
	(0.00)	(0.01)	(0.01)	(0.01)
BoFem	0.02***	−0.01	0.02***	0.01*
	(0.00)	(0.01)	(0.00)	(0.01)

BoIndep	0.00	0.02***	0.00	0.01*
	(0.00)	(0.01)	(0.00)	(0.00)
Duality	−0.09	0.71***	−0.14*	0.28**
	(0.07)	(0.19)	(0.08)	(0.13)
CSRCom-mitte	2.34***	3.00***	2.43***	2.46***
	(0.06)	(0.23)	(0.07)	(0.14)
Industry	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Log likeli-hood	−20,839.53	−2470.81	−17,645.25	−5953.91

n = 5376 firms (37,632 observations). *t* = 2016–2022. Coeff., coefficient; SD, standard deviation
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

5. Further Evidence

5.1. Complementary Analysis I

To complement the evidence presented in the previous section, Table 6 presents the results of estimating Equation 1 for each of the initiatives that make up the ClimateTECH score. As these are dichotomous variables, the methodology used is based on logistic regressions for panel data.

Table 6. Complementary results I

	buildingTECH	cleanTECH	resourcesTECH	wasteTECH
	Logistic regression for Equation 1			
	Coeff.	Coeff.	Coeff.	Coeff.
	(SD)	(SD)	(SD)	(SD)
DisrT	0.80***	0.87***	1.70***	0.51***
	(0.09)	(0.15)	(0.08)	(0.07)
EU	0.68**	0.12	4.16***	1.98***
	(0.32)	(0.30)	(0.25)	(0.20)
logTA	1.81***	0.41***	1.58***	1.01***
	(0.11)	(0.10)	(0.08)	(0.07)
Leverage	0.35	−0.72	−1.00***	0.04
	(0.44)	(0.64)	(0.36)	(0.33)
ROA	1.90***	1.31	3.72***	3.25***
	(0.64)	(0.93)	(0.51)	(0.52)
WC	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Dividend	0.00	−0.01	0.14***	0.04*
	(0.00)	(0.01)	(0.04)	(0.02)
logInves	0.37***	0.43***	0.25***	0.19***
	(0.10)	(0.10)	(0.06)	(0.06)
StrInv	0.10**	0.10	0.05	0.11***
	(0.04)	(0.08)	(0.04)	(0.04)
BoActivity	−0.01	0.00	0.02**	−0.02*
	(0.01)	(0.01)	(0.01)	(0.01)
BoFem	0.03***	−0.01	0.04***	0.02***
	(0.01)	(0.01)	(0.006)	(0.00)
BoIndep	0.01**	0.01*	−0.01***	−0.01**
	(0.00)	(0.017)	(0.00)	(0.00)
Duality	0.67***	0.18	−0.40***	−0.35***
	(0.15)	(0.20)	(0.13)	(0.12)
CSRCom-mitte	1.41***	0.97***	3.03***	2.51***
	(0.14)	(0.20)	(0.13)	(0.11)
Industry	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Constant	−56.35***	−29.21***	−42.01***	−30.94***
	(2.03)	(1.71)	(1.44)	(1.18)
Log likeli-hood	−6692.82***	−2040.91***	−7609.20***	−7671.66***

n = 5376 firms (37,632 observations). *t* =2016–2022. Coeff., coefficient; SD, standard deviation
***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

The results confirm that the impact of disruptive events is maintained at a 99% confidence level when each of the climate technologies analyzed is considered in isolation. Comparing the coefficients of the four models, we observed that the influence was greater in the case of eco-efficiency technologies aimed at optimizing the use of resources (, followed by clean technologies (, green building technologies (, and advanced waste management systems (.

Regarding the impact of the European institutional framework, we observed that it haf no impact on investments in clean technologies. Moreover, its influence was stronger, in this order, for eco-efficiency technologies aimed at optimizing the use of resources (, advanced waste management systems (, and green building technologies (.

