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Pricing climate risk: policy signals and carbon emissions

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Abstract

Purpose – This study examines the dynamic association between Climate Policy, CO_2 Emissions and European stock market returns. While the existing literature offers mixed evidence regarding the pricing of climate risk, we investigate whether these associations are regime-dependent and differ across levels of climate exposure.
Design/methodology/approach – Using an annual panel of 28 European countries spanning 2007–2024, we estimate dynamic conditional associations using a local projections framework (Jordà, 2005, 2023) to assess the dynamic responses of stock returns to changes in climate-related variables. We then combine the threshold model of Seo and Shin (2016) with the local projection framework by estimating the benchmark model within each regime, to capture endogenous regime shifts in climate risk exposure. Finally, we conduct robustness checks on the baseline specification adding alternative macroeconomic controls and sample restrictions.
Findings – The threshold estimation provides strong evidence of regime dependence. In particular, the pricing of CO_2 emissions in stock returns depends critically on the level of climate policy stringency. Emissions are positively associated with stock returns in low-policy environments but are negatively associated in high-policy regimes. In contrast, changes in climate policy are generally associated with positive stock market responses.
Research limitations/implications – The reliance on aggregate market indices limits our ability to assess how firm-level characteristics shape exposure to transition risk. A more granular analysis based on individual stock data could yield deeper insights, particularly with respect to portfolio diversification.
Practical implications – The findings highlight that the pricing of climate risk is shaped by policy credibility. Investors and policymakers should account for the interaction between emission intensity and regulatory stringency when assessing financial stability and transition risks.
Originality/value – This study provides novel evidence of regime-dependent and dynamic associations between climate risks and European stock markets by integrating local projections with an endogenous dynamic panel threshold framework.

Keywords Climate change, Threshold, Local projection, Climate policy, Stock markets, CO_2 emissions
Paper type Research article

1. Introduction

Over the past decade, the European Central Bank has repeatedly emphasized that climate change and environmental degradation constitute major sources of physical and transition risk for both the real economy and the financial system. These risks are intrinsically linked to the ongoing transition toward a low-carbon economy and are therefore of growing relevance for investors, policymakers, and central banks alike. In this context, understanding and managing climate-related risks has become essential for preserving macroeconomic and financial stability. A major milestone in global climate governance was reached with the adoption of the Paris Agreement (2015), a legally binding international framework signed by more than 190 countries and aimed at limiting global warming through substantial reductions in greenhouse gas (GHG) emissions (Zhang, 2022). The Agreement marked a turning point in climate policy by reinforcing expectations of a gradual but potentially disruptive transition toward a more

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sustainable economic model. Such a transition is expected to have far-reaching consequences across sectors, including energy, transportation, agriculture, and financial markets, particularly over the long run (Albanese *et al.*, 2025). Against this backdrop, financial markets have become increasingly sensitive to climate-related developments and policy actions. Investors are required not only to assess the direct implications of environmental regulation, but also to evaluate how evolving climate awareness affects firm valuation, stock market dynamics, and the effectiveness of climate policies (Arin *et al.*, 2024; Gong *et al.*, 2022; Financial Stability Board, 2020). In particular, transition risk depends critically on expectations regarding the timing, credibility, and intensity of future policy interventions. Uncertainty surrounding the policymaking process complicates the assessment of future asset returns and contributes to greater instability in financial markets, especially in the presence of fat-tailed risk distributions (Battiston *et al.*, 2017). As a result, investors with significant exposure to carbon-intensive assets may rebalance their portfolios during periods of heightened climate policy uncertainty. Recent evidence supports this view. For example, Tedeschi *et al.* (2024) show that climate policy uncertainty during the COVID-19 pandemic generated positive abnormal returns in European clean energy markets, while Gong *et al.* (2022) document that investors in sustainable assets adjusted their strategies in response to changes in international political commitments and climate-related expectations.

More recently, the European Central Bank has refined its assessment of climate-related financial risks by placing greater emphasis on carbon intensity as a measurable dimension of transition risk. This reflects the recognition that policy-based indicators alone are insufficient to capture the financial system's exposure to carbon-intensive activities (European Central Bank, 2025). In line with this perspective, this study treats carbon intensity as an integral component of transition risk rather than merely as a proxy for physical exposure, as is commonly assumed in the existing literature. Accordingly, the analysis focuses exclusively on transition risk and distinguishes between two key dimensions: Climate Policy (CP) measures and CO_2 emissions. Their relationship with stock market returns is examined in order to better understand how financial markets price climate-related risks. Evidence reported by European Commission *et al.* (2025) indicates that global GHG emissions have continued to rise steadily since the beginning of the 21st century, largely driven by rapidly developing economies. The resulting increase in atmospheric GHG concentrations has intensified the greenhouse effect, generating substantial risks for ecosystems, economic activity, and human well-being.

