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The Effects of Physical and Transition Climate Risk on Stock Markets: Some Multi-Country Evidence

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1. Introduction

In recent decades climate change and global warming have become key issues for the planet Earth. To tackle their negative effects, various commitments have been made by world leaders at the UN Climate Change Conferences held regularly since 1995. In particular, a legally binding international treaty known as the Paris Agreement was signed by 196 countries at COP21 (Conference of the Parties 21) on 12 December 2015; this agreement set the goal of reducing greenhouse gas emissions to limit the temperature increase in the current century to 2 degrees Celsius, and also of adopting additional measures to bring it down further to 1.5 degrees.

Both climate change itself and policies aiming for a gradual shift from fossil fuels to renewable energy can have direct consequences for the economy and for financial markets.

Climate transition risk can affect individual economies but also spill over to others. As a evidence on the impact of climate risk on financial markets we also use individual components of CCPI as well as a set of alternative climate indices found in the existing literature.

The empirical model is a balanced panel VAR including aggregate stock indices (as opposed to company data) for 48 countries over the period from 2007 to 2021, our aim being to examine the response of stock markets as a whole to climate change. Forecast Error Variance Decomposition and Local Projection methods (Jorda, 2005, 2023) are also applied to shed further light on the issues of interest. The estimation is carried out for the whole set of countries considered as well as a subset including the 27 European Union (EU) countries and the UK (which was a EU member for most of our sample period), the latter being a group of countries sharing supranational and binding climate policies which might affect the response of financial markets to climate risk.

The layout of the paper is the following: Section 2 reviews the literature on the impact of climate change on financial markets and on measures of climate risk; Section 3 describes the CCPI index as well as the alternative climate risk indicators used for the analysis; Section 4 outlines the empirical framework and discusses the empirical results, including robustness checks; Section 5 offers some concluding remarks.

2. Literature Review

This section provides an overview of the existing studies examining the effects of climate change on financial markets, and also of the different measures of climate risk proposed in the literature. For the convenience of the reader, the most relevant studies are also summarised in Tables 1 and 2.

Insert Tables 1 and 2 about here

2.1 Climate Risk and Financial Markets

Climate change poses a challenge to investors, namely accurately pricing climate risk and measuring climate risk premia (Bua et al.,26(thb54( )-129(e)4(x)-9(ist)-4(ing)8( )-129(studi)-4(e)4(s)-140(

gauging firms' exposure to this type of risk and the challenge of estimating accurately the possible impact of specific climate events. In particular, investors may encounter difficulties in effectively screening firms that are vulnerable to climate risk, thereby possibly overlooking profitable investment opportunities as a whole as well as financial markets, with sectors associated with fossil fuels being particularly vulnerable. This highlights the importance of policies aimed at mitigating the impact of transition risk, despite the fact that in the absence of frictions the transition toward a lower carbon economy should be expected to be smooth (the reason being that structural changes to achieve net zero emissions should be part of the information set of economic agents).

Faccini et al. (2023) use textual analysis to show that in fact only the climate-policy factor is priced by investors, especially after 2012. Their estimates of risk premium imply that investors hedge the transition risks from government intervention, as opposed to the direct risks from climate change itself. Textual analysis is also applied in the study by Yang et al. (2023b), who conclude that climate mitigation news are partially priced in the Canadian stock market; more specifically, they find asymmetric effects, namely stock prices react positively to market-wide climate-favourable news but not negatively to climate-unfavourable ones. Finally, Boungou and Urom (2023) find instead adverse effects of climate risk on banks' stock performance by applying a Quantile Regression method to daily stock index data for global and G20 banks.

