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The impact of banks' climate engagement on systemic risk. Does committing a little or a lot make a difference?

Giuliana Birindelli [a], Stefano Dell'Atti [b], Caterina Di Tommaso [c,*], Antonia Patrizia Iannuzzi [d], Vincenzo Pacelli [e]

[a] Department of Economics and Management, University of Pisa, Pisa, Italy
[b] Department of Political Science, University of Bari "Aldo Moro", Bari, Italy
[c] Ionian Department in "Legal and Economic Systems of the Mediterranean: Society, Environment, Cultures", University of Bari "Aldo Moro", Bari, Italy
[d] Department of Economics, Management and Business Law, University of Bari "Aldo Moro", Bari, Italy
[e] Ionian Department in "Legal and Economic Systems of the Mediterranean: Society, Environment, Cultures", University of Bari "Aldo Moro", Bari, Italy

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ABSTRACT

We investigate the relationship between climate change commitment and systemic risk using a sample of 211 international banks over the period 2011–2020. We hypothesize that banks that are more committed to climate change, which is measured by a score scale provided by the Carbon Disclosure Project, contribute less to systemic risk. Furthermore, we expect that banks that slip into the lowest score category by not even providing sufficient information on their climate change activity ("*worst rating*"), and banks that reduce their commitment along the climate change score scale will increase their exposure to systemic risk ("*downgrade*" effect). The results confirm all our hypotheses. Banks' commitment to climate change is an important driver of systemic risk, and the level of this commitment also matters. We demonstrate the effectiveness of climate change management in reducing a bank's contribution to the overall financial crisis and thereby increasing financial stability. Our study confirms the importance of the efforts to combat climate change for the benefit of financial stability.

1. Introduction

There are several reasons for attributing significant systemic effects to climate change risks. First, if we define systemic risks as those linked to events that have the potential to destabilize capital markets and lead to serious negative consequences for financial markets and institutions (Rusmanto et al., 2020), climate change certainly has a systemic connotation (Nieto, 2019). The extensive physical consequences of climate risk, coupled with the anticipated shift towards a net-zero carbon economy, are poised to materialize in various cumulative and unforeseen manners. These developments pose evident systemic risks to all financial markets and the broader economy. Indeed, there are several amplifiers of climate risk across the financial system. Many physical risks, including water stress, heat stress, and wildfires, can exacerbate each other because the manifestation of one could trigger the others. Meanwhile, in a disorderly climate transition scenario, a surge in carbon prices could increase the likelihood that one company's default will lead to the

* Corresponding author.
E-mail address: caterina.ditommaso@uniba.it (C. Di Tommaso).

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default of others. This, in turn, could cause a collapse in market prices resulting in losses for banks, investment and pension funds, and insurance companies (ECB and ESRB, 2022). Therefore, left unmanaged, climate-related risks could have significant and disruptive impacts on asset assessments, global financial markets, and overall economic stability (ECB and ESRB, 2022; BIS, 2022).

Secondly, if we recognize that climate-related risks are strongly correlated with all other financial risks, such as credit risk, market risk, and liquidity risk, this further aspect amplifies the systemic impacts. In other words, the man of climate risks can trigger other financial risks and thus lead to economic consequences that are difficult to measure, manage, and alleviate.

Climate change also has significant reputational effects. Indeed, according to the Task Force on Climate-related Financial Disclosures (TCFD), climate change risks include important reputational implications tied to stakeholders' perceptions of the ability of banks to make an effective contribution to the transition to a low-carbon economy. If this perception is negative, clients could shift their preferences and the financial sector could be stigmatized, leading to negative stakeholder feedback (TCFD, 2017). Overall, negative stakeholder feedback can significantly affect a bank's reputation, operational effectiveness, and financial performance. Therefore, it is crucial for financial institutions to proactively address climate-related risks and communicate their strategies and actions transparently to stakeholders to mitigate potential negative feedback. A further entanglement between climate change and reputational risk for banks could arise from scandals caused by financing environmentally controversial activities (ECB, 2020).

The systemic implications of climate-related risks have long been recognized by supervisory authorities. Back in 2010, Article 23 (Identification and measurement of systemic risk) of the EU Regulation[1] included a specific reference to the potential environment-related systemic risk to be reflected in the stress-testing regime. In particular, it is stated that the European Banking Authority (EBA) should develop common methodologies to assess the effect of economic scenarios on an institution's financial position, taking into account, inter alia, risks stemming from adverse environmental developments and the impact of transition risks caused by environmental policy changes. More recently, the European Systemic Risk Board (ESRB) stressed the importance of focusing on the macroeconomic dimension of climate-related risks, highlighting that the manifestation of these risks has significant impacts on the overall financial stability (ESRB, 2021; ECB/ESRB, 2022). In the same vein, the European Central Bank (ECB) explicitly affirms that "*climate risks constitute an emerging source of systemic risk and have the potential to destabilize the provision of services by financial institutions and the normal functioning of financial markets, with knock-on effects for the real economy*" (ECB, 2021: 4). Also, "*climate change thus represents a major source of systemic risk, particularly for banks with portfolios concentrated in certain economic sectors and, more importantly, in specific geographical areas*" (ECB, 2021: 5). These considerations are in line with quantitative analyses: estimates suggest that physical damage from climate change could reach one-tenth, or even one-fifth, of global GDP by the end of this century, with considerable uncertainties around amplifying dynamics. In terms of current global output, this would amount to USD 8–17 trillion (ESRB, 2020). As far as the EU banking sector is concerned, credit risk losses under adverse climate scenarios could amount to 1.60–1.75% of corporate risk-weighted assets in a 30-year time frame (ESRB, 2021).

Against this background, we intend to shed light on the relationship between climate change commitment by banks, which we measure by a score scale provided by the Carbon Disclosure Project, and their exposure to systemic risk. Specifically, we aim to verify whether a greater commitment to climate change by banks leads to minimizing the systemic risk of these institutions. Additionally, we test both a "*worst rating*" and a "*downgrade*" effect by verifying, respectively, whether banks that experience a reduction in their climate change commitment by falling into the worst score category (characterized by a lack of sufficient disclosure of firm environmental performance, as we will specify in Section 3) increase their contribution to overall systemic risk (*worst rating effect*) and whether this effect also occurs with a downgrade – even one class – of the climate change score along the value scale used in our research (*downgrade effect*).

We perform this analysis using a sample of worldwide banks during the period 2011–2020. We constructed our original sample by matching banks surveyed by the Carbon Disclosure Project (*CDP*) and banks included in the sample retained by the NY Stern Business School Systemic Risk Rankings. This process yields a sample of 211 largest banks from 39 countries. We find that banks more engaged in climate change concerns reduce their exposure to systemic risk. Similarly, banks that suffer a reduction in environmental commitment by falling into the worst category increase their exposure to systemic risk (*worst rating effect*). The same consequence occurs for banks that suffer a climate rating downgrade because of their decreased efforts toward environmental concerns (*downgrading effect*).

Our study contributes to the literature in several ways. First, we add a new piece to the still limited literature analysing the interactions between climate risk and finance. Indeed, as stated by Carè and Weber (2023), "*only a few articles have started to look at the concept of climate finance under the lens of the interactions between climate change and financial markets*" (page 2). Second, to the best of our knowledge, this is the first study offering an empirical investigation of the relationship between systemic risk and climate change commitment, taking into account score movements on a value scale. Previous research has mainly focused on the theoretical framework to explore the link between systemic risk and climate-related risk (Beard et al., 2021; Campiglio et al., 2018) while existing empirical studies on systemic risk relate this principally to the social responsibility performance of financial institutions and not just to climate change performance (Sonnenberger and Weiss, 2021; Bellavite Pellegrini et al., 2022). Third, we contribute to the policy debate about the role of financial institutions in the transition to a low-carbon economy and hence about the actions that can be taken by banks to safeguard financial stability (Fatica et al., 2021; Carè and Weber, 2023). Finally, our paper offers an insight into the climate considerations for financial supervisors and their prudential policies that have launched the idea to introduce climate change as part of stress-testing exercises (Battiston et al., 2017; EIOPA, 2019; Grippa and Mann, 2020).

[1] Regulation (EU) No. 1093/2010 of the European Parliament and of the Council of 24 November 2010 establishing a European Supervisory Authority (European Banking Authority), amending Decision No. 716/2009/EC and repealing Commission Decision 2009/78/EC.