This study investigates the relationship between climate-related transition risks and stock market returns by addressing the following research question: How are stock market returns dynamically associated with changes in Climate Policy (CP) and CO_2 emissions, and does this association vary across different levels of climate exposure? The empirical analysis proceeds in three steps. First, we estimate the dynamic relationship between Climate Policy, CO_2 emissions, and stock market returns using the Local Projection (LP) framework developed by Jordà (2005, 2023) over the full sample. This baseline specification provides a benchmark assessment of the aggregate market association with climate-related risks. Second, we explore potential regime dependence through the dynamic panel threshold model of Seo and Shin (2016). This approach allows us to identify an endogenous threshold in climate exposure and to distinguish between low- and high-exposure regimes. Regime-specific dynamic responses are then estimated to assess whether the effects of climate risks differ across regimes. Potential distributional heterogeneity is further explored through quantile analysis.

Third, we assess the robustness of the baseline specification through additional macroeconomic controls and sample restrictions, including specifications that exclude the United Kingdom and major crisis periods, namely the Global Financial Crisis and the COVID-19 pandemic.

The analysis contributes to the climate-finance and asset-pricing literature in two main ways: 1) it provides new evidence on the dynamic association between Climate Policy, CO_2 emissions, and stock market returns within a unified panel framework; 2) by combining Local

Projections with the dynamic panel threshold model of Seo and Shin (2016), it documents the presence of regime dependence in the pricing of transition risk.

The remainder of the study is organized as follows. Section 2 reviews the literature on climate-risk asset pricing and transition risk. Section 3 describes the data and variables employed in the empirical analysis. Section 4 presents the empirical framework and methodology. Section 5 discusses the main empirical findings and their implications. Section 6 reports the robustness checks and Section 7 concludes.

2. Literature review

With the increasingly visible effects of global warming, climate change has moved to the forefront of the international policy agenda, accompanied by a substantial rise in public and institutional awareness. In parallel, a growing body of literature has examined the economic and financial implications of climate-related risks, with particular attention devoted to their effects on financial markets and asset pricing.

2.1 Climate risks and financial markets

From a theoretical perspective, climate-related risks can be viewed as sources of systematic risk affecting both firms' expected cash flows and discount rates. Among these, transition risk, driven by changes in climate policy, regulation, technological innovation, and investor preferences, plays a central role by altering firms' profitability prospects and production costs. Importantly, carbon-transition risk is inherently time-varying, as the economic and regulatory environment evolves over time in response to decarbonization objectives and tightening climate commitments. Consequently, the pricing of climate-related risks may vary across periods and policy regimes, even in the absence of abrupt changes in emissions levels (Bolton and Kacperczyk, 2023).

A rapidly expanding literature investigates whether and through which channels climate-related risks are incorporated into financial asset prices, affecting expected returns, risk premia, and portfolio allocation decisions. Yet, climate risk remains particularly challenging for investors because it is difficult both to quantify and to hedge effectively. Its implications across asset classes, including equities and fixed-income securities, are therefore still not fully understood. This difficulty is compounded by the absence of universally accepted measures of firms' climate exposure and by the uncertainty surrounding the economic consequences of climate-related events (Antoniuk and Leirvik, 2024). As a result, investors may face substantial challenges in identifying the firms most vulnerable to transition risk, potentially overlooking profitable investment opportunities (Bua *et al.*, 2024). Despite the increasing importance of these issues, empirical evidence on the pricing of climate-related risks remains relatively limited.

Early contributions show that climate risks are gradually incorporated into asset prices.

Alessi *et al.* (2019), report the existence of a negative "greenium" in European stock markets, identifying a green factor that is priced by investors. Their findings suggest that environmentally sustainable firms tend to offer lower expected returns because investors are willing to accept lower compensation for holding greener assets that hedge climate-related risks. Conversely, firms with greater carbon exposure ("brown" firms) command higher expected returns, consistent with the existence of a climate risk premium.

More recent studies further explore the transmission channels through which transition risk affects financial markets. Using textual analysis, Bua *et al.* (2024) show that increases in transition risk are associated with higher returns for green firms and lower returns for brown firms, reinforcing the view that green assets may act as hedges against transition risk. Similarly, Engle *et al.* (2020), employing a mimicking portfolio approach, find that the effects of climate change on European equity markets became more pronounced following the Paris Agreement. Monasterolo and De Angelis (2020) analyse how European and US equity markets adjusted to the Paris Agreement in terms of carbon risk pricing. Using a portfolio optimization framework, they show that low-carbon indices were perceived as less risky after the Agreement, thereby increasing their attractiveness to investors.

Within this framework, CO_2 emissions can be interpreted as a state variable capturing economies' exposure to transition risk, while Climate Policy reflects the degree of regulatory stringency and policy credibility perceived by financial markets.

2.2 Climate policy

Recent research emphasizes the central role of climate policy in shaping investor expectations and financial market dynamics, as market participants respond not only to the direction of policy measures but also to their credibility and persistence (Antoniuk and Leirvik, 2024). Nevertheless, measuring the economic effects of climate policy remains challenging. The existing literature has primarily relied on two empirical approaches: event-study methodologies and indices capturing climate policy uncertainty. Event-based studies provide evidence that financial markets react significantly to major climate policy announcements.