2.2 Climate Risk Indicators

As already mentioned, the literature distinguishes between two types of climate risk, namely transition and physical risk, both of which affect especially countries lacking adequate resilience, coping mechanisms, or adaptation capacities to a green economy (Frege et al., 2023). Physical risk comprises both acute and chronic risk. The former denotes sudden, episodic occurrences capable of causing substantial physical harm, such as wildfires, river and ocean flooding, and tropical storms. The latter instead refers to on-going processes such as sea level rise and increases in global mean temperature (Buhr et al., 2022). In the case of financial markets, physical risk encompass

It is noteworthy that there is currently a lack of consensus concerning the most appropriate measures for both physical and transition risk. Both GHG emissions (Ciccarelli et al., 2024, among others) and precipitation (Muntaz et al., 2024, among others) have been proposed as possible indicators for physical risk, whilst a wider range of measures have been developed for transition risk. As previously mentioned, a strand of the literature uses textual analysis to create indices based on news concerning climate change. For instance, Engle et al. (2020) extract innovations from climate news series and then use a mimicking portfolio approach to build climate change hedge portfolios. Bua et al. (2022) also develop physical and transition risk indicators based on textual analysis; these enable them to estimate climate risk premia, ambitious targets including a 40% reduction in greenhouse gas emissions (from 1990 levels), a 32% target for renewable energy, and a 32.5% improvement in energy efficiency.

Subsequently, targeted measures were implemented in line with the Paris Agreement. In particular, t

3.1 Climate Transition Risk Indicators

The database used for the analysis combines several variables coming from different sources. To capture the ability of countries to tackle the transition risk resulting from climate change, we use i) the Climate Change Performance Index (CCPI) from Germanwatch and ii) the Vulnerability Index from the World Risk Index, constructed by the United Nations University Institute for Environment and Human Security.

Insert Table 4 about here

The CCPI is an independent measure of countries' climate protection efforts, which provides transparency in international climate politics and facilitates cross-country comparisons. It is calculated for 63 countries that together account for more than 92% of global greenhouse gas (GHG) emissions (Burck et al., 2023). Evaluations based on the CCPI use standardised criteria to rank countries' climate performance.

National Centre for Atmospheric Science at the University of East Anglia (see Mumtaz et al., 2024).

3.2.2 Acute Risks

In contrast to chronic risks, acute risks are immediate, short-term events that occur suddenly. They are typically intense and may have an immediate and severe impact. Acute risks often stem from extreme weather and climate-related events, such as storms, floods, droughts, heat waves, wildfires, or other sudden natural disasters. While they may cause significant damage and disruption in the short term, their effects are generally short-lived compared to chronic risks. The data on heat waves, extreme precipitation, and droughts were taken from EM-DAT database. This records the type of natural disaster, the period when it occurred, the number of deaths, injuries and people affected by such extreme climate events. Following a similar approach to Caporale et al. (2018), we construct the following Acute Index per year/country:

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4. Empirical Analysis

To analyse the impact of climate risk shocks on stock market returns we obtain impulse responses (IRs) from a balanced panel Vector Autoregression (VAR) model specified as follows:

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where ῢٳ,ٹ= (Stock Market Returnsٳ,ٹ;

Figure 1a displays for all 48 stock market return series the impulse responses (with the corresponding 95% confidence intervals) to a one standard deviation shock to the transition climate risk indicators (CCPI and its components). It can be seen that a shock to the CCPI total score has a positive but insignificant effect on stock market returns. When focusing on the components of CCPI, we find instead a positive and significant response over a two-year horizon to an international climate policy shock, whilst there is no evidence of any significant effects of national climate policy shocks. A plausible explanation for this finding is that investors perceive as effective only climate policies agreed and coordinated at the international level

$$Returns_{i,t+k} \quad \alpha_{i,t} \quad \beta_k Climate\ Risk_{i,t} \quad \omega_{i,t+k} \quad e_{i,t+k} \qquad (3)$$

where $Returns_{i,t+k} = (Stock\ Market\ Returns_{i,t+k})$; $Climate\ Risk_{i,t} = (Physical\ Risk_{i,t}$ or $Transition\ Risk_{i,t}$, in turns); *k* stands for the number of periods after a reference year t; the vector $\omega_{i,t+k}$ contains the global financial uncertainty index as well as real GDP growth and the 3-month policy rate to capture country-specific macroeconomic effects; $e_{i,t}$ is the residual vector. [7]

Insert Figures 3a and 3b about here

Figures 3a and 3b display the response of stock market returns (with the corresponding 95% confidence intervals) to a one standard deviation shock to each of our measures of climate change risk, for the full sample. Reassuringly, the results of the LP exercise are consistent with those obtained from the VAR models. For instance, international, but not national, climate policies are again found to have statistically significant effects lasting two years. It is important to note that LPs, in contrast to IRs, are not constrained to converge towards zero and therefore are expected to provide more accurate confidence intervals for longer horizons (Psaradakis et al., 2024). However, in our case we do not find any significant effects of the shocks considered over horizons longer than two years.