The rest of this paper is organized as follows. In Section 2, we present a literature review and the research hypotheses. In Section 3, we look at the data and methodology employed. In Section 4, we analyze the empirical results and discuss them. Robustness checks are reported in Section 5. And finally, in Section 6 we conclude.

2. Literature review and hypotheses development

2.1. Climate change and financial stability

Our paper primarily relates to two complementary strands of literature: studies that highlight the adverse impact of climate change on overall financial stability (Carney, 2015; Dietz et al., 2016; Liu et al., 2021; Roncoroni et al., 2021), and research aimed at proving a negative relationship between ESG performance and overall firm risk, especially in times of crisis (Chiaramonte et al., 2022).

Looking at the impact of climate change on finance, there is growing evidence of a negative linkage between climate risk and financial stability (Carney, 2015). Starting with the Paris Agreement, this topic has taken centre stage in the policy debate and the recommendations and assessments by financial supervisors (Bank of England, 2018; Campiglio et al., 2018; ECB, 2019). Different analyses show that climate change-related risks have the potential to become systemic by destabilizing the overall financial system. For instance, the European Systemic Risk Board estimates that European banks could experience a loss of around 10% of their balance sheets if the high-emitting firms were to have their credit rating downgraded. This is even more critical for investment funds where over 55% of investments are tilted towards high-emitting firms and only an estimated 1% of assets are aligned with the EU taxonomy. With regard to the European insurance sector, while direct holdings towards high-emitting firms are limited, they could be amplified by spillover effects. Indeed, about 30% of investments by insurers are in investment funds whose exposure is largely oriented toward high-emitting sectors (ESRB, 2021). "*Such impacts could be particularly pronounced should financial markets abruptly reprice the financial risk associated with climate change – against a backdrop of rapid market growth of green finance and environmental, social and governance (ESG) investing despite still limited disclosures, standards and taxonomies*" (ESRB, 2021: 4). In the same vein, the recent climate stress tests conducted by the European Central Bank on 104 of the largest banks show other concerns: a) around 60% of banks do not have a climate risk stress-testing framework; b) most banks do not yet include climate risk in their credit risk models; and finally, c) more than 50% of banks' income from non-financial corporate customers comes from greenhouse gas-intensive industries (Elderson, 2022). Thus, it appears that financial institutions are far from being resilient to the adverse conditions caused by climate change.

Additional insights can be found in the existing literature, which is increasingly interested in the systemic repercussions of climate change (King et al., 2015). Indeed, many scholars from different disciplines agree that the impacts of climate change are a global and complex issue and that the indirect and systemic impacts are no less important than the direct ones (Beard et al., 2021). In line with Liu et al. (2021), climate disasters not only cause severe damage to infrastructure and private property, leading to adverse effects on financial stability, but they also represent highly uncertain events that are challenging forecasts. While the primary impact of climate change is felt at the local level, the effects can spread across different regions and sectors, through interconnected socio-economic and financial systems (Li et al., 2021). Li et al. (2021) state that systemic risk resulting from climate change is a holistic risk generated by the interconnection, interaction, and dynamic evolution of different types of single risks. This type of cascading effect is its fundamental and defining feature. According to Liu et al. (2021), the nexus between climate change and financial stability is non-linear and asymmetric. First, these scholars distinguish between positive and negative climate shocks: the positive ones, concerning an increase in average temperature and manifesting as extreme weather events such as heatwaves, hurricanes, or droughts, destroy the stability of the financial system through physical risk mechanisms; and the negative ones, concerning a decrease in average temperature and arising from the transition to a low-carbon economy and efforts to mitigate climate change, damage financial stability through the transition risk mechanism. While positive shocks prevail in the short term, the greatest financial instability is caused by negative climate change shocks over the long term (Zhang et al., 2022). Finally, Capasso et al. (2020) argue that, since companies with high carbon footprints are perceived by the market as more likely to default, banks should consider the borrower's carbon footprint to efficiently price the risks, thus reducing the systematic impact of climate change.

Even though the existing literature agrees on the extreme importance of systemic risks induced by climate change, there are still gaps in the understanding and assessment of such dynamic processes. Therefore, further research is necessary because only a proper assessment and management of climate risk and its systemic impacts can offer a significant contribution to financial stability.

2.2. ESG/climate commitment and bank risk

An increasing number of recent studies focus on the impact of ESG activities on bank risk and financial stability. These studies agree on the importance of documenting the risk-reducing effect of a firm's ESG commitment (Chollet and Sandwidi, 2018; Gillan et al., 2021), especially during adverse economic conditions (Bouslah et al., 2018; Chiaramonte et al., 2022) and for larger (Aevoae et al., 2022) or systemic banks (Scholtens and van't Klooster, 2019). This strand of research is the intersection of the theoretical background on stakeholders and moral capital theories, which views Corporate Social Responsibility (CSR) as an insurance-like strategy aimed at shareholder value maximization, by mitigating conflicts between the management and the stakeholders, especially in times of crisis (Bouslah et al., 2018).

Among the more recent studies, Chiaramonte et al. (2022) focus on a sample of European banks operating in 21 countries over the period 2005–2017, revealing that banks with ESG strategies can minimize their financial fragility, especially during periods of financial turbulence. This stabilizing effect appears to be stronger both for banks with higher ESG ratings and for those that have been disclosing their ESG strategies for longer periods. Therefore, it seems that greater stability might be the result not only of the promotion

Table 1
Numerical values assigned to *CCS* score.

CCS score	*Numerical value*
A	10
A-	9
B	8
B-	7
C	6
C-	5
D	4
D-	3
E	2
F	1

Table 2
Summary statistics of dependent, independent, and control variables for the sample over the period 2011–2020.

	Obs	Mean	25 (%)	Median	75 (%)	Sd
Panel A: Dependent variable- Bank's level systemic risk						
SRISK	1127	13.32	0.00	4.58	18.97	20.83
Panel B: Variable of interest						
CCS score	1127	5.32	1.00	6.00	8.00	3.38
Panel C: Control variables						
Banks size	1127	18.71	17.64	18.60	20.00	1.55
ROA	1127	0.75	0.34	0.70	1.12	0.95
Tier 1	1127	14.26	11.70	13.40	15.99	4.10
NPL	1127	4.32	0.97	2.10	4.95	6.36
CIR	1127	57.06	48.10	58.31	65.72	16.92
Liquid asset	1127	26.62	17.57	24.54	34.17	12.46
Net loans	1127	57.85	49.23	59.96	67.75	14.45
Country Rating	1127	2.77	2.00	3.00	4.00	1.22
GDP growth	1127	1.45	0.78	1.99	2.98	3.28

This table reports yearly summary statistics of the bank's level systemic risk (Panel A), CCS score, and control variables (Panel B and C) for the sample over the period 2011–2020. We report the mean, the 25th percentile, the median, the 75th percentile, and the standard deviation.
The definition of the variables is reported in Table A2.
SRISK, ROA, Tier 1, NPL ratio, CIR, Liquid assets, Net loans, and GDP growth are expressed in percentage, and Bank size in log.
Source: V-lab, CDP, BankFocus, and authors' calculations

of sustainability strategies but also of steady implementation and disclosure of them over time. Similar findings come from Aevoae et al. (2022) with a sample of 367 worldwide banks from 2007 to 2020. They specifically show that bank ESG strategies bolster financial stability and that this power is more pronounced for larger banks and banks located in developed countries. As the ESG performance rises, these banks account for less of the distress in the overall system. Broadly put, this study highlights an important aspect of engaging in ESG activities: it brings benefits to the bank itself and the entire financial system. Scholtens and van't Klooster, 2019 provide additional findings. Based on 43 European banks from 2002 to 2016, they find that a bank's sustainability is significantly associated with a lower default risk (*Z-Score*) and with decreased systemic risk (*SRISK*). This suggests that bank sustainability can act as a mitigating tool for systemic risk by increasing overall financial stability.