5.2. Complementary Analysis II

To further unpack the underlying causal mechanisms driving climate technology investments during disruptive periods, we introduced an additional set of estimates based on a subsample analysis according to the DisrT variable, categorizing periods as either stable (2016–2019) or disruptive (2020–2022) times. In line with recent literature (e.g., García-Sánchez et al., 2025c), we proxied four distinct potential channels: regulatory pressure, risk management, economic incentives, and reputational concerns. Firstly, we used our existing European headquarters dummy variable to capture the heightened regulatory pressure inherent in the EU's stringent environmental frameworks. Secondly, we measured risk management motives using a categorical variable that indicates whether or not the firm publicly discloses commercial risks related to climate change. Thirdly, we used operational efficiency as a proxy for economic incentives, hypothesizing that less efficient firms are more financially motivated to invest in cost-saving climate technologies. Finally, we used the presence of environmental controversies as a proxy for reputational concerns, testing whether firms use these investments as a strategic tool to improve their public image.

As shown in Table 7, the results confirm that investment in climate technologies is driven by multiple strategic channels, the impact of which varies depending on the macroeconomic context. Specifically, we found that, in addition to regulatory pressures, climate risks and reputational concerns significantly amplify investment during both stable (2016–2019) and disruptive (2020–2022) periods.

Firstly, regulatory pressure from the EU institutional environment is the main driver of investment. It exhibits a positive and significant coefficient at a given level of confidence in both periods. However, the magnitude of its impact decreases during the disruptive phase, falling from a coefficient of β_1 = 2.79 before the disruption to β_1 = 1.92 during the disruption.

Conversely, commercial risks linked to climate change show an inverse dynamic. Not only does the risk variable maintain its strong statistical significance at a 99% confidence level, but the magnitude of its impact also increases during disruptive times (the coefficient rises from β_2 = 1.86 to β_2 = 2.02). This suggests that companies become more sensitive to, and more proactive in their response to, tangible climate threats in the face of systemic crises.

Regarding reputational concerns (controversies), the data confirm that a history of environmental controversies motivates investment in climate technologies. However, its relative weight decreased in the face of macroeconomic disruption; the coefficient fell from β_4 = 0.35 in the 2016–2019 period to β_4 = 0.20 in the 2020–2022 period, and its level of statistical significance weakened.

Finally, it is worth noting that economic incentives, as measured by operational efficiency (OpeEffi), were not statistically significant in any of the analyzed periods (with respective coefficients of β_3 = −0.12 and β_3 = 0.08). This finding is crucial, as it demonstrates that the transition to climate technologies is driven by risk mitigation and institutional and social pressures, rather than the pursuit of short-term cost savings.

Table 7. Complementary results II: Drivers behind disruptive events effect

climateTECH

Ordered regression for Equation 1

	Stable (2016–2019)	Disruptive times (2020–2022)
	Coeff.	Coeff.
	(SD)	(SD)
EU	2.79***	1.92***
	(0.25)	(0.19)
Risk	1.86***	2.02***
	(0.12)	(0.10)
OpeEffi	−0.12	0.08
	(0.11)	(0.07)
Controversies	0.35***	0.20*
	(0.12)	(0.12)
logTA	1.48***	1.14**
	(0.13)	(0.09)
Leverage	−0.17	0.21
	(0.40)	(0.37)
ROA	2.41***	1.26**
	(0.92)	(0.55)
WC	0.00	0.00
	(0.00)	(0.00)
Dividend	0.01	0.00
	(0.00)	(0.00)
logInves	0.35***	0.24***
	(0.07)	(0.06)
StrInv	−0.08**	−0.09***
	(0.04)	(0.03)
BoActivity	0.00	−0.01*
	(0.01)	(0.01)
BoFem	0.03***	0.02***
	(0.00)	(0.00)
BoIndep	0.00	−0.01**
	(0.00)	(0.00)
Duality	0.15	0.00
	(0.13)	(0.12)
CSRCommitte	3.26***	2.58***
	(0.13)	(0.11)
Industry	yes	yes
Country	yes	yes
Year	yes	yes
Log likelihood	−9795.78	−12,073.49

n = 5376 firms (37,632 observations). *t* = 2016–2022. Coeff., coefficient; SD, standard deviation
$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

6. Discussion

The results of the study confirm the two research hypotheses, showing that both recent disruptive events (i.e., the COVID-19 pandemic and the invasion of Ukraine) and the EU institutional environment have driven business investment in climate technologies. However, the impact of the EU institutional environment is more determinant than that of disruptive events, suggesting that regulatory structure and political pressures play a more relevant role in promoting corporate sustainability.

