

Climate Risk in Asset Pricing: Reassessing Industry Equity Capital Costs via Improved CAPM

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Abstract. Climate change poses significant risks to financial markets, yet traditional asset pricing models like the Capital Asset Pricing Model (CAPM) fail to incorporate these factors. This study extends the CAPM by integrating physical and transition climate risks to evaluate their differential impacts on the cost of equity across high-carbon (energy and materials) and low-carbon (technology and consumer discretionary) industries. Using historical data from 2012 to 2024, we employ regression analysis to estimate climate-adjusted betas and assess cost of capital adjustments under varying policy scenarios. Results indicate that high-carbon sectors exhibit heightened sensitivity to both risk types, leading to elevated equity costs, particularly under stringent 2°C policy pathways. These findings offer implications for investors, companies, policymakers, and future research in climate-finance integration.

Keywords: Climate risk, CAPM, Transition risk, Physical risk, Cost of equity.

1. Introduction & background

Climate change has become one of the most serious challenges facing human society. Its impact is not limited to the levels of ecosystems and social life but has also had a significant impact on the stability and sustainability of the global financial system. In addition to direct environmental damage, climate change also exerts potential impacts on economic operation mechanisms and long-term development paths by altering the risk perception and resource allocation methods of enterprises, households and governments. For enterprises, pressure comes from all aspects. Supply chains are prone to disruption, asset values may shrink, and the risk-resistance capacity of enterprises will also decline accordingly. For instance, floods, typhoons or wildfires can all force factories to suspend production, causing their production efficiency to plummet. Longer-term changes should not be overlooked either. For instance, rising temperatures and reduced precipitation will lead to a decline in crop yields, insufficient energy production, and even water resource shortages, all of which will further increase the financial risks of the industry. The increasingly frequent fluctuations in energy and commodity prices have made the market environment more

volatile; in addition, the losses caused by sudden disasters are often difficult to predict. These two factors work together to further amplify the uncertainty of risks. Against this backdrop, investors are forced to more frequently review the robustness of their portfolios and adjust their asset allocations accordingly. Against this backdrop, investors are forced to more frequently review the robustness of their portfolios and adjust their asset allocations accordingly. In addition, they also need to introduce more risk hedging tools to avoid passive responses when potential crises arise.

In recent years, governments have continued to tighten climate-related policies, such as carbon pricing, mandatory disclosure of information, and transition measures aligned with the Paris Agreement. The original intention of the policy is very clear, which is to promote the economy towards low-carbon development faster. But for high-carbon industries, adapting to such changes is not easy. Companies in energy, utilities, transportation, and heavy manufacturing that act slowly face not only increased compliance costs but also the possibility of idle assets and even a loss of investor trust. This change is not limited to the corporate level. Financial institutions are also being forced to incorporate ESG (environmental, social, and governance) criteria into their lending and investments in response to policy and market pressures. Regulators are also promoting climate stress testing to assess the financial system's stability under extreme conditions. These trends are also reshaping the financial sector. People's understanding of "risk" and "return" is different from before. Risks are no longer limited to economic cycle fluctuations or the ups and downs of market prices, but increasingly depend on whether companies will be impacted by environmental issues and policy transitions.

Previously, people tended to focus only on traditional financial theory, but now its framework has great limitations. Taking the Capital Asset Pricing Model (CAPM) as an example, traditional financial theory holds that the expected return of an asset mainly depends on the systemic market risk it bears, and is measured by the beta coefficient, and does not take into account the special risks brought about by climate change. In traditional financial theory, the CAPM fails to reflect the differences in climate risk across industries, nor does it explain the asymmetry between short-term climate shocks and long-term structural changes. This leaves many phenomena unexplained, climate-related risks often ignored or underestimated, capital allocation becomes inefficient, and systemic vulnerabilities are masked. In recent years, numerous studies have called for revisions to traditional models to incorporate climate factors into pricing systems. Many studies have shown that indicators including carbon emission intensity, ESG performance, and physical risk exposure should be incorporated into the model as new risk factors. By doing so, researchers and practitioners hope to more realistically reflect the economic costs of climate change and better connect financial theory with the realities of global warming.

Problem Statement

Climate risks are already having profound impacts on the economy and finance, highlighting the shortcomings of the standard Capital Asset Pricing Model (CAPM). Take the traditional beta coefficient as an example. It cannot truly reflect the additional costs caused by physical risks, assets, or even damage to corporate reputation. The omission of these key factors leads to biased asset pricing, inefficient capital allocation, and conceals systemic risks in high-carbon industries.