Other studies, focusing only on environmental performance, provide similar results. For instance, Neitzert and Petras, 2022, analysing a data set of 582 worldwide banks from 2002 to 2018, find not only a negative and statistically significant relationship between overall CSR activities and banks' default risk but also that this effect is driven especially by environmental performance. In other words, it is mainly the environmental outcomes that mitigate a bank's overall riskiness compared to social and governance activities, which do not produce such clear effects. In the same vein, using a sample of 142 banks from 35 countries between 2011 and 2015, Gangi et al. (2019) show that banks that are more sensitive to environmental issues exhibit less risk. Similarly, focusing on non-financial firms, Capasso et al. (2020) note that greater exposure to climate change issues makes companies riskier. They show that as a firm's carbon emissions increase, its distance to default increases. This implies that companies with higher carbon footprints are perceived by the market as facing a greater risk of default. In other words, investors and stakeholders view firms with significant carbon emissions as potentially less financially stable or resilient compared to those with lower emissions. This perception may stem from concerns about the long-term viability of business models reliant on high carbon intensity, as well as the potential regulatory, reputational, and operational risks associated with climate change.

Finally, other studies come to similar conclusions while focusing on the capital market. For example, Agliardi and Agliardi (2021) find important beneficial effects of green bonds issued by firms. A green bond is a financial instrument issued by an entity to fund environmentally beneficial projects. It allows investors to support initiatives such as renewable energy and sustainable infrastructure. Investors in green bonds receive regular interest payments while supporting projects with positive environmental impacts. On the one hand, these financial instruments can help mitigate a firm's exposure to climate change transition risks, and the greater the volume of

Table 3
Panel model estimates: the impact of CCS on systemic risk.

	(1)	(2)	(3)	(4)
SRISK-1	0.217***	0.607***	0.218***	0.633***
	(0.004)	(0.005)	(0.004)	(0.005)
CCS	-0.080**	-0.020***	-0.078**	-0.021***
	(0.032)	(0.005)	(0.032)	(0.003)
Bank size-1	1.763***	2.444***	1.853***	2.313***
	(0.469)	(0.102)	(0.460)	(0.098)
ROA-1	0.058***	0.046***	0.056***	0.050***
	(0.003)	(0.004)	(0.003)	(0.005)
Tier 1–1	-0.015	-0.019	-0.015	-0.019
	(0.094)	(0.093)	(0.097)	(0.094)
NPL-1	0.028***	0.125***	0.009*	0.158***
	(0.003)	(0.002)	(0.005)	(0.001)
CIR-1	0.033***	0.027***	0.034***	0.027***
	(0.000)	(0.003)	(0.001)	(0.004)
Liquid asset-1	-0.028***	-0.075***	-0.029***	-0.078***
	(0.008)	(0.000)	(0.008)	(0.000)
Net Loans-1	-0.132***	-0.062***	-0.131***	-0.063***
	(0.014)	(0.010)	(0.014)	(0.009)
GDP growth			0.068	0.142
			(0.061)	(0.109)
Country Rating			0.377***	0.835***
			(0.009)	(0.078)
Intercept	-27.036***	-27.092***	-30.196***	-29.446***
	(7.482)	(2.212)	(7.239)	(2.576)
Observations	1630	1630	1630	1630
R-squared	0.2677	0.2571	0.2681	0.2572
Bank FE	YES	NO	YES	NO
Year FE	YES	YES	YES	YES
Country FE	NO	YES	NO	YES

This table reports the results of the model in Eq. (1). The dependent variable is SRISK (in %). In columns (1), and (2) we report the results including the bank-specific variables as control variables. In columns (3), and (4) we report the results including the banks-specific and country variables. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

green bonds issued, the higher the effect of mitigation. On the other hand, green bonds may contribute to reducing systemic risk and thus improve financial stability in the global bond market. Cerqueti et al. (2021) show that funds with more investments in ESG-compliant assets are less exposed to systemic shocks and are thus able to neutralize systemic risk to a greater extent. In other words, the higher a fund's share of ESG investments, the greater its resilience to financial contagion. This occurs because investors in socially responsible funds are less sensitive to past negative returns than investors in conventional funds. Overall, it can be assumed that ESG investments (green bonds or SRI funds) are more able than conventional ones to contain and neutralize systemic risk.

Given the discussion above, we formulate the following research hypothesis:

H1. : The greater a bank's commitment to climate change, the lower its contribution to systemic risk.

2.3. ESG/climate commitment levels and bank risk

The demand for corporate data on climate risk management has increased significantly in recent years, becoming more and more stringent. As for the banking sector, the EBA has recently published new binding technical standards on Pillar 3 disclosures on ESG and climate-related risks aimed at ensuring that stakeholders are well informed about risks and vulnerabilities that banks may face as a consequence of climate change (EBA, 2022). Institutional investors declare that their investment strategies will be based forevermore on the environmental commitment of target firms (Krueger et al., 2020). Therefore, demonstrating a high commitment to climate risk is currently a key asset for companies (both financial and non-financial firms) that can enable them to be better appreciated by the market with important benefits in terms of increased reputation capital, reduced funding costs, and improved performance. Recent empirical studies confirm this linkage. Birindelli et al. (2022), using a large sample of international listed banks over the period 2011–2019, find that only the achievement of high-level commitment to climate change allows banks to increase the quality of their assets and thus reduce their riskiness. Conversely, a low commitment to climate risks is unable to produce any benefit. Similarly, Eratalay and Cortés Ángel (2022), focusing on constituent stocks of the S&P Europe 350 Index from 2016 to 2020, find that firms with greater ESG ratings contribute less to systemic risk. However, this effect is marginal for small improvements in the ESG ratings because only high ESG ratings can exert an important reductive effect on firms' systemic risk exposure. Finally, Drago et al. (2019), focusing on all European public non-financial firms from 2007 to 2017, show that better CSR ratings lead to lower CDS spreads 30 days after the rating announcement, indicating a significant decrease in credit risk perceived by investors. Moreover, this negative impact is significant especially for upgrades of the overall rating and the environmental scores, confirming the greater attention paid by investors to climate change concerns.

Table 4
Panel model estimates "worst rating effect".

	SRISK			
	(1)	(2)	(3)	(4)
SRISK-1	0.284***	0.653***	0.284***	0.653***
	(0.011)	(0.003)	(0.011)	(0.003)
Switch	0.676***	0.289***	0.695***	0.304***
	(0.207)	(0.098)	(0.195)	(0.105)
Bank size-1	2.035***	1.941***	1.930***	1.944***
	(0.068)	(0.034)	(0.078)	(0.035)
ROA-1	0.014**	0.022***	0.015**	0.021***
	(0.006)	(0.006)	(0.007)	(0.006)
Tier 1–1	0.048	-0.099	0.050	-0.097
	(0.131)	(0.108)	(0.132)	(0.108)
NPL-1	0.065***	0.101***	0.059***	0.109***
	(0.015)	(0.009)	(0.016)	(0.009)
CIR-1	0.051***	0.030***	0.053***	0.032***
	(0.011)	(0.001)	(0.012)	(0.000)
Liquid asset-1	-0.091**	-0.072***	-0.093***	-0.073***
	(0.042)	(0.025)	(0.040)	(0.025)
Net Loans-1	-0.163***	-0.157***	-0.162***	-0.156***
	(0.062)	(0.012)	(0.060)	(0.012)
GDP growth			-0.111	-0.027
			(0.218)	(0.115)
Country Rating			0.292***	0.549***
			(0.032)	(0.014)
Intercept	-35.370***	-15.972***	-34.438***	-19.291***
	(3.685)	(0.941)	(3.841)	(1.021)
Observations	1630	1630	1630	1630
R-squared	0.2712	0.2435	0.2717	0.2432
Bank FE	YES	NO	YES	NO
Year FE	YES	YES	YES	YES
Country FE	NO	YES	NO	YES

This table reports the results of the model in Eq. (1) including the switch variable. The dependent variable is SRISK (in %). In columns (1) and (2) we report the results including the bank-specific variables as control variables. In columns (3) and (4) we report the results including the banks-specific and country variables.
***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Overall, this evidence leads us to formulate two further research hypotheses:

H2a. Banks moving to the lowest level of environmental commitment (characterized by the absence of sufficient disclosure on environmental performance) increase their contribution to overall systemic risk ("worst rating effect").

H2b. The downgrade in the commitment to climate change increases the banks' contribution to overall systemic risk ("downgrade effect").