The positive effect of disruptive events on business investment in climate technologies is consistent with RDT and DCT assumptions. Disruptive crises such as the COVID-19 pandemic and the war in Ukraine have caused significant disruption to the business environment, affecting supply chains, the availability of critical resources and energy security, market conditions, economic stability, and regulatory expectations (Bapuji et al., 2020; Agrawal et al., 2024). In such contexts, firms must adapt to external constraints, respond to institutional pressures, and develop organizational capabilities that enable them to reconfigure resources and strategies, maintaining competitiveness in highly uncertain environments. In this sense, adopting climate technologies may be a strategic response aimed at mitigating risks, improving operational efficiency, and strengthening organizational resilience (Zakeri et al., 2022; García-Sánchez et al., 2023a). Although previous research has often emphasized the negative impact of crises on corporate investment (Bo et al., 2014), our findings suggest that disruptive events can also encourage firms to rethink their strategic priorities and speed up investments that are in line with long-term environmental goals (García-Sánchez et al., 2025a).

The positive association between the EU institutional environment and business investment in climate technologies reflects the influence that the EU's regulatory and legislative framework on environmental and social practices has on companies' environmental behavior (Nuber & Velte, 2021). Over the last two decades, the EU has progressively developed a comprehensive framework of environmental and climate policies and regulations that not only impose regulatory obligations but also shape the expectations of companies, stakeholders, and society regarding the direction of the transition to a low-carbon economy (Ruiz et al., 2023; Lobonț et al., 2025). Initiatives such as the European Green Deal, the EU Emissions Trading Scheme, and the EU Taxonomy for Sustainable Activities have contributed to establishing clear political signals that favor investments aligned with climate change mitigation objectives, generating a context that is conducive and motivating for companies to invest in climate-related technology (Haque & Ntim, 2022; García-Sánchez et al., 2023a; Aydin et al., 2024; You & Teirlinck, 2024). In this sense, this finding reinforces the argument that firms' strategic responses to environmental challenges are shaped by changing market conditions, resource constraints, and the regulatory and normative structures within which organizations operate.

The fact that the EU's institutional environment has a stronger influence on business investment in climate technologies than disruptive events is consistent with the tenets of institutional theory and confirms the words of Berkhout et al. (2024, p. 10) that the responses of social actors to climate risks are to a large extent "the outcome of the institutional and cultural contexts" in which they are embedded. Thus, the presence of coercive pressures from EU regulation has created an environment in which sustainability is not just a strategic choice but a requirement for legitimacy and market access (Cifuentes-Faura, 2022; Rayner, 2023). This finding underlines the importance of regulation as a key mechanism for transforming business practices and aligning them with decarbonization goals. Moreover, the fact that the impact of disruptive crises is smaller than that of regulation suggests that, while shocks may create temporary incentives for sustainability, their impact is less structural and determinant than the influence of the regulatory framework and the institutional pressures that flow from it (Berkouot et al., 2024) by providing a more stable and predictable driver for sustainable investment, which favors a deeper integration of climate technologies into business strategies.

These results have important theoretical implications. Firstly, they extend the application of RDT, DCT, and institutional theory to corporate climate strategies, showing that, while disruptive events affect firms' decisions on sustainability investments, their impact appears to be less significant than that of institutional pressures stemming from the EU regulatory framework. This finding reinforces the idea that firms' strategic responses to environmental challenges are affected not only by changing market conditions and resource limitations but also by the regulatory and normative structures within which organizations operate (García-Sánchez et al., 2025a). Furthermore, the results support the view that firms facing systemic disruptions engage in processes of strategic adaptation and resource reconfiguration to strengthen their long-term resilience (Kyrdoda et al., 2023; Sahebalzamani et al., 2023; Opoku et al., 2025). Investment in climate technologies can therefore be interpreted not only as a response to regulatory pressures but also as part of a broader organizational capability to anticipate structural changes in the economic and energy landscape. Secondly, the study contributes to existing literature by providing empirical evidence of the role disruptive crises and regulation can play in encouraging sustainability-oriented technological change. By demonstrating that such events can lead companies to rethink their strategic priorities and make investments that align with long-term environmental goals, our study enriches the growing body of research examining how major disruptions can influence corporate sustainability behavior. Additionally, the results emphasize the pivotal role of coercive pressures arising from environmental regulation in driving the shift toward sustainable business models (Wesseling et al., 2022; Berkhout et al., 2024).