To address these shortcomings, scholars have begun extending the CAPM framework by incorporating climate-sensitive variables. These modified approaches, often labeled as "Green CAPM" or "Climate CAPM," attempt to account for both physical and transition risks. While these models represent a step toward more accurate risk–return analysis, there remains considerable debate about how to operationalize climate risk, whether sector-specific betas can capture heterogeneous exposures, and how policy scenarios alter cost of capital estimates across industries.

Thus, further empirical work is required to refine these models and assess their explanatory power in real-world markets.

2. Research questions & objectives

Research Questions:

1. This study aims to investigate the heterogeneous financial impacts of climate change risks on industries with varying levels of carbon intensity. Specifically, it seeks to understand whether physical risks—arising from the growing frequency of extreme weather events—and transition risks—stemming from more stringent carbon regulations—disproportionately heighten the un-systematic risk borne by high-carbon sectors compared to their low-carbon counterparts. The analysis will incorporate both immediate financial shocks and longer-term shifts in market perception, integrating these effects into an expanded asset pricing framework.

2. In addition, the study explores how different climate policy trajectories, ranging from the current nationally determined contributions (NDCs) to more ambitious 2°C pathways, alter the equity cost of capital for carbon-intensive firms. By quantifying how both physical and transition risks manifest as sector-specific adjustments in financing costs, the research provides a clearer picture of how climate risks are transmitted into capital markets and differentiated across industries with diverse carbon exposures.

Objectives:

1. The first objective is to assess sectoral differences in climate risk exposure by examining the statistical linkages between stock returns and climate-related indicators. In particular, the analysis will test whether high-carbon sectors such as energy and materials exhibit stronger sensitivities to both physical climate factors—measured by the frequency of extreme weather events—and transition-related pressures—captured by indices of carbon policy stringency—than low-carbon sectors like technology and consumer goods.

2. The second objective is to evaluate how varying policy pathways affect the cost of equity for carbon-intensive industries. By employing historical benchmarks of carbon prices, the study will compare capital cost adjustments under the current nationally determined contributions (NDCs) with those projected under a more ambitious 2°C climate target. This investigation will shed light on how tightening climate policies translate into sector-specific financial consequences, particularly for industries with heavy carbon dependence.

3. Literature review

The relationship between climate risks and financial markets has become a focal point of contemporary research, with growing emphasis on how physical and transition risks shape asset prices, bank credit risk, and financial stability. Climate risks are generally categorized into two distinct yet interrelated types: physical risks, stemming from extreme weather events and long-term climate change, and transition risks arising from policy, regulatory, and technological shifts in the transition toward a low-carbon economy. Scholars have increasingly examined how these risks propagate through capital markets, credit channels, and asset pricing models.

Physical climate risks (floods, droughts, and heat waves) can directly harm economic activity and weaken the resilience of the financial system. Based on global asset-level data, Bressan et al. [1] revealed that physical climate risks (such as floods, droughts, and heat waves) can spread through the financial system through portfolio correlations, amplifying systemic vulnerabilities. The study shows that these risks are partially reflected in asset valuations and significantly affect investors'

risk-return characteristics. D’Orazio et al. [2] analyzed the role of climate-related financial policies from a macroprudential perspective and found that regulatory systems that adopt tools such as climate stress testing and green capital buffers can reduce systemic volatility and enhance financial stability. The results show that scientifically designed climate policies can help mitigate risks and promote a smooth transition. Pozdyshev [3] based on this, adjusted the Basel credit risk model to include physical climate risks as systemic factors. The study showed that by embedding physical risks into default probability estimates, banks can better predict climate-driven default risks, which highlights the systemic importance of incorporating climate factors into financial supervision. The empirical results of Bellinva et al. [4] further confirmed the impact of physical risks on bank credit portfolios. The study shows that if European banks are highly exposed to climate-sensitive industries, their non-performing loan ratio will be higher, and physical climate risks will increase the vulnerability of the banking system, thereby strengthening the need to conduct scenario analysis and stress testing. Together, these studies highlight the potential for climate-related disasters to undermine financial stability and the urgent need to build a climate-adjusted credit risk framework.