3. Data and methodology

To construct our sample, we first identify all banks surveyed by the *CDP*[2], a leading international non-profit organization assessing the efforts of companies worldwide to reduce their greenhouse gas emissions, safeguard water resources, and protect forests.[3] To proxy the climate change commitment made by banks, we use the climate change score *(CCS)* measured by the *CDP* that many other studies have already used (Birindelli et al., 2022; Damert and Baumgartner, 2018; Galletta et al., 2021; Matisoff et al., 2013). The *CCS* provided by the *CDP* summarizes a company's disclosure and environmental performance. It offers an accurate and transparent assessment of the company's progress in fighting climate change. The company has to provide, through a questionnaire (fully aligned with the TCFD recommendations), specific information that is transformed by the *CDP* into a scale ranging from *A* (best *CCS*) to *F* (a requested company fails to disclose through the *CDP*). Therefore, the best *CCS* is awarded to companies most committed to activities against the harmful effects of climate change and to disclosing their efforts.

We obtain data from 250 banks around the world. Next, we verify whether these banks have a measure of systemic risk using the V-

[2] https://www.cdp.net/en/climate

[3] The *CDP* is a globally recognized initiative that measures and discloses carbon emissions and the environmental information of organizations. It collects data from thousands of companies worldwide, encouraging them to disclose their greenhouse gas emissions, water usage, and other environmental impacts. The *CDP* serves as a crucial platform for promoting corporate transparency and accountability in addressing climate change. It enables stakeholders to assess and compare companies based on their environmental practices, thereby encouraging sustainable actions and fostering a greater commitment to environmental responsibility.

Table 5
Panel model estimates "Downgrade effect".

	SRISK							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SRISK-1	0.284***	0.653***	0.284***	0.653***	0.284***	0.653***	0.284***	0.653***
	(0.011)	(0.027)	(0.045)	(0.027)	(0.011)	(0.027)	(0.045)	(0.027)
Downgrade	1.032***	1.116***	1.053***	1.138***				
	(0.095)	(0.210)	(0.138)	(0.218)				
Dimension					0.402***	0.452***	0.409***	0.457***
					(0.064)	(0.116)	(0.087)	(0.118)
Bank size-1	2.067***	1.908***	1.961**	1.911***	2.052***	1.915***	1.943**	1.918***
	(0.066)	(0.143)	(0.952)	(0.141)	(0.063)	(0.140)	(0.926)	(0.138)
ROA-1	0.016**	0.023***	0.013***	0.022***	0.017***	0.023***	0.014***	0.022***
	(0.006)	(0.004)	(0.001)	(0.006)	(0.006)	(0.004)	(0.002)	(0.007)
Tier 1–1	0.046	-0.102	0.047	-0.101	0.044	-0.106	0.045	-0.105
	(0.131)	(0.202)	(0.053)	(0.202)	(0.131)	(0.204)	(0.058)	(0.205)
NPL-1	0.064***	0.104***	0.057***	0.112***	0.062***	0.106***	0.055***	0.114***
	(0.015)	(0.029)	(0.004)	(0.028)	(0.014)	(0.031)	(0.003)	(0.030)
CIR-1	0.051***	0.031**	0.054***	0.032***	0.051***	0.031**	0.054***	0.032***
	(0.010)	(0.013)	(0.003)	(0.011)	(0.010)	(0.014)	(0.003)	(0.012)
Liquid asset-1	-0.013***	-0.072***	-0.015***	-0.073***	-0.012***	-0.072***	-0.014***	-0.073***
	(0.001)	(0.000)	(0.002)	(0.000)	(0.002)	(0.000)	(0.001)	(0.000)
Net Loans-1	-0.065***	-0.057***	-0.065***	-0.057***	-0.067***	-0.058***	-0.066***	-0.058***
	(0.001)	(0.000)	(0.015)	(0.001)	(0.002)	(0.000)	(0.014)	(0.001)
GDP growth			-0.114	-0.031			-0.114	-0.032
			(0.078)	(0.116)			(0.077)	(0.115)
Country Rating			0.305***	0.565***			0.298***	0.557***
			(0.104)	(0.033)			(0.098)	(0.038)
Intercept	-35.691***	-15.795***	-34.777**	-19.216***	-35.261***	-15.911***	-34.280**	-19.288***
	(3.596)	(1.326)	(17.230)	(1.802)	(3.640)	(1.117)	(16.799)	(1.616)
Observations	1630	1630	1630	1630	1630	1630	1630	1630
R-squared	0.2946	0.2878	0.2941	0.2876	0.2947	0.2879	186	186
Bank FE	YES	NO	YES	NO	YES	NO	YES	NO
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Country FE	NO	YES	NO	YES	NO	YES	NO	YES

This table reports the results of the model in Eq. (1) including the Downgrade and Dimension variable. The dependent variable is SRISK (in %). In columns (1), (2), (5), and (6) we report the results including the bank-specific variables as control variables. In columns (3), (4), (7), and (8) we report the results including the banks-specific and country variables.
***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

lab maintained by the NY Stern Business School,[4] which actively reports different measures of systemic risk. We use the *SRISK* that measures a financial firm's contribution to overall systemic risk (Acharya et al., 2017; Arif, 2020; Halili et al., 2021; Laeven et al., 2016). This score ranges between 0% and 100%: the higher the systemic risk the bank presents, the higher the percentage. This matching process based on the two data sets (*CDP* and NY Stern Business School) yields a sample that includes an unbalanced panel of 1127 bank-year observations throughout the period 2011–2020, using data from 211 banks (for a more detailed description see Table A1 in the Appendix).

To deal with the presence of potential outliers, all the employed variables are winsorized at a 1% level in each tail of the distribution. Definitions of the variables used in the model, the data sources, and the expected signs are provided in Table A2 in the Appendix.

To address our research hypotheses, we use a panel of yearly data, ranging from 2011 to 2020. By estimating the following panel regression with fixed effects, we aim to test how and to what extent a bank's contribution to systemic risk is influenced by its climate change commitment:

$$Systemic_{i,t} = \propto_i + \beta_0 * CCS_{i,t} + \gamma * X_{i,t-1} + \delta * Z_{j,t} + \varepsilon_{i,t} \quad (1)$$

where the dependent variable, i.e. $Systemic_{i,t}$, is the systemic risk of bank *i* at time *t* measured by *SRISK*. The variable $CCS_{i,t}$ captures the climate change commitment of bank *i* at time *t*. The *CCS* variable represents the evaluation of a company's (including banks) progress towards environmental stewardship. The *CDP* scale[5] is expressed using the categories A and A- (Leadership level), B and B- (Management level), C and C- (Awareness level), D and D- (Disclosure level), and F (Failure to provide sufficient information to be evaluated). From A to F, the climate change commitment of the bank decreases. A statistically significant coefficient on the *CCS* implies that climate risks constitute a source or a deterrent of systemic risk. It is very important to understand the sign of this coefficient. A

[4] https://vlab.stern.nyu.edu/welcome/srisk

[5] The *CDP* scoring system utilizes different categories (Leadership, Management, Awareness, and Disclosure) to assess and communicate the climate change commitment of organizations.

Table 6
The robustness Panel model estimates: the impact of CCS on LRMES.

LRMES				
	(1)	(2)	(3)	(4)
LRMES-1	0.501***	0.478***	0.507***	0.475***
	(0.054)	(0.049)	(0.062)	(0.046)
CCS	-0.099***	-0.054***	-0.082***	-0.048***
	(0.001)	(0.012)	(0.014)	(0.013)
Bank size-1	0.412***	0.829***	0.368***	0.823***
	(0.115)	(0.215)	(0.123)	(0.220)
ROA-1	0.012**	0.009***	0.012**	0.016***
	(0.005)	(0.003)	(0.006)	(0.005)
Tier 1–1	-0.172	-0.295***	-0.203	-0.309***
	(0.123)	(0.034)	(0.150)	(0.041)
NPL-1	0.434***	0.252***	0.388***	0.222***
	(0.024)	(0.058)	(0.007)	(0.057)
CIR-1	0.094	-0.048	0.091	-0.047
	(0.147)	(0.034)	(0.148)	(0.035)
Liquid asset-1	0.038	0.038	0.041	0.041
	(0.091)	(0.034)	(0.093)	(0.032)
Net Loans-1	-0.068	-0.052	-0.084	-0.053
	(0.089)	(0.057)	(0.087)	(0.056)
GDP growth			-0.214	-0.285
			(0.451)	(0.438)
Country Rating			0.474***	0.482***
			(0.115)	(0.109)
Intercept	-45.477	-25.008***	-36.764	-25.721***
	(29.799)	(4.804)	(30.182)	(1.861)
Observations	1630	1630	1630	1630
R-squared	0.4092	0.3041	0.4168	0.3112
Bank FE	YES	NO	YES	NO
Year FE	YES	YES	YES	YES
Country FE	NO	YES	NO	YES

This table reports the results of the model in Eq. (1). The dependent variable is LRMES (in %). In columns (1) and (2) we report the results including the bank-specific variables as control variables. In columns (3) and (4) we report the results including the banks-specific and country variables. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively

positive *CCS* coefficient would imply that climate change commitment has the potential to destabilize the normal functioning of financial markets, with knock-on effects on financial stability. In contrast, a negative sign would imply that the climate change commitment of a bank induces a more stable financial system by lowering the contribution of a bank to a systemic financial crisis. In line with Birindelli et al. (2022), we assign a numerical value to each climate change score issued by the *CDP*. We use the rating scale presented in Table 1.