Caporale *et al*. (2023), applying the spillover framework of Diebold and Yilmaz (2014), document substantial market responses to policy decisions announced during COP conferences. Similarly, Albanese *et al*. (2025) using a VAR framework, find that climate policies generally exert positive effects in European economies, largely driven by international initiatives such as the Paris Agreement and subsequent United Nations actions promoting the green transition through international investment treaties and broader climate governance mechanisms. At the sectoral level, Pham *et al*. (2019), focussing on the German stock market, show that strengthened climate policy negatively affects brown-energy sectors following the Paris Agreement. Consistent with these findings, Gong *et al*. (2022) report that global stock markets respond significantly to increases in international political uncertainty related to climate commitments. Alongside event-study approaches, an increasing number of studies employ indices designed to measure climate policy uncertainty. Among the most widely used is the Climate Policy Uncertainty (CPU) index developed by Gavriilidis (2021), in addition to the climate-related indicators proposed by Engle *et al*. (2020), Bua *et al*. (2024). Using an autoregressive framework, Lv and Li (2023) show that CPU possesses predictive power for sectoral volatility, particularly during periods characterized by relatively low uncertainty. Likewise, Alharbey and Ben-Salha (2024) find that climate policy uncertainty significantly predicts both returns and volatility in renewable energy equities. However, empirical evidence on the relationship between CPU and financial markets remains mixed. For instance Bezgin and Gungor (2025), analysing several European countries, report heterogeneous causal relationships between climate policy uncertainty and stock markets, suggesting that investors adjust their strategies differently depending on the institutional and regulatory environment. Building on this literature, we select countries according to their performance in the Climate Change Performance Index (Germanwatch, 2024). Specifically, we employ the Climate Change Performance Index (CCPI) as our proxy for Climate Policy (see Section 3.1). The CCPI provides a forward-looking measure of countries' climate policy commitment by incorporating recent developments in domestic regulation, policy implementation, and broader institutional efforts toward decarbonization.

2.3 CO_2 emissions

Over recent decades, international efforts to mitigate climate change have increasingly focused on reducing greenhouse gas emissions and accelerating the green transition. Within this framework, the Kyoto Protocol (1997) represented the first legally binding international agreement specifically aimed at regulating greenhouse gas emissions. The central role assigned to emissions reflects the fact that they constitute the principal climate-related variable over which governments can undertake binding and enforceable commitments. While higher income levels are often associated with greater per capita emissions, substantial heterogeneity persists across countries with similar standards of living. According to the Global Carbon Budget (2025), several European economies record significantly lower emissions than major fossil-fuel-producing countries. Moreover, countries such as Portugal, France, and the United Kingdom display per capita emissions close to the global average and substantially below those of neighbouring economies with comparable income levels. Despite international climate commitments, CO_2 emissions have continued to rise over time, largely driven by energy-intensive economic activity (Sadorsky, 2010). This trend has attracted growing attention from policymakers, international institutions, and financial researchers. Noh and Park (2023), analysing 35 OECD countries, show that higher greenhouse gas emissions are associated with greater stock market volatility. At the European level, Dutta *et al*. (2018) using a bivariate VAR-GARCH framework, find that volatility in carbon emissions markets significantly affects renewable energy equity indices. Although the literature examining the economic consequences of greenhouse gas emissions has expanded considerably, empirical evidence directly linking carbon emissions to stock market returns remains relatively scarce. This study contributes to the existing literature by examining the dynamic association between CO_2 emissions and stock returns while jointly analysing how Climate Policy and emissions are associated with stock market performance across countries characterized by different levels of climate exposure.

3. Data

This study employs an annual panel dataset covering 28 European countries, including the United Kingdom, over the period 2007–2024, for a total of 504 observations. The sample period and country selection are primarily determined by the availability of data for the Climate Policy Index. Although the United Kingdom is no longer part of the European Union, it is retained in the sample because it has been a member of the EU for most of the period under consideration and remained closely integrated within the European regulatory and financial environment. Restricting the analysis to European economies offers several advantages. First, European countries operate within relatively comparable institutional and regulatory frameworks regarding climate policy and environmental governance. Second, emissions data are collected and monitored under harmonized European statistical standards (see Section 3.2), thereby improving consistency and comparability across observations. Focussing on a geographically and institutionally coherent sample also reduces potential heterogeneity arising from major differences in climate governance structures and policy implementation across regions.