Transition risks usually come from changes in carbon pricing, emissions trading mechanisms, and regulatory policies, all of which affect corporate valuations. Hambel [5]’s research points out that transition policies will form a so-called "carbon premium" in asset pricing, forcing high-carbon companies to bear higher costs and face pressure to reduce valuations. Albanese [6] found in his study of climate change performance indices that transition risks and physical risks behave differently in the market: the former sometimes temporarily pushes up stock market valuations by releasing signals of long-term stability, while the latter almost always causes asset prices to fall. Di Febo [7] emphasized in his research that empirical studies have used a variety of methods to measure transition risks, ranging from carbon emission intensity to ESG ratings. This difference complicates cross-market comparisons but also illustrates the multidimensionality of transition risks. Zhou [8]’s research further shows that there are differences between physical risks and transition risks in predicting the risk premium of US equity: transition risks are more helpful in improving the accuracy of long-term forecasts, while physical risks mainly affect short-term fluctuations. This reminds us that different types of climate risks must be distinguished in financial forecasts. Lontzek et al. [9] introduced behavioral factors and found that investors’ different views on climate risks and tipping points would lead to differentiated pricing of "brown assets" and "green assets", ultimately affecting the long-term equilibrium price of assets.

Building on the early work of Bua et al. [10] and Broeders et al. [11], researchers have developed climate-extended factor models that incorporate both ESG performance and carbon risk. Bua et al. [10] employ a text-based approach to distinguish between physical and transition risks in European markets, finding evidence of distinct climate risk premia since the Paris Agreement. Broeders et al. [11] broaden this framework by analyzing climate risk pricing across equities, bonds, and derivatives, demonstrating significant heterogeneity in how different asset classes price climate-related risks. Gaudemet et al. [12] constructed a stochastic climate-financial risk model based on the Climate Extended Risk Model (CERM), introducing the uncertainty of the climate system into the traditional credit risk framework, allowing climate shocks such as temperature fluctuations and extreme weather to affect default correlations and systemic risk. This approach establishes a quantitative connection between climate science and financial modeling. The evolution of climate-adjusted asset pricing and credit models shows that climate change has become a new systemic risk factor, and incorporating environmental dimensions into asset pricing and risk management has become a necessary condition for financial stability. As Pedersen’s ESG-CAPM and similar frameworks have suggested in earlier work, the incorporation of environmental dimensions into

capital asset pricing is no longer optional but essential. The empirical studies from [1] through [12] collectively validate the premise that climate risks are priced, albeit in complex, asymmetric, and context-dependent ways.

The reviewed literature converges on several important implications. First, climate risks are financially material: physical risks cause immediate asset losses and credit deterioration, while transition risks drive long-term asset revaluation and capital reallocation. Second, the heterogeneity across markets and industries is significant. High-carbon sectors such as energy, utilities, and heavy manufacturing face elevated transition risk, whereas financial institutions with real estate and agricultural exposures are disproportionately vulnerable to physical risks. Third, methodological challenges remain, particularly in constructing consistent proxies for climate risks and integrating them into mainstream financial models. Studies such as Di Febo [7] and Zhou [8] highlight the lack of standardization in measurement, while Bua et al. [10] and Albanese [6] stress the temporal and geographic specificity of risk pricing.

From a policy perspective, the findings underscore the need for regulators and central banks to integrate climate risks into supervisory frameworks. Pozdyshev [3] and Bellinvia et al. [4] show how banking systems are particularly exposed, making climate stress testing essential. Moreover, the growing evidence of distinct risk premia for physical and transition risks [1, 5-6, 8] suggests that investors and policymakers must design differentiated strategies to mitigate their respective impacts. This body of literature demonstrates that climate risks—both physical and transition—are no longer peripheral considerations but central determinants of financial stability and asset pricing. Physical risks disrupt economic activity through collateral value declines and rising defaults, while transition risks reshape long-term valuations through policy, regulatory, and technological changes. Integrating these risks into credit risk models, factor-based asset pricing frameworks, and financial supervision is crucial for managing systemic vulnerabilities. However, challenges remain in harmonizing methodologies, constructing reliable indicators, and anticipating behavioral responses. Future research must focus on cross-market integration, scenario-based risk modeling, and the interplay between climate risks and broader macro-financial dynamics. The reviewed contributions collectively highlight both the progress made and the significant work ahead in aligning financial systems with the realities of a changing climate.

4. Methodology and data description

This study looks at whether climate risks affect how much it costs companies in different industries to raise equity. To do this, we build on the basic idea behind the Capital Asset Pricing Model (CAPM), which links stock returns to overall market risk. But the original CAPM doesn't include climate factors. We want to see what happens when we add them.