$X_{i,t-1}$ is a vector of bank-specific characteristics. We account for factors that have been found to be significant in the relevant literature. Based on prior literature on the determinants of banks' systemic risk (Altunbas et al., 2022; Arif, 2020; Halili et al., 2021; Laeven et al., 2016), we add (i) the logarithm of total assets as a proxy for bank size to capture its impact on the systemic risk (Altunbas et al., 2022; Laeven et al., 2016); (ii) the ratio of net income to average total assets (return on assets, ROA) as an indicator of bank profitability (Altunbas et al., 2022; Arif, 2020); (iii) the ratio of Tier 1 capital to total risk-weighted assets (Tier 1 ratio) as a measure of bank capitalization (Arif, 2020; Laeven et al., 2016; Ly et al., 2017); (iv) the ratio of NPLs to gross loans as a proxy for bank loan quality (Altunbas et al., 2022; Ly et al., 2017); (v) the cost to income ratio as a measure of bank efficiency (Bierth et al., 2015); (vi) the ratio of liquid assets to total assets as a proxy for liquidity (Altunbas et al., 2022; Arif, 2020); (vii) the ratio of net loans to total assets as a proxy for business model (Laeven et al., 2016). The vector $Z_{i,t}$ includes the country's variables, such as the year-over-year change in a country's economic output to measure the growth of the economy (GDP growth) and the country rating (Wasi et al., 2023; Ly et al., 2017; Vassalou and Xing, 2004). The country credit rating issued by the S&P rating agency and obtained by Refinitiv has been transformed into a numerical scale with values ranging from 1 to 6. We construct a scale where countries classified as high-grade countries are assigned a value equal to 1, upper-medium-grade countries are assigned a value that is equal to 2, and lower-medium-grade countries are assigned a value equal to 3 (Drago and Gallo, 2016). Lastly, robust standard errors ($\varepsilon_{i,t}$) are considered. To account for potential endogeneity concerns, bank-specific variables are lagged by one year when entering the regression models. To control for potential correlations between the variables, we report the matrix correlation in Table A3 in the Appendix.

Table 2 reports the mean, the 25th percentile, the median, the 75th percentile, and the standard deviation of our dependent variable, the variable of interest, and the control variables. As for our dependent variable, the average bank's *SRISK* is equal to 13.32%. The 75th percentile level of the dependent variable (18.97%) shows that the banks' contribution to systemic risk is low. The mean *CCS* is 5.32, indicating an overall "*Awareness level*" based on the CDP's assessment process.

Table 7
The robustness Panel model estimates: the "worst rating effect".

	LMRES			
	(1)	(2)	(3)	(4)
LRMES-1	0.098***	0.498***	0.085**	0.494***
	(0.038)	(0.043)	(0.042)	(0.043)
Switch	0.592***	1.153***	0.610***	1.133***
	(0.114)	(0.149)	(0.174)	(0.130)
Bank size-1	4.840***	0.837***	4.126***	0.834***
	(0.807)	(0.120)	(0.824)	(0.120)
ROA-1	0.055***	0.083***	0.070***	0.091***
	(0.014)	(0.007)	(0.012)	(0.007)
Tier 1–1	-0.291***	-0.328***	-0.279***	-0.330***
	(0.024)	(0.001)	(0.030)	(0.003)
NPL-1	0.127***	0.089***	0.093***	0.064***
	(0.026)	(0.024)	(0.020)	(0.025)
CIR-1	-0.019	0.026	-0.023	0.024
	(0.105)	(0.108)	(0.102)	(0.109)
Liquid asset-1	-0.037	0.014	-0.029	0.016
	(0.204)	(0.205)	(0.206)	(0.204)
Net Loans-1	-0.031	-0.041	-0.037	-0.041
	(0.118)	(0.110)	(0.120)	(0.112)
GDP growth			-0.546	-0.393
			(0.652)	(0.425)
Country Rating			0.414**	0.985***
			(0.210)	(0.174)
Intercept	-62.357***	-17.187***	-46.772***	-22.430***
	(16.707)	(0.179)	(16.640)	(1.028)
Observations	1630	1630	1630	1630
R-squared	0.4316	0.3702	0.4351	0.3725
Bank FE	YES	NO	YES	NO
Year FE	YES	YES	YES	YES
Country FE	NO	YES	NO	YES

This table reports the results of the model in Eq. (1) including the switch variable. The dependent variable is LRMES (in %). In columns (1) and (2) we report the results including the bank-specific variables as control variables. In columns (3) and (4) we report the results including the banks-specific and country variables.
***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

4. Results and discussion

This section presents the empirical results of our econometric strategy. We first run Eq. (1) by including the *CCS* and the bank-specific variables. In a second model, we add country-specific variables. Overall, the results show a negative relationship between systemic risk and climate change commitment. Therefore, banks with a greater climate change commitment contribute to strengthening financial stability.

Table 3 reports the results of the model in Eq. (1). In columns (1) and (2) we report the results including the bank-specific variables as control variables. In columns (3) and (4) we report the results including the bank-specific and country measures as control variables. The results confirm our H1: the climate change commitment influences the contribution of a bank to systemic risk. Specifically, a greater bank climate change engagement decreases the contribution of banks to the overall systemic risk. Indeed, the sign of the *CCS* coefficient is negative and statistically significant in all our specifications (Table 3). This negative effect suggests that climate change commitment is a key factor in lowering systemic risk and thus helping boost financial stability.

Moreover, our estimates highlight the size effect of climate change commitment. For example, a bank that demonstrates best practices in strategy and action, as well as its awareness of climate change issues, the adoption of management methods, and the progress towards action taken on climate change could expect a reduction in its systemic risk of around 0.8% (-0.08×10) when controlling for bank fixed effects and 0.21% (-0.021 $\times$ 10) when controlling for country fixed effects, whereas banks that do not provide sufficient information to be evaluated (their score is "F") could expect a decrease in the contribution to systemic risk of only 0.08% (-0.08×1) when controlling for bank fixed effects and 0.021% (-0.021 $\times$ 1) when controlling for country fixed effects. Thus, a more intensive climate commitment leads to a lower contribution of banks to systemic risk, as shown by SRISK.

This finding is in line with the current empirical literature that demonstrates a relevant beneficial impact of all ESG activities on bank risk (Chiaramonte et al., 2022; Aevoae et al., 2022; Scholtens and van't Klooster, 2019). Additionally, it also confirms that climate change commitment plays a central role not only in ESG issues, but also in containing systemic risk (Eratalay and Cortés Ángel, 2022), and in achieving greater financial stability (ESRB, 2020, 2021). Therefore, regulatory pressure on financial institutions for climate change commitment will increase the stability of the whole financial system (EBA, 2022).

Table 8
The robustness Panel model estimates: the "Downgrade effect".