From a practical viewpoint, the results also offer valuable implications for policymakers, business managers, and investors. For policymakers and regulators, the results emphasize the importance of maintaining robust and credible regulatory frameworks that encourage investment in climate technologies (Ruiz et al., 2023; Aydin et al., 2024; You & Teirlinck, 2024; Lobonț et al., 2025). The results highlight the importance of long-term policy commitments and consistent regulatory signals, as well as well-designed policy instruments that can reduce uncertainty and support companies' strategic planning in the context of the transition to a low-carbon economy. For business leaders, the findings emphasize the importance of adopting proactive and forward-looking sustainability strategies. Rather than merely reacting to external crises and regulatory changes, companies must anticipate these events and incorporate climate-related technological investments into their long-term innovation and competitiveness strategies (Ghisetti & Rennings, 2014). In highly institutionalized contexts, such as the EU, environmental regulation is becoming an increasingly important driver of technological improvement, operational efficiency, and reputational positioning. Consequently, companies that anticipate these institutional dynamics are likely to be better placed to capitalize on emerging opportunities associated with the transition to a low-carbon economy. Finally, for investors, the results suggest that the EU provides a favorable institutional environment for allocating capital to sustainable technology projects. Robust regulatory frameworks and credible climate policy commitments can reduce political uncertainty and improve the expected viability of climate-related investments, thereby enhancing their appeal in terms of risk and return (Aibar-Guzmán et al., 2023a; García-Sánchez et al., 2024a). Investors may therefore consider this when assessing companies' climate strategies and innovation trajectories, particularly in sectors where technological transformation is essential for achieving long-term decarbonization goals (Aibar-Guzmán et al., 2024).

7. Conclusions

This study analyzes the impact of recent disruptive events (i.e., the COVID-19 pandemic and the war in Ukraine) and the influence of the EU institutional environment on business investment in climate technologies. Drawing on RDT and institutional theory, two hypotheses are formulated and tested to examine the impact that the uncertainty generated by these disruptive events has on sustainability investment decisions and the influence of coercive pressures stemming from EU sustainability regulation on the adoption of climate technologies by firms. For a sample of 5376 companies for the period 2016–2022, the results confirm both hypotheses but also show that the EU institutional environment exerts a more decisive influence than disruptive events.

Despite the study being novel and its findings interesting, it has certain limitations that should be taken into account when interpreting its results. First, although the study found a positive relationship between disruptive events and investment in climate technologies, these events were measured on an aggregate basis, without differentiating the specific impact of each crisis. Similarly, we considered the impact of institutional pressures stemming from sustainability regulations in the EU as a whole, without differentiating between the different regulations, the effect of which has been shown to be non-homogeneous (García-Sánchez et al., 2023b). In terms of the study's empirical design, while the sample size allowed for representation of different institutional and economic contexts, thereby enriching the analysis, we recognize that this may have introduced heterogeneity that the empirical model cannot fully capture. Therefore, caution should be exercised when generalizing the results to specific national or regional environments, as these may have institutional or regulatory characteristics that differ from those represented in the sample. Furthermore, using secondary data sources inevitably imposes limitations on how variables are measured. Finally, despite our study period spanning 7 years (from 2016 to 2022), our data do not permit observation of long-term structural changes in corporate investment behavior or assessment of the persistence or evolution of the observed relationships, as climate policies and market expectations continue to develop. In this regard, while the study period encompasses recent global crises, it does not fully reflect the most recent geopolitical and political events that could impact companies' climate strategies, such as changes in international climate commitments, recent conflicts, or shifts in the position of major institutional investors.

These limitations open up avenues for future research. For example, it would be interesting to extend the study to other regions with different regulatory frameworks and levels of sustainability policy development to assess the robustness of the results in different institutional contexts. Similarly, future studies could analyze the differentiated impact of each disruptive event and regulation in different economic sectors, taking into account factors such as market structure, resource dependence, or exposure to environmental risks. Finally, longitudinal studies examining the evolution of investment in climate technologies in response to new regulatory changes and the emergence of new crises would allow for a better understanding of the temporal dynamics of the relationship between regulation, uncertainty, and corporate sustainability.

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