3.1 Climate Policy Index

To measure climate policy, this study employs the Climate Policy component of the Climate Change Performance Index (CCPI), developed by Germanwatch (2024). The CCPI is an independent indicator designed to evaluate countries' progress in climate protection and their alignment with the objectives established under the Paris Agreement. The index covers 63 countries and is updated annually. The overall CCPI score is constructed from four dimensions: greenhouse gas emissions (40%), renewable energy (20%), energy use (20%), and Climate Policy (20%). While the first three components are primarily based on quantitative indicators, the Climate Policy (CP) category relies on qualitative assessments provided by experts from universities, think tanks, and non-governmental organizations operating in the countries under evaluation. These experts assess the strength and effectiveness of climate policy measures using scores ranging from 1 (weak) to 5 (strong). The policy component is further divided into national policy measures (10%) and international climate engagement (10%). The national policy dimension evaluates countries' performance across several areas, including long-term decarbonization strategies, energy transition policies, industrial and transport efficiency, future emissions targets, management of non-energy sectors, and policies aimed at reducing fossil fuel extraction and subsidies. The international component captures the degree of participation and engagement in international climate initiatives and negotiations, including forums such as the UNFCCC and G7/G20 climate discussions. Compared with alternative indicators commonly used in the literature (see Section 2), the CCPI offers two important advantages for the purposes of this study. First, it provides annual country-level observations, making it particularly suitable for panel-data analysis. Second, the index captures not only the existence of climate policies, but also their perceived credibility, direction, and effectiveness. From a financial market perspective, these dimensions are especially relevant because they shape expectations regarding future regulation, transition costs, and broader macroeconomic conditions. Although the CCPI covers both advanced and emerging economies worldwide, the empirical analysis focuses exclusively on European countries in order to maintain greater institutional comparability and policy homogeneity within the sample.

3.2 CO_2 emissions per capita

In addition to Climate Policy, the analysis considers CO_2 emissions as a proxy for exposure to transition risk. Fossil-fuel-related CO_2 emissions remain the largest contributor to global greenhouse gas emissions and continue to attract considerable attention from policymakers, financial markets, and international institutions. Despite the expansion of international climate agreements, global emissions have remained persistently high, reflecting the continued importance of carbon-intensive economic activity. From a financial perspective, emissions are often interpreted as indicators of industrial production and energy dependence, making them relevant for assessing countries' exposure to climate-related transition risks. In this study, CO_2 emissions are measured on a per capita basis in order to ensure comparability across countries and to capture differences in emission intensity rather than differences in economic or demographic size. This approach provides a more informative measure of climate exposure within a cross-country framework. In particular, we employ the CO_2 emissions per capita dataset provided by European Commission *et al.* (2025), which offers harmonized annual data for all countries over the period 1990–2024. The dataset is constructed according to a transparent methodology consistent with the most recent Intergovernmental Panel on Climate Change (IPCC) guidelines.

3.3 Dependent and control variables

The dependent variable consists of annual stock market indices obtained from Bloomberg. All indices are value-weighted market indices. Stock returns are computed as the first difference of the logarithm of index levels. The empirical specification includes several macro-financial control variables commonly employed in the literature. First, we include the Chicago Board Options Exchange Volatility Index (VIX) as a proxy for global financial uncertainty (Bloom, 2009). Second, we control for the three-month policy interest rate, which captures the stance of monetary policy and broader financing conditions (Bernanke and Kuttner, 2005). Interest rate and VIX data are obtained from Refinitiv Workspace.

Table 1 reports summary statistics and panel unit root test results for all variables over the sample period. Stock market returns display substantial volatility, with an average annual return of 4.72 and a standard deviation of 22.63. The Climate Policy index has a mean value of 10.41 and a standard deviation of 4.08, indicating considerable variation in climate policy commitment across countries. CO_2 emissions per capita average 6.85 and range from 3.18 to 18.10, highlighting significant differences in carbon intensity within the sample. It is worth noting that both Climate Policy and CO_2 emissions exhibit variation not only across countries but also over time within countries (see Tables A.1 and A.2 in the Appendix). This suggests that a substantial share of the observed variation reflects time-series dynamics rather than purely cross-sectional heterogeneity. A similar pattern emerges for CO_2 emissions per capita,

Table 1. Summary statistics and unit root tests

Summary statistics	Mean	Std. dev.	Min	Max
Returns100	4.72	22.63	−79.71	73.40
Climate Policy	10.41	4.08	0.90	20.00
CO_2 Emissions	6.85	2.57	3.18	18.10
VIX	19.95	6.11	11.09	32.69
Short Interest	1.50	2.23	−0.74	14.28

Unit root tests	LLC Test stat.	*p*-value	Pesaran Test stat.	*p*-value
Stock Returns	−23.11	0.00	−2.13	0.00
Climate Policy	−3.34	0.00	−2.09	0.00
CO_2 Emissions	−10.97	0.00	−1.60	0.00
Short Interest Rate	−30.11	0.00	−7.23	0.00
ADF Test				
VIX	30.16		0.00	

Note(s): The sample covers the period 2007–2024 for a total of 504 observations. LLC and Pesaran refer to the (Levin *et al.*, 2002) and (Pesaran, 2007) panel unit root tests, respectively. The LLC (Pesaran) test sets as the null hypothesis that the series contains a common (individual) unit root process, with the alternative hypothesis of stationarity. Since the VIX does not exhibit a longitudinal (panel) dimension, its stationarity is assessed using the Augmented Dickey–Fuller (ADF) test. Descriptive statistics at the within-country level are reported in Tables A.1 and A.2 in the Appendix

whose evolution reflects changes in economic activity, energy composition, and environmental regulation over time. Consequently, the empirical analysis captures both cross-country differences and within-country dynamics associated with transition risk exposure.