LRMES								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LRMES-1	0.083***	0.492***	0.069***	0.488***	0.082***	0.492***	0.068***	0.488***
	(0.014)	(0.012)	(0.019)	(0.013)	(0.012)	(0.026)	(0.011)	(0.023)
Downgrade	0.632***	1.107***	0.571*	1.083***				
	(0.114)	(0.303)	(0.292)	(0.276)				
Dimension					0.077***	0.294***	0.051***	0.279***
					(0.022)	(0.004)	(0.016)	(0.002)
Bank size-1	0.480***	0.778***	0.429***	0.772***	0.482***	0.763***	0.432***	0.757***
	(0.031)	(0.036)	(0.082)	(0.048)	(0.004)	(0.141)	(0.004)	(0.141)
ROA-1	0.152***	0.073***	0.141***	0.067***	0.153***	0.073***	0.142***	0.067***
	(0.010)	(0.004)	(0.006)	(0.007)	(0.016)	(0.002)	(0.016)	(0.005)
Tier 1–1	-0.008	-0.241***	-0.014	-0.246***	-0.009	-0.239***	-0.014	-0.245***
	(0.088)	(0.014)	(0.153)	(0.014)	(0.157)	(0.062)	(0.153)	(0.061)
NPL-1	0.113***	0.169***	0.099**	0.149***	0.113***	0.169***	0.099***	0.149***
	(0.013)	(0.010)	(0.049)	(0.023)	(0.010)	(0.010)	(0.005)	(0.012)
CIR-1	-0.056	-0.013	-0.050	-0.010	-0.056	-0.012	-0.049	-0.010
	(0.127)	(0.012)	(0.102)	(0.018)	(0.102)	(0.014)	(0.102)	(0.018)
Liquid asset-1	-0.123***	-0.038***	-0.112***	-0.035***	-0.122***	-0.038***	-0.111***	-0.034***
	(0.009)	(0.005)	(0.005)	(0.005)	(0.018)	(0.004)	(0.017)	(0.005)
Net Loans-1	-0.092***	-0.093***	-0.093***	-0.093***	-0.093***	-0.093***	-0.094***	-0.092***
	(0.012)	(0.003)	(0.005)	(0.001)	(0.012)	(0.031)	(0.012)	(0.031)
GDP growth			-0.480	-0.342			-0.482	-0.343
			(0.433)	(0.304)			(0.506)	(0.371)
Country Rating			0.357***	0.995***			0.350*	0.984***
			(0.104)	(0.157)			(0.186)	(0.068)
Intercept	-56.086***	-29.861***	-44.843***	-35.055***	-56.428***	-29.986***	-45.185***	-35.116***
	(5.602)	(0.848)	(17.062)	(1.731)	(1.260)	(4.725)	(0.842)	(5.380)
Observations	1630	1630	1630	1630	1630	1630	1630	1630
R-squared	0.3202	0.2375	0.3316	0.2464	0.3197	0.2367	0.3311	0.2456
Bank FE	YES	NO	YES	NO	YES	NO	YES	NO
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Country FE	NO	YES	NO	YES	NO	YES	NO	YES

This table reports the results of the model in Eq. (1) including the Downgrade and Dimension variable. The dependent variable is LRMES (in %). In columns (1), (2), (5), and (6) we report the results including the bank-specific variables as control variables. In columns (3), (4), (7), and (8) we report the results including the banks-specific and country variables.
***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

To answer our second a) research hypothesis (H2a), we run the model in Eq. (1) by including the dummy variable *Switch* that takes the value one if the banks switch from other classes to class F and zero otherwise.[6] The results are reported in Table 4 and confirm our prediction: banks that switch from other classes to class F increase their contribution to overall systemic risk, in particular from 0.289 % to 0.695 %. This evidence confirms the importance assigned by the banking regulator to climate change disclosure, especially in recent times (EBA, 2022; ECB, 2020b). We can interpret the increased systemic risk of banks reluctant to disclose their environmental engagement as a strong market sanction, according to the market discipline (EBA, 2022).

Finally, we test our second (b) research hypothesis (H2b) by considering the impact of a downgrade in *CCS* on the systemic risk measure. Specifically, we substitute the variable *CCS* in the model in Eq. (1) with a dummy variable, *Downgrade*, which takes the value one if the banks have registered a downgrade in climate change score and zero otherwise. The downgrading occurs whenever the bank scales its *CCS* from any class (A, A-, B, B-, C, C-, D, D-, or E) to a lower one.

Table 5 reports the results that confirm our last prediction: the downgrade in the commitment to climate change increases the banks' contribution to overall systemic risk. We find a positive and significant coefficient on the downgrade in all our specifications. Specifically, the banks that reduce their climate change commitment from one year to another increase the contribution to the overall systemic risk by more than 1%. Once again, the contribution to systemic risk strongly depends on the score assigned to each bank.

Additionally, to further investigate the downgrade effect, we substitute the dummy variable *Downgrade* with a variable that measures the dimension of the downgrade, *Dimension*. The variable *Dimension* ranges from 0 to 9.[7] The results in columns (5), (6), (7), and (8) of Table 5 confirm the presence of a "*downgrade effect*" that is even more evident when the downgrade on the climate change score is bigger. Specifically, if the downgrade has a dimension of 2 (from A to B), the contribution of banks to systemic risk increases by around 0.40%. On the other hand, if the downgrade has a dimension of 4 (from A to C), the contribution of banks to systemic risk increases by around 0.90% (0.40% x 2). This last empirical evidence corroborates the previous ones. Moreover, it provides further

[6] Class F groups banks providing no information or insufficient information to be evaluated by the *CDP*.
[7] 0 indicates that there is no change in the climate change score, 1 indicates that the downgrade is of one class (for example, from A to A-), 2 indicates that the downgrade is of two classes (for example, from A to B), and so on.

Table 9
The robustness Panel model estimates: the impact of CCS on systemic risk by regions.

	America	*Asia*	*Europe*
	(2)	(1)	(3)
SRISK-1	0.441***	0.638***	0.753***
	(0.002)	(0.002)	(0.019)
CCS	-0.853***	-0.178***	-0.193***
	(0.023)	(0.015)	(0.006)
Bank size-1	4.336***	1.317***	2.162***
	(0.000)	(0.052)	(0.336)
ROA-1	0.644***	0.060***	0.040***
	(0.012)	(0.008)	(0.007)
Tier 1–1	-0.091	-0.083	0.008
	(0.080)	(0.055)	(0.052)
NPL-1	0.525***	0.216***	0.215***
	(0.004)	(0.001)	(0.014)
CIR-1	0.002***	0.253***	0.005***
	(0.000)	(0.003)	(0.002)
Liquid asset-1	-0.251***	-0.015*	-0.108***
	(0.007)	(0.008)	(0.014)
Net Loans-1	0.359	-0.062***	-0.113***
	(0.537)	(0.003)	(0.008)
GDP growth	0.450	0.154	0.027
	(0.435)	(0.103)	(0.025)
Country Rating	5.377***	0.831***	0.948***
	(0.042)	(0.178)	(0.175)
Intercept	-29.552***	-33.304***	-29.433***
	(0.000)	(0.223)	(0.414)
Observations	323	586	721
R-squared	0.3085	0.3029	0.3105
Bank FE	NO	NO	NO
Year FE	YES	YES	YES
Country FE	YES	YES	YES

The Table reports the results of the model in Eq. (1) with country-fixed effects divided by regions. The dependent variable is SRISK (in %). Column (1) reports the results for American banks, column (2) for Asian banks, and column (3) for European banks. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

evidence that the intensity of environmental engagement matters. As documented by other studies (Birindelli et al., 2022; Eratalay and Cortés Ángel, 2022), only through the achievement of high levels of climate change commitment is it possible to benefit from positive effects. As a result, reducing efforts towards climate change management – that is, suffering a downgrade of an environmental rating – can negatively impact bank performance and riskiness and hence can undermine financial stability as a whole.

In addition to the above variables of interest, the results show that a bank's size, profitability, non-performing loans, and cost-to-income ratio as well as the country's credit rating undermine the bank's systemic risk, and their effects remain consistent for all specifications of our model. In contrast, the other variables such as liquidity assets and net loans decrease the overall contribution to systemic risk (Tables 3, 4, and 5).

5. Robustness checks

To corroborate our results, we run the model in Eq. (1) by substituting the dependent variable SRISK with the long-run marginal expected shortfall (LRMES). LRMES indicates the decline in equity values to be expected if there is a financial crisis (Acharya et al., 2012).

This exercise confirms all our previous results. Specifically, the results, reported in Table 6, confirm our first hypothesis (H1). The greater a bank's commitment to climate change, the less the decline in equity values to be expected if there is a financial crisis. Therefore, climate change engagement is a benefit in terms of systemic risk for international banks because it increases financial stability.