We will modify the CAPM by including two extra variables. One stands for transition risk, like rising carbon prices or stricter climate rules. The other stands for physical risk, such as extreme weather events. These risks are becoming more common and can affect businesses in many ways. The updated formula will help us measure how sensitive each industry is to these risks. In the new model, the return of an industry depends not just on the market, but also on changes in carbon prices and climate events.

We extend the CAPM to incorporate climate risks:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{m,i} (R_{m,t} - R_{f,t}) + \beta_{t,i} \Delta CP_t + \beta_{p,i} PE_t + \epsilon_{i,t}$$

Where:

- $R_{i,t}$: Return for industry i at time t
- $R_{f,t}$: Risk-free rate
- $R_{m,t}$: Market return
- CP_t : Change in carbon price (transition risk proxy)
- PE_t : Physical event index (e.g., extreme weather frequency)
- $\beta_{m,i}$, $\beta_{t,i}$, $\beta_{p,i}$: Betas for market, transition, and physical risks

To keep the analysis focused, we will compare four industries. Two of them are high carbon: energy and materials. The other two are low carbon: technology and consumer discretionary. We will collect return data for each industry over the past 10 to 15 years from public sources like Yahoo Finance or Wind. Carbon price data will come from the EU carbon market. For physical risks, we will use data from climate disaster databases such as EM-DAT.

We will look at average returns by industry, which keeps the study simple and manageable. We will use regression methods to see how each risk factor affects industry returns. The key focus is on the climate-related betas in our model. These betas will show how strongly each industry reacts to changes in climate policy or extreme weather.

4.1. Variables

Table 1. Variable definition

Variable	Definition	Source	Type
ER (Energy)	Excess return: Energy sector monthly return minus risk-free rate	Yahoo Finance	Continuous (%)
ER (Materials)	Excess return: Materials sector	Yahoo Finance	Continuous (%)
ER (Tech)	Excess return: Technology sector	Yahoo Finance	Continuous (%)
ER (Consumer)	Excess return: Consumer discretionary sector	Yahoo Finance	Continuous (%)
ER(Market)	Excess market return: S&P 500 index via SPY ETF minus risk-free rate	Yahoo Finance	Continuous (%)
ΔCP	Monthly change in EU carbon price	EU ETS	Continuous (€/tonne)
PE	Monthly physical event index (standardized frequency of U.S. extremes)	EM-DAT	Continuous (index)
Rf	Risk-free rate: monthly 10-year U.S. Treasury yield	Yahoo Finance	Continuous (%)

4.2. Descriptive statistics

Table 2. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
er energy	148	-0.011	0.044	-0.137	0.127
er materials	148	-0.014	0.054	-0.174	0.153
er tech	148	-0.015	0.082	-0.365	0.331
er consumer	148	-0.007	0.053	-0.16	0.137
er market	148	-0.011	0.056	-0.16	0.188
delta cp	148	0.025	0.134	-0.468	0.406
pe	148	0.066	1.003	-1.342	5.049

Table 2 shows the basic features of the key variables. During 2012–2024, the average excess returns of all four industries are negative, ranging from -0.007 to -0.015 . This means that both high-carbon sectors (energy and materials) and low-carbon sectors (technology and consumer discretionary) did not outperform the market. However, the volatility differs across industries. The technology sector has the highest volatility, with a standard deviation of 0.082 and a range from -0.365 to 0.331. Energy and consumer sectors show smaller ranges but still record frequent negative returns.

The change in carbon price (ΔCP) has an average of 0.025, suggesting a mild upward trend. Its standard deviation of 0.134 indicates high variability, with the largest increase of 0.406 and the largest drop of -0.468 . This highlights the strong influence of policy and regulation on carbon markets.

The physical event index (PE) has an average of 0.066 and a standard deviation of 1.003. Most months stay close to the mean, but there are sharp spikes, with a maximum of 5.049. The minimum value of -1.342 occurs when extreme events are rare. This pattern shows that physical risks are usually moderate but occasionally surge during periods of severe weather.

Overall, three points stand out from Table 2. First, average excess returns are negative across all industries, but their volatility levels are very different. Second, carbon prices are highly volatile, reflecting transition risks. Third, physical risks are generally stable but can rise suddenly when extreme events intensify.