Finally, all variables appear to be stationary, I(0), according to the Levin–Lin–Chu (LLC) panel unit root test (Levin *et al.*, 2002) and the Pesaran panel unit root test (Pesaran, 2007) whose results are reported in Table 1. In all cases, the null hypothesis is that the series contains a unit root, while the alternative is that it is stationary.

4. Empirical framework

The objective of this study is to analyse the dynamic relationship between climate-related variables and stock market returns. The empirical strategy is structured around three complementary components. We begin by analysing the time-varying relationship between climate-related variables and stock market returns through the Local Projection (LP) framework of Jordà (2005, 2023). The benchmark specification is estimated using the full panel and includes, in turn, Climate Policy and CO_2 Emissions as the variables of interest, while controlling for financial uncertainty and monetary policy conditions. We then extend the analysis by introducing the dynamic panel threshold model developed by Seo and Shin (2016) in order to capture possible regime dependence in the association between transition risk and stock returns. This methodology identifies endogenous threshold values in climate exposure and separates the sample into regimes associated with different degrees of climate risk. Dynamic responses are subsequently estimated within each regime to evaluate whether stock market behaviour differs across climate exposure states. As an additional exploratory exercise, we further investigate potential distributional heterogeneity through a quartile decomposition of the sample based on Climate Policy commitment and CO_2 Emissions per capita [1]. Finally, we conduct a broad robustness analysis focussing on the baseline specification. In particular, we assess whether the results remain robust to the inclusion of additional macroeconomic controls and to the exclusion of observations related to the United Kingdom and major crisis periods.

4.1 Baseline model

The empirical analysis relies on the Local Projection methodology introduced by Jordà (2005, 2023). Compared with standard vector autoregressive (VAR) models, the LP approach offers greater flexibility and avoids imposing restrictive dynamic structures on the data (Plagborg-Møller and Wolf, 2021). Dynamic responses are obtained by estimating separate regressions for each forecast horizon k. The baseline specification is given by:

$$y_{i,t+k} = \alpha_{i,k} + \beta_k \, \text{ClimateRisk}_{i,t} + Z_{i,t,k} + \varepsilon_{i,t+k}, \tag{1}$$

where $y_{i,t+k}$ denotes stock market returns at horizon k, while $\text{ClimateRisk}_{i,t}$ represents either $\text{ClimatePolicy}_{i,t}$ or CO_2 $\text{Emissions}_{i,t}$ depending on the specification considered. The vector $Z_{i,t+k}$ includes the control variables, namely the VIX index and the three-month policy interest rate, while $\varepsilon_{i,t+k}$ denotes the error term. To account for cross-sectional dependence arising from common shocks and global risk factors, standard errors are clustered at the country level (Ugarte-Ruiz, 2025). Since Local Projections are known to be sensitive to lag length selection, we determine the appropriate lag structure using both the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Both criteria consistently indicate a specification with two lags (Plagborg-Møller and Wolf, 2021). The LP framework is employed here as a flexible dynamic regression methodology rather than as a structural identification device. Consequently, the estimated coefficients should not be interpreted as causal effects, but rather as conditional dynamic associations between climate-related variables and stock market returns. While the baseline specification provides an aggregate benchmark for the full sample, it imposes homogeneous responses across countries and over time. This assumption may be restrictive if financial markets respond differently depending on the degree of climate exposure or policy stringency. To address this issue, the analysis is extended using a threshold framework [2].

4.2 Dynamic panel threshold model

The linear LP specification provides a useful benchmark but may neglect potential regime dependence in the relationship between climate-related risks and stock market returns. In practice, the pricing of climate risk is unlikely to be homogeneous across countries, particularly when differences in carbon exposure and climate policy commitment are substantial. To capture this heterogeneity, we employ the dynamic panel threshold model developed by Seo and Shin (2016). This methodology allows for endogenous regime classification and provides a data-driven approach for identifying threshold effects in panel settings. More specifically, the model permits slope coefficients to vary across regimes conditional on an estimated threshold variable, thereby accommodating nonlinear transmission mechanisms in the relationship between climate risks and financial markets. An additional advantage of the Seo and Shin framework is that it allows for endogeneity in both the explanatory variables and the threshold variable itself. The threshold parameter is estimated through a grid-search procedure, while statistical inference is conducted using bootstrap-based confidence intervals. Dynamic persistence is incorporated by including lagged dependent variables among the regressors. The threshold model is specified as follows:

$$y_{it} = \alpha_i + \rho \, y_{i,t-1} + \beta_1 X_{it} \mathbf{1}(q_{it} \leq \gamma) + \beta_2 X_{it} \mathbf{1}(q_{it} > \gamma) + \varepsilon_{it}, \tag{2}$$

where q_{it} denotes the threshold variable, alternatively specified as Climate Policy or CO_2 Emissions per capita, γ represents the unknown threshold parameter, and $\mathbf{1}(\cdot)$ is the indicator function defining the two regimes. The vector X_{it} includes Climate Policy, CO_2 Emissions, the VIX index and the three-month policy interest rate, depending on the specification considered. After identifying the threshold value, equation (1) is re-estimated separately within each regime using the Local Projection framework. This procedure allows the dynamic responses of stock market returns to vary according to the level of climate exposure and highlights nonlinear effects that may not be captured by the linear benchmark model.