The results in Table 7 provide evidence for the second a) research hypothesis (H2a). The banks' failure to provide sufficient information on their climate change commitment increases their contribution to systemic risk. Therefore, there is a "*worst rating effect*" that contributes to weakening financial stability. When a bank fails to provide information about climate change, this creates instability in the financial sector.

Finally, the results shown in Table 8 confirm the presence of a downgrade effect in the banking sector by underlining that the decrease in the commitment to climate change reduces equity values in the case of a financial crisis. Again, these results confirm that the banks' commitment to climate change and the information that banks provide to the market are important factors for systemic risk and, in turn, financial stability. Those banks providing information to the market are less likely to face a capital shortage in an adverse financial scenario. This may be due to the greater involvement of these banks in actions supporting climate change. Banks with a strong climate change commitment are probably the ones most inclined to finance green projects and provide financing for the green

Table 10
The robustness Panel model estimates the "worst rating effect".

	America	*Asia*	*Europe*
	(1)	(2)	(3)
SRISK-1	0.477***	0.665***	0.744***
	(0.051)	(0.004)	(0.016)
Switch	-1.408	0.425***	0.322***
	(1.250)	(0.019)	(0.110)
Bank size-1	3.974***	0.932***	2.142***
	(1.329)	(0.055)	(0.296)
ROA-1	-0.127	-0.006	0.038***
	(0.219)	(0.007)	(0.002)
Tier 1–1	-0.905	-0.577	0.039
	(0.588)	(0.367)	(0.061)
NPL-1	0.465***	0.107***	0.108***
	(0.081)	(0.004)	(0.019)
CIR-1	0.045	0.236***	0.054***
	(0.146)	(0.002)	(0.001)
Liquid asset-1	-0.099***	-0.059***	-0.211***
	(0.002)	(0.016)	(0.028)
Net Loans-1	0.184	-0.002***	-0.187***
	(0.207)	(0.000)	(0.033)
GDP growth	0.188	0.143	0.024
	(0.767)	(0.604)	(0.026)
Country Rating	0.661**	0.356***	0.579***
	(0.295)	(0.056)	(0.126)
Intercept	-33.373**	-16.430***	-28.174***
	(11.334)	(0.296)	(12.897)
Observations	323	586	721
R-squared	0.2908	0.3021	0.3120
Bank FE	NO	NO	NO
Year FE	YES	YES	YES
Country FE	YES	YES	YES

The Table reports the results of the model in Eq. (1) with country-fixed effects divided by regions. The dependent variable is SRISK (in %). Column (1) reports the results for American banks, column (2) for Asian banks, and column (3) for European banks.
***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

transition, thereby strengthening their social legitimacy among investors and customers.

To further investigate the effects of regulatory environments and approaches within each country, we perform a cross-country analysis by segmenting our sample into distinct regions. Specifically, we examine three different regions: America, consisting of 43 banks; Asia, encompassing 73 banks; and Europe, comprising 95 banks.

Table 9 addresses our first research question by demonstrating that climate change commitment across all regions exerts a negative and significant influence on SRISK, thereby affirming that banks with higher involvement in climate change mitigation tend to reduce their systemic risk.

The *"worst effect"* is observed for Asian and European banks, in compliance with our findings, while empirical evidence for American banks is lacking (see Table 10). Specifically, while Asian and European banks show a significant increase in systemic risk when transitioning to class F, American banks do not display the same effect. This suggests that the regulatory environment or approaches to climate change mitigation in America may differ from those in Asia and Europe, leading to differing impacts on systemic risk reduction among banks. This finding highlights the importance of considering regional differences when evaluating the effectiveness of climate change policies and their implications for financial institutions and implies potential variations in the effectiveness of climate change commitments across different geographical regions.

Finally, as shown in Table 11, we observe a "*Downgrade effect*" across all regions, indicating that varying regulatory frameworks and environmental policies do not alter the impact of a downgrade in CCS score on the financial stability of banks. Our analysis reveals a more substantial impact on American banks, with the least pronounced effect among Asian banks. This underscores the importance of considering climate change resilience in assessing the overall stability of financial institutions, regardless of their geographical location or regulatory context. However, the varying degrees of impact observed among American and Asian banks highlight potential regional differences in vulnerability to climate-related risks. This suggests that while climate change poses a universal challenge to financial stability, the extent of its impact may differ based on regional factors such as regulatory frameworks, market conditions, and exposure to climate-related hazards. As such, policymakers and financial regulators should tailor their strategies to address the specific vulnerabilities and resilience needs of each region, ensuring a more effective and targeted approach to managing climate-related risks in the financial sector.

In conclusion, these supplementary analyses not only reinforce the consistency of the results across various measures of systemic risk and regions but also emphasize the broader implications. The robustness observed suggests that the identified relationships between climate change commitments and systemic risk transcend geographical boundaries and measurement methodologies. This

Table 11
The robustness Panel model estimates: the "Downgrade effect".

	America	*Asia*	*Europe*	*America*	*Asia*	*Europe*
	(1)	(2)	(3)	(4)	(5)	(6)
$SRISK_{-1}$	0.508***	0.528***	0.772***	0.505***	0.528***	0.772***
	(0.130)	(0.005)	(0.008)	(0.127)	(0.005)	(0.008)
Downgrade	0.357***	0.270***	0.406***			
	(0.049)	(0.045)	(0.015)			
Dimension				0.430***	0.276***	0.398***
				(0.043)	(0.007)	(0.054)
Bank $size_{-1}$	1.406***	1.608***	2.108***	1.445***	1.599***	2.118***
	(0.110)	(0.004)	(0.090)	(0.015)	(0.003)	(0.091)
ROA_{-1}	0.213***	0.077*	0.020***	0.249***	0.076*	0.020***
	(0.000)	(0.040)	(0.007)	(0.030)	(0.040)	(0.007)
Tier 1_{-1}	-0.318	-0.260	0.064	-0.328	-0.260	0.063
	(0.392)	(0.244)	(0.228)	(0.200)	(0.244)	(0.228)
NPL_{-1}	0.630***	-0.114	0.063**	0.676***	-0.114	0.063*
	(0.041)	(0.105)	(0.032)	(0.052)	(0.104)	(0.033)
CIR_{-1}	0.059***	0.212***	0.033***	0.059***	0.213***	0.033***
	(0.016)	(0.014)	(0.005)	(0.020)	(0.014)	(0.005)
Liquid $asset_{-1}$	-0.082**	-0.038***	-0.070***	-0.073**	-0.039***	-0.070***
	(0.038)	(0.001)	(0.023)	(0.037)	(0.001)	(0.023)
Net $Loans_{-1}$	0.056	0.012	-0.043**	0.052	0.011	-0.043**
	(0.080)	(0.008)	(0.017)	(0.091)	(0.008)	(0.017)
GDP growth	-0.365	-0.135	-0.036	-0.310	-0.141	-0.038
	(0.556)	(0.121)	(0.066)	(0.565)	(0.121)	(0.066)
Country Rating	3.884**	0.512***	0.114***	4.023**	0.501***	0.131***
	(1.898)	(0.135)	(0.001)	(1.914)	(0.134)	(0.006)
Intercept	-29.603*	-27.954***	-28.832***	-29.617*	-28.003***	-28.942***
	(16.710)	(5.787)	(4.553)	(17.620)	(6.543)	(4.632)
Observations	323	586	721	323	586	721
R-squared	0.2681	0.3595	0.2716	0.2701	0.3597	0.2715
Bank FE	NO	NO	NO	NO	NO	NO
Year FE	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES

The Table reports the results of the model in Eq. (1) with country-fixed effects divided by regions including the Downgrade and Dimension variable. The dependent variable is SRISK (in %). Columns (1) and (4) report the results for American banks, columns (2) and (5) for Asian banks, and columns (3) and (6) for European banks.
***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

underscores the universal importance of climate change mitigation efforts in reducing systemic risk within the global financial system.

6. Conclusions and implications

This study aims to investigate the relationship between climate change commitment and banks' systemic risk. We find that banks more engaged in climate change, proxied by the *CCS* calculated by the CDP, reduce their contribution to systemic risk. Likewise, banks that, from one year to another, fail to provide sufficient information on their climate change commitment ("*worst rating effect*") or that suffer even just a downgrade as a result of decreased efforts towards such concerns ("*downgrading effect*") boost their exposure to overall systemic risk.