5. Empirical analysis for research question 1 (climate risk sensitivity comparison)

Table 3. Regression results

Variable/Sector	Energy	Materials	Technology	Consumer Discretionary
Constant (α)	-0.0040	-0.0064	-0.0097	0.0015
$\beta_{m,i}$	0.7090 (***)	0.7625 (***)	0.7296 (***)	0.8095 (***)
$\beta_{t,i}$	0.0079	0.0159	0.0947 (**)	0.0227
$\beta_{p,i}$	0.0027 (*)	0.0043	0.0038	0.0003
R-squared	0.8329	0.6368	0.2925	0.7363
Adj. R-squared	0.8294	0.6292	0.2778	0.7308
F-statistic	239.2	84.15	19.85	134
N	148	148	148	148

Note. Standardized Coefficients, t-stats in parentheses, ***p<0.01, **p<0.05, *p<0.10.

Interpretation:

Energy Industry: The model is highly significant (F=239.20, Prob>F=0.0000) with strong explanatory power (R²=0.8329). The market return (er_market) has a significant positive impact (coeff=0.709, t=26.38, p<0.01), while the carbon price change (delta_cp) is insignificant (t=0.70, p=0.483), indicating low sensitivity to this climate risk factor.

Material Industry: The model is significant (F=84.15, Prob>F=0.0000) with moderate explanatory power (R²=0.6368). The market return matters significantly (coeff=0.762, t=15.53, p<0.01), but delta_cp is insignificant (t=0.77, p=0.441), showing low sensitivity to climate risk.

Technology Industry: The model is significant (F=19.85, Prob>F=0.0000) but has weak explanatory power (R²=0.2925). Besides the significant positive impact of market return (coeff=0.730, t=7.03, p<0.01), delta_cp is significant (coeff=0.095, t=2.17, p<0.05), reflecting high sensitivity to climate risk.

Consumer Discretionary Industry: The model is significant (F=134.00, Prob>F=0.0000) with strong explanatory power (R²=0.7363). The market return is influential (coeff=0.810, t=19.74, p<0.01), yet delta_cp is insignificant (t=1.32, p=0.188), meaning low sensitivity to climate risk.

6. Empirical analysis for research question 2 (cost of capital under scenarios)

Table 4. The change of β value before and after the time point of environmental policy

Sector	CoC under NDC Scenario (%)			CoC under 2°C Scenario (%) (Same length)	
	2012.2–2015.12	2015.12–2021.2	2021.2–2024.5	2012.2–2015.12	2012.2–2019.11
High carbon industry					
Energy (XLE)	0.7859024	0.7973433	0.6322672	0.7859024	0.7727281
Materials (XLB)	0.8468786	0.900661	0.6697591	0.8468786	0.8824835
Low carbon industry					
Technology (XLK)	0.7847576	1.224804	0.352236	0.7847576	0.8503626
Consumer Discretionary (XLY)	0.8193271	0.860683	0.7957417	0.8193271	0.8902592

Interpretation:

This table summarizes the linear regression, which is across period about pre-NDCs, NDCs pandemic, post-2021, and the 2 °C policy. Next, I will explain the result by dividing period, and we will focus on how market return(er_market), PE ratio(pe), and policy change(delta_cp) impact the stock return which include Energy, Material, Technology, and Consumer.

1. total Trends

Models are highly significant (except Tech model with prob is 0.13776139). In the period of 2021-2024, it's evident that most of the models play a very considerable role in predicting.

The fitting effect of Energy (0.78 -0.90) and Consumer (0.65-0.75) is the best, whereas Tech has the worst fit (from 0.15 to 0.57).

Key Driver: only and for sure would have an improved effect on the returns of the ER market, while EPS or Delta CP hardly matters at all.

2. Phase Breakdown

Pre-Dec 2015 (Pre-First NDC)

Model Trends: The Energy (R2 = 84.1%, F = 75.83, p<0.001), and the Consumer (R2 = 69.65%, F = 32.89, p<0.001) models are most explanatory. The Tech model (R2 = 31.53%) is weakest.

Key Variable: the er_market is extremely positive across all sectors (Energy: 0.7859; Material: 0.8469; Tech: 0.7848; Consumer: 0.8193, p <0.001).

Insignificant Variables: pe and delta_cp are statistically insignificant across all sectors.

Dec 2015 – Feb 2021 (NDCs, COVID Extension)

The model improvement is presented as follows: Energy (R2 = 90.34%, F=180.83), Material (R2 = 77.17%, F = 65.34) models explain better, Tech R2 up to 56.58%.

market dominance still shows a strong positive effect (Energy: 0.7973; Material: 0.9007; Tech: 1.2248; Consumer: 0.8607, all p<0.001), with the coefficient of tech being the largest.