5. Empirical results

5.1 Baseline model results

The full-sample Local Projection estimates provide a benchmark assessment of the dynamic association between climate-related variables and stock market returns. The results reveal asymmetric responses over time, suggesting that financial markets react differently to Climate Policy and CO_2 Emissions, as shown in Figure 1.

Changes in Climate Policy are initially associated with a positive and statistically significant relationship with stock returns (1.47). This suggests that stronger climate policy may be perceived by investors as reducing uncertainty and creating opportunities related to the transition toward cleaner technologies. However, after two years, the relationship turns negative (−0.56), indicating that markets may gradually incorporate the costs of adjustment and the risks associated with the transition process. This pattern is consistent with Bezgin and Gungor (2025). By contrast, increases in CO_2 Emissions generate a positive short-run association with stock returns (3.86). This may reflect the link between emissions, production activity, and short-term profitability. The result is also consistent with Bolton and Kacperczyk (2023), who report higher average returns for firms with greater carbon exposure due to the presence of a carbon risk premium. Once this information is incorporated into prices, however, emissions are associated with a negative response (−6.69), plausibly reflecting expectations of higher future transition costs. The spillover then becomes positive again in the following period (2.19), pointing to a dynamic adjustment process. Overall, the baseline results are mixed and suggest that the relationship between climate-related variables and stock returns is not stable over time. The estimations results are shown in Table A.3 in the Appendix section. These patterns indicate the potential presence of heterogeneity that may not be fully captured when the panel is analysed as a whole. For this reason, we next employ the dynamic panel threshold model of Seo and Shin (2016), which allows the data to identify distinct regimes based on the level of climate risk exposure.

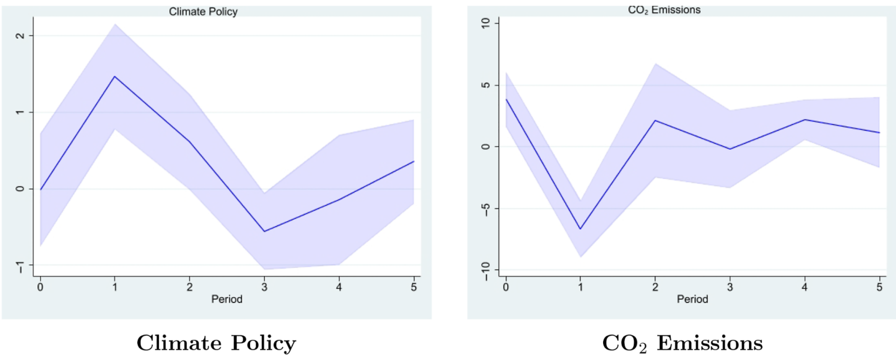


Figure 1. Dynamic responses of stock market returns to climate risks – full sample. *Notes:* The sample includes 28 countries. The blue line is the dynamic response, whilst the shaded area is the 95% confidence intervals

5.2 Endogenous panel threshold model results

The threshold estimation provides evidence of regime dependence in both model specifications. When either Climate Policy or CO_2 Emissions is used as the threshold variable, the bootstrap test rejects the null hypothesis of no threshold effect. This indicates that the transmission of climate-related risks to stock market returns varies systematically with the level of climate exposure. When Climate Policy is used as the threshold variable, the estimated threshold is 10.27. This cut-off divides the sample into 264 observations in the high-policy regime and 240 observations in the low-policy regime. In the high-policy regime, CO_2 Emissions are associated with a negative response in stock returns (−9.63). In the low-policy regime, the estimated effect is positive (1.42), although not statistically significant. This evidence suggests that financial markets penalize carbon emissions mainly when climate policy commitment is sufficiently strong and credible. Using CO_2 Emissions as the threshold variable, the estimated threshold is 8.70, separating the sample into 397 observations in the high-emissions regime and 107 observations in the low-emissions regime. Under this specification, Climate Policy exerts a negative and statistically significant effect (−14.04) exclusively in the high-emissions regime, as shown in Table A.4 and A.5 in the Appendix. This result indicates that climate policy has a more pronounced association with stock returns in carbon-intensive economies, where expected transition costs are likely to be greater.

For each regime identified by the threshold model, we subsequently estimate Local Projections to examine the dynamic association between stock returns and climate-related variables. The regime-specific estimates confirm that the relationship between climate risk and stock market performance is heterogeneous across both time and regimes. Within the Climate Policy regimes, the Local Projection estimates reveal heterogeneous patterns in the association between CO_2 Emissions and stock returns, as illustrated in Figure 2.