We analyzed a sample of 211 international banks over the period 2011–2020. We constructed an original data set based on a measure of systemic risk, calculated by the NY Stern Business School, and a climate change score, provided by the Carbon Disclosure Project. To construct our final sample, we included banks that have both scores.

Our results confirm that climate change commitment is a driver of systemic risk reduction and hence suggest the effectiveness of climate change engagement in increasing financial stability by lowering a bank's contribution to overall financial distress. When banks increase their climate change commitment the financial system becomes more stable. Therefore, public initiatives that have been proposed by policymakers and regulators about climate change should increase the feasibility of the climate change commitment, which we show to be a systemic risk-reducing factor (Campiglio et al., 2018). Overall, our results support public initiatives aimed at increasing banks' climate change commitment because of the positive impact on financial stability (BIS, 2022).

Our findings have several important policy implications. First, the increase in financial stability associated with climate change commitment is an incentive for banks to increase the quantity and quality of information about climate change policies, in accordance with international and European expectations (BCBS, 2022; ECB, 2020). Second, in assessing systemic risk, the impact of climate change disclosure on the banking sector has to be considered. Better disclosure of climate change commitment and exposure to environmental risks should be required to have a clear idea about the impact that green and brown assets can have on financial stability. In this respect, the new CSRD (Corporate Sustainability Reporting Directive), which strengthens and extends the rules for corporate sustainability reporting, is to be welcomed, as is the Sustainable Finance Disclosure Regulation, which improves transparency within the market for sustainable investment products.

Among the supervisory tools, the results highlight the need to develop a more comprehensive approach to closing data gaps (ECB, 2020) to enhance the capacity to measure, monitor, and mitigate climate-related financial risks (Nieto, 2019) and, from there, increase financial stability.

From a macroprudential perspective, the systemic nature of climate risk leads regulators to consider the system as a whole and possible cross-sectoral interconnection, as well as possible propagation mechanisms from the financial system to the real economy. However, the microprudential focus of this paper does not allow us to draw conclusions from macroprudential perspectives. In future developments of this research, it would be interesting to empirically investigate the impact of climate change commitment in different industries, other than financial, by analysing the interlinkages between the sectors, the real economy, and the financial system. Moreover, it would be interesting to verify whether the same research hypotheses are confirmed for other financial intermediaries, such as insurance companies.

CRediT authorship contribution statement

Antonia Patrizia Iannuzzi: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Vincenzo Pacelli:** Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Giuliana Birindelli:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Stefano Dell'Atti:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Investigation, Formal analysis, Conceptualization. **Caterina Di Tommaso:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Data Availability

The authors do not have permission to share data.

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Appendix

Table A1
Distribution of the sample by country

Country	# of banks before the cleaning	% of banks before the cleaning	# of banks in the sample	% of banks in the sample
Argentina	1	0.40%	1	0.47%
Australia	6	2.40%	6	2.84%
Austria	2	0.80%	2	0.95%
Belgium	2	0.80%	2	0.95%
Bermuda	1	0.40%	–	–
Brazil	5	2.00%	3	1.42%
Canada	9	3.60%	9	4.27%
Chile	3	1.20%	3	1.42%
China	11	4.40%	11	5.21%
Colombia	4	1.60%	4	1.90%
Czech Republic	2	0.80%	2	0.95%
Denmark	5	2.00%	5	2.37%
Egypt	1	0.40%	–	–
Estonia	1	0.40%	–	–
Finland	2	0.80%	1	0.47%
France	3	1.20%	3	1.42%
Germany	5	2.00%	5	2.37%
Greece	4	1.60%	3	1.42%
Hong Kong	3	1.20%	3	1.42%
Hungary	1	0.40%	1	0.47%
India	16	6.40%	11	5.21%
Indonesia	7	2.80%	7	3.32%
Ireland	2	0.80%	2	0.95%
Israel	1	0.40%	1	0.47%

(*continued on next page*)

Table A1 (*continued*)

Country	# of banks before the cleaning	% of banks before the cleaning	# of banks in the sample	% of banks in the sample
Italy	15	6.00%	13	6.16%
Japan	23	9.20%	14	6.64%
Korea	6	2.40%	6	2.84%
Kuwait	1	0.40%	1	0.47%
Liechtenstein	1	0.40%	–	–
Lithuania	1	0.40%	–	–
Malaysia	4	1.60%	4	1.90%
Mexico	1	0.40%	1	0.47%
Netherlands	2	0.80%	2	0.95%
Norway	2	0.80%	1	0.47%
Pakistan	3	1.20%	3	1.42%
Philippines	2	0.80%	2	0.95%
Poland	5	2.00%	4	1.90%
Portugal	1	0.40%	1	0.47%
Qatar	3	1.20%	3	1.42%
Russia	4	1.60%	2	0.95%
Singapore	1	0.40%	1	0.47%
South Africa	3	1.20%	2	0.95%
Spain	5	2.00%	4	1.90%
Sweden	4	1.60%	3	1.42%
Switzerland	13	5.20%	12	5.69%
Taiwan	4	1.60%	–	–
Thailand	3	1.20%	3	1.42%
Turkey	11	4.40%	9	4.27%
United Arab Emirates	3	1.20%	3	1.42%
United Kingdom	10	4.00%	10	4.74%
United States	22	8.80%	22	10.43%
Total	**250**	**100.00%**	**211**	**100.00%**

Table A2
Variable definition

Variables	Description	Source	Expected sign	References
Panel A: Dependent variable- Bank's level systemic risk				
SRISK(%)	Systemic risk contribution of a financial firm to the overall systemic risk	V-Lab		
Panel B: Variable of interest				
CCS score	Climate change score that puts banks in one of the performance categories (A, A-, B, B-, C, C-, D, D-, E and F)	Carbon Disclosure Project (*CDP*)	-	
Panel C: Control variables				
Banks size	Natural logarithm of total assets	BankFocus	+	Altunbas et al. (2022); Laeven et al. (2016)
ROA	Return on assets	BankFocus	+/-	Chen and Shen (2023); Altunbas et al. (2022); Arif (2020)
Tier 1	The ratio of tier 1 capital and risk-weighted assets	BankFocus	-	Arif (2020); Laeven et al. (2016); Ly et al. (2017)
NPL	The ratio of non-performing loans to gross loans	BankFocus	+	Altunbas et al. (2022); Ly et al. (2017)
CIR	The ratio of operating expenses to operating income	BankFocus	+	Bierth et al. (2015)
Liquid asset	The ratio of liquid assets to total assets	BankFocus	-	Altunbas et al. (2022); Arif (2020)
Net loans	The ratio of net loans to total assets	BankFocus	-	Laeven et al. (2016)
GDP growth	The yearly change in a country's economic output	World bank	+	Ly et al. (2017); Vassalou & Xing (2004)
Country Rating	Country's S&P rating	Refinitiv	+	Wasi et al. (2023)

Table A3
Matrix correlation

	SRISK	*CCS*	*Bank size*	*ROA*	*Tier 1*	*NPL*	*CIR*	*Liquid asset*	*Net Loans*	*GDP growth*	*Country Rating*
SRISK	1										
CCS	-0.2775	1									
Bank size	0.3697	-0.0054	1								
ROA	0.1178	-0.0355	-0.0812	1							

(*continued on next page*)

Table A3 (*continued*)

	SRISK	*CCS*	*Bank size*	*ROA*	*Tier 1*	*NPL*	*CIR*	*Liquid asset*	*Net Loans*	*GDP growth*	*Country Rating*
Tier 1	-0.0412	0.0061	-0.2141	0.1017	1						
NPL	0.0814	0.0206	-0.1684	-0.2507	0.1844	1					
CIR	0.0639	-0.0127	0.1165	-0.2302	0.0306	0.0631	1				
Liquid asset	-0.0778	-0.0194	0.2125	0.069	0.2523	-0.0921	0.2315	1			
Net Loans	-0.1214	0.0108	-0.2573	-0.0195	-0.2126	-0.163	-0.0672	-0.6793	1		
GDP growth	0.1281	0.0074	-0.0565	0.2329	-0.1402	-0.1205	-0.2055	-0.1793	0.074	1	
Country Rating	0.0458	0.0104	-0.1802	-0.006	-0.0681	0.3863	-0.2522	-0.1045	-0.1301	0.0923	1

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