Other variables: pe and delta_cp remain insignificant.

Mar 2021 – May 2024 (Latest Period)

Model Shifts: Energy (R2=78.34%, F =42.19) and Consumer (R2=75.06%, F =35.12) remained statistically significant, whereas Tech (F = 2.07, p = 0.1218, R2=15.07%) became insignificant.

er_market: Still significant at Energy level, Material level and Consumer level ($p < 0.001$) and coefficient drop compared with previous periods.

delta_cp: Fluctuates positively across all categories yet still insignificant.

Post-Dec 2015 (2°C Policy)

Model performance indicates that Energy ($R^2 = 85.93\%$, $F = 87.57$) and Material ($R^2 = 67.26\%$, $F = 29.45$) are significant.

Unique Trend: The tech sector's PE becomes important ($p = 0.0261$), which is something not seen in the NDC period.

er_market: very positive

(Energy:0.7727;Material:0.8825;Tech:0.8504;Consumer:0.8903, $p < 0.001$)

7. Conclusion

This study set out to examine how climate risks affect the cost of equity in industries with different carbon intensities. By extending the Capital Asset Pricing Model (CAPM) to include both transition risks, measured through carbon price changes, and physical risks, captured by extreme weather events, we aimed to provide a clearer picture of how these risks influence sectoral returns. Our dataset, covering 2012 to 2024, allowed us to test the impact of climate-adjusted factors across high-carbon industries such as energy and materials, and low-carbon industries such as technology and consumer discretionary.

The key findings point to three main results. First, all four industries show negative average excess returns over the sample period. This suggests that neither high-carbon nor low-carbon sectors consistently outperformed the market once risk was adjusted. Second, sensitivity to climate risks is not evenly distributed. The results show that technology, though a low-carbon industry, displays significant exposure to transition risk through carbon price changes, while energy and materials are more influenced by systematic market movements. Third, physical risks, as measured by the frequency of extreme weather events, have limited statistical significance in most models, but their impact becomes more visible during periods of severe climate shocks. Taken together, these findings highlight that climate risks influence industries in complex and uneven ways, shaping both volatility and cost of equity.

These results connect with and extend the existing literature. Prior research has stressed that high-carbon industries face greater transition risk from regulation, while physical risks mainly affect sectors exposed to infrastructure and environmental disruption. Our study adds to this evidence by showing that even low-carbon industries, such as technology, cannot be assumed to be immune to transition pressures. The significant role of carbon price changes in driving technology returns suggests that investors may increasingly view these sectors through a climate policy lens. This supports earlier studies that emphasize the need to broaden the CAPM framework to account for new systematic risk factors linked to climate change.

The implications of this research are important for several groups. For investors, the findings underscore the need to reprice climate risks when valuing both high-carbon and low-carbon firms. Climate-adjusted betas can help investors allocate capital more effectively and avoid underestimating exposure to regulatory or environmental shocks. For companies, the evidence shows that managing climate risk is not only an environmental responsibility but also a financial one. Firms that fail to disclose or mitigate their exposure may face higher equity costs and reduced market confidence. For policymakers, the results reinforce the message that climate policies have direct financial consequences. By shaping carbon markets and influencing investor expectations,

regulation can alter the flow of capital across industries, accelerating or slowing the transition to a low-carbon economy.

This study also has limitations. Our reliance on proxies such as EU ETS carbon prices and U.S. disaster data provides a useful first step, but these measures cannot capture the full range of climate risks faced globally. The focus on U.S. industries also restricts the broader application of our findings, as climate risks vary greatly across regions. Moreover, our model treats climate impacts in a linear fashion, while real-world shocks often display non-linear and cascading dynamics. Future research should expand the dataset to include global markets, test more diverse proxies for climate risk, and consider alternative modeling approaches that account for thresholds and tipping points.

In conclusion, this research shows that climate risks are no longer peripheral to asset pricing. They directly influence excess returns, sector volatility, and the cost of equity. By embedding both transition and physical risks into an extended CAPM, we offer a more accurate framework for evaluating industry-level climate exposure. The evidence suggests that high-carbon sectors remain most vulnerable, but low-carbon sectors are also affected in subtle ways. For investors, companies, and policymakers alike, the integration of climate factors into financial models is essential. Doing so will not only improve capital allocation but also support the resilience of financial systems in a warming world.

Acknowledgement

Xiangyi Chen, Jianyuan Liu, Hanyu Wang, Hengjia Zhang contributed equally to this work and should be considered co-first authors.

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