In the low-policy regime, CO_2 Emissions are associated with a negative relationship with stock returns (−13.52), suggesting that emissions may increase uncertainty regarding future transition costs in environments characterized by weak or less credible climate policies. By contrast, in the high-policy regime, CO_2 Emissions are initially associated with a positive relationship with stock returns (8.26), followed by a negative association in the subsequent period (−11.00) and then by a renewed positive association (9.57). This pattern points to a more unstable adjustment process, consistent with state-dependent market dynamics.

Figure 3 reports the regimes obtained using CO_2 Emissions as the threshold variable. In the low-emissions regime, Climate Policy displays a positive association with stock returns during the first two periods (1.44 and 0.75). In the high-emissions regime, the association remains positive, although it is statistically significant only in the first period (1.23). These findings

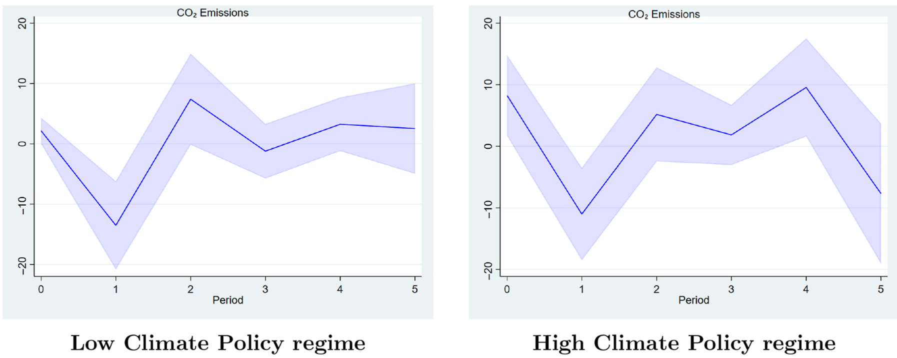
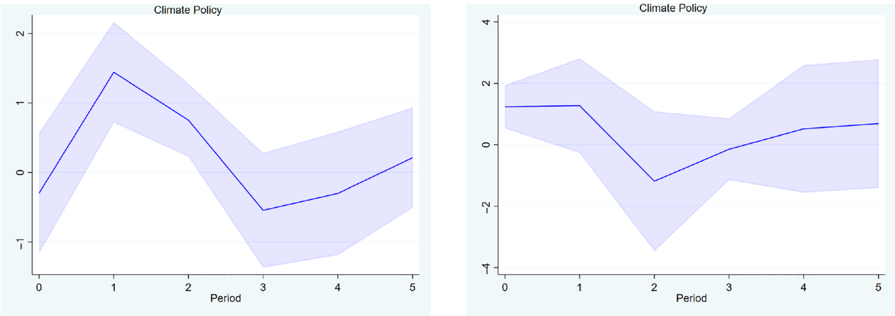


Figure 2. Dynamic responses of stock market returns to CO_2 emissions by climate policy regimes. *Notes:* The blue line represents the dynamic response of stock market returns to CO_2 Emissions, while the shaded area denotes the 95% confidence interval



Low CO_2 Emissions regime **High CO_2 Emissions regime**

Figure 3. Dynamic responses of stock market returns to climate policy by CO_2 emissions regimes. *Notes:* The blue line represents the dynamic response of stock market returns to a Climate Policy, while the shaded area denotes the 95% confidence interval

suggest that Climate Policy is generally positively priced by financial markets; however, its association with stock returns appears more short-lived and less pronounced in economies characterized by higher carbon exposure. Overall, the threshold model confirms the presence of regime dependence. The full estimation results are reported in Tables A.6 and A.7 in the Appendix section.

5.2.1 Potential distributional effects. To further explore potential distributional heterogeneity, we conduct an exploratory exercise by controlling for quartiles, of the sample using Climate Policy commitment and CO_2 emissions per capita. This analysis is motivated by the fact that the dynamic panel threshold model of Seo and Shin (2016) does not allow for testing the presence of multiple endogenous thresholds. To provide a more granular partition of the distribution, we therefore estimate the Local Projection framework separately for each quartile.

Overall, the quartile-based results are only weakly informative and do not reveal substantially different patterns beyond those already identified by the threshold model. More specifically, the findings broadly confirm the clustering structure implied by the Seo and Shin (2016) framework, suggesting that the main source of heterogeneity is already adequately captured by the estimated threshold regimes. The full set of estimation results is reported in Tables A.8–A.9 in the Appendix section.

6. Robustness checks

We assess the robustness of the baseline specification by re-estimating the Local Projection model using alternative controls and sample restrictions. These exercises evaluate whether the empirical findings are sensitive to macroeconomic controls, specific countries, or major crisis periods.

First, we extend the baseline specification by adding GDP growth to the VIX and the short-term interest rate (Eurostat *et al.*, 2026). The results remain broadly consistent with the baseline specification. Climate Policy continues to display a positive and statistically significant association with stock returns at short horizons, followed by a weaker negative association at medium horizons. Similarly, the relationship between CO_2 Emissions and stock returns remains mixed, with an initial positive association followed by a negative response, which turns positive in the long run. We further assess robustness by excluding the United Kingdom, the Global Financial Crisis period (2007–2009), and the COVID-19 period (2020–2021). Across all specifications, the main empirical patterns remain qualitatively unchanged. Climate Policy continues to exhibit a positive short-run association with stock returns, while

CO_2 Emissions preserve their mixed dynamic relationship with market performance over time.

Overall, the main patterns remain broadly consistent across alternative specifications. Full robustness results are reported in Tables A.10–A.13 in the Appendix.

7. Conclusions

This study examines the dynamic relationship between climate-related risks and stock market returns across European countries over the period 2007–2024. Using the Climate Policy Index (Germanwatch, 2024) and CO_2 Emissions per capita (European Commission *et al.*, 2025) as proxies for transition risk, the analysis explores how stock market returns are associated with changes in regulatory commitment and carbon exposure. Climate Policy captures the perceived credibility and intensity of climate-related regulation, whereas CO_2 Emissions proxy the carbon intensity of economic activity and the degree of exposure to transition risk associated with future regulatory tightening, technological substitution, and changing investor preferences. Using the Local Projection framework of Jordà (2005, 2023), we show that the association between climate-related variables and stock market returns is both dynamic and heterogeneous over time. Climate Policy is initially associated with positive stock market performance, suggesting that investors may interpret stronger climate commitments as reducing uncertainty and supporting investment opportunities linked to the green transition. Over longer horizons, however, the association becomes negative, consistent with the gradual incorporation of transition costs and policy-related adjustment burdens. CO_2 Emissions display a similarly time-varying pattern, whereby higher emissions are initially associated with stronger stock market performance, potentially reflecting their link with production activity and short-term profitability, while the association turns negative over time as markets increasingly incorporate transition risks and future compliance costs into valuations. To account for potential regime dependence, we implement the dynamic panel threshold model of Seo and Shin (2016). The results suggest that the association between climate-related risks and stock market returns varies systematically across regimes. In particular, the pricing of carbon emissions depends critically on the credibility and stringency of the policy environment. Emissions are penalized more strongly in countries characterized by higher climate policy commitment, while the association between Climate Policy and stock returns is more pronounced in carbon-intensive economies, where expected transition costs are likely to be greater. These findings indicate that the relationship between climate risk and financial markets is state-dependent and cannot be fully captured within a linear framework.

The analysis contributes to the literature in several ways. First, it provides new evidence on the dynamic and nonlinear association between climate-related risks and European stock market returns within a unified panel framework. Second, by jointly considering Climate Policy and CO_2 Emissions, it highlights the importance of the interaction between regulatory stringency and carbon exposure in shaping market valuations. Third, the findings contribute to the broader asset-pricing literature by showing that transition risk is not incorporated uniformly across countries or over time, but instead varies according to the stage of the transition process and the credibility of climate-related policy frameworks. From a policy perspective, the findings suggest that the financial implications of climate risk depend not only on the level of emissions, but also on the institutional and regulatory environment in which the transition takes place. For investors, this implies that portfolio exposure to climate-related risks cannot be evaluated independently of policy credibility and transition intensity. In particular, carbon-intensive assets may be more vulnerable to repricing in countries characterized by stronger and more credible climate policy frameworks, where future regulatory costs are more likely to be incorporated into market valuations. For policymakers and central banks, the results highlight the importance of credible and consistent climate policies in shaping market expectations and limiting transition-related uncertainty. The findings also suggest that climate policy credibility may influence the transmission of transition risk to financial markets and should therefore be considered within broader assessments of financial stability and climate-related vulnerabilities. The analysis is nevertheless subject to several limitations. First, the empirical framework relies on aggregate stock market indices and therefore does not account for firm-level heterogeneity in carbon intensity, sectoral exposure, financial structure, or green investment strategies. As a result, the empirical framework cannot distinguish between the responses of carbon-intensive and low-carbon sectors, nor can it account for changes in countries' sectoral composition over time. Future research could address this limitation by employing sector-level or firm-level data to examine whether the pricing of climate transition risk differs across industries and economic activities. Second, although the analysis explores heterogeneity across different levels of Climate Policy and CO_2 Emissions, it does not explicitly account for potential asymmetries across market conditions or return distributions.

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Notes

1. A possible extension of the present analysis would be to implement a Local Projections Difference-in-Differences (LP-DiD) framework following Dube *et al*. (2025). However, since the threshold values identified by the Seo–Shin model generate endogenous regime classifications rather than discrete exogenous treatment events, such an approach is not fully data-congruent with the structure of our empirical setting. We therefore leave this extension for future research.
2. All empirical estimates reported in the paper, including the baseline regressions, the dynamic panel threshold model of Seo and Shin (2016), the Local Projections by quartiles, and the robustness analyses, were conducted in Stata using standard built-in commands and widely used user-written econometric packages.

Supplementary material
The supplementary material for this article can be found online.

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