Finally, Figures 4a and 4b display the LPs for the EU-28 countries. On the whole, the results are again consistent with the IR ones. In particular, national climate policies appear to have a positive impact on stock markets, which is further evidence of their having higher credibility when being pursued within a supranational framework.

Insert Figures 4a and 4b about here

5. Conclusions

This paper examines the impact of transition and physical climate risks on stock markets in 48 countries using yearly data from 2007 to 2023. For this purpose a balanced panel VAR model is estimated to obtain impulse responses for the whole set of countries as well as a

[7] Jorda (2023) discusses the pros and cons of estimating VARs vis-à-vis local projections.

subset including the EU-28 only, and then other methods such as Local Projections (Jorda, 2005, 2023) are applied as robustness checks. The contribution to the literature is twofold. First, ours is the first paper to use the CCPI index calculated by Germanwatch as well as its components to assess the impact of transition risk on stock markets. Second, it is the most thorough study to date on the consequences of climate change for stock markets since it analyses this issue for a very large set of countries and uses a wide range of indices for both transition and physical risk, thereby providing valuable evidence to investors and policymakers to make informed decisions during the on-going green transition.

Various empirical studies had already examined the impact of climate change on financial markets distinguishing between physical risk and transition risk (see, e.g., Pagnottoni et al., 2022; Bua et al. 2022), using textual analysis (Engle et al., 2020; Apel et al. 2023), or other physical and transition risk indicators (Boungou et al. 2023). Our findings are broadly consistent with earlier ones. In particular, they point to a positive impact of transition risk and a negative one of physical risk, especially in the short term (Bua et al., 2022). Moreover, transition risk is shown to have an effect only with a time lag, while physical risk appears to have an immediate impact. Our analysis also yields a number of new additional insights. More specifically, shocks to the Climate Policy index are shown to have a positive and sign nBT/F4.43 551.83 406.99 Tm g0q842.u nB2del(0.0a0 72.024 572.59 Tm0 g0 6866 0 5n2.04 reW*n0 g0

Finally, it is well known that climate change adversely affects the global economy, particularly through natural phenomena-induced physical risks (see Fabris, 2020). The World Risk Index (WRI) exposure component, reflecting geographical location and chronic climate physical risks, is found to have a negative impact on the EU-28 and on the full sample, albeit this effect is statistically significantly only for the latter. Instead, in the case of the acute index related to extreme natural disasters, our findings are consistent with earlier ones (see Pagnottoni et al., 2022, and Campiglio et al., 2023) suggesting that they have short-term negative effects, with the EU-28 stock markets being more exposed.

It should be acknowledged that the present study has some limitations arising from the low frequency and the aggregate nature of the climate risk indicators used. Future work should aim to gather additional evidence on the issues of interest by also examining the role of firm-specific characteristics such as industry, energy-intensity, renewable R&D activity, and expectations about future energy prices for the countries for which such data are available. This additional information would lead to a greater understanding of the impact of climate risk on different sectors with different degrees of readiness/vulnerability, and thus to the design of more effective sector-specific mitigation strategies.

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Table 3: List of Countries – Full Sample

EU-28		**NO EU-28**	
Austria	Italy	Australia	Mexico
Belgium	Latvia	Brazil	Morocco
Bulgaria	Lithuania	Canada	New Zealand
Croatia	Malta	China	Russia
Cyprus	Netherlands	Egypt	Saudi Arabia
Czech Republic	Norway	India	South Afric0 G[ )]T

Table 4: Climate (Transition) Risk Indicators, Sources and Descriptions

Indicator	Source and Sample	Definition
CCPI	Germanwatch 2007-2023	It assesses and compares the climate performances of a wide range of economies, promoting transparency and action against climate change. response to climate change.
CCPI components		
National Climate Policy	Germanwatch 2007-2023	
International Climate Policy		

Table 7:

Figure 1a: IR of stock market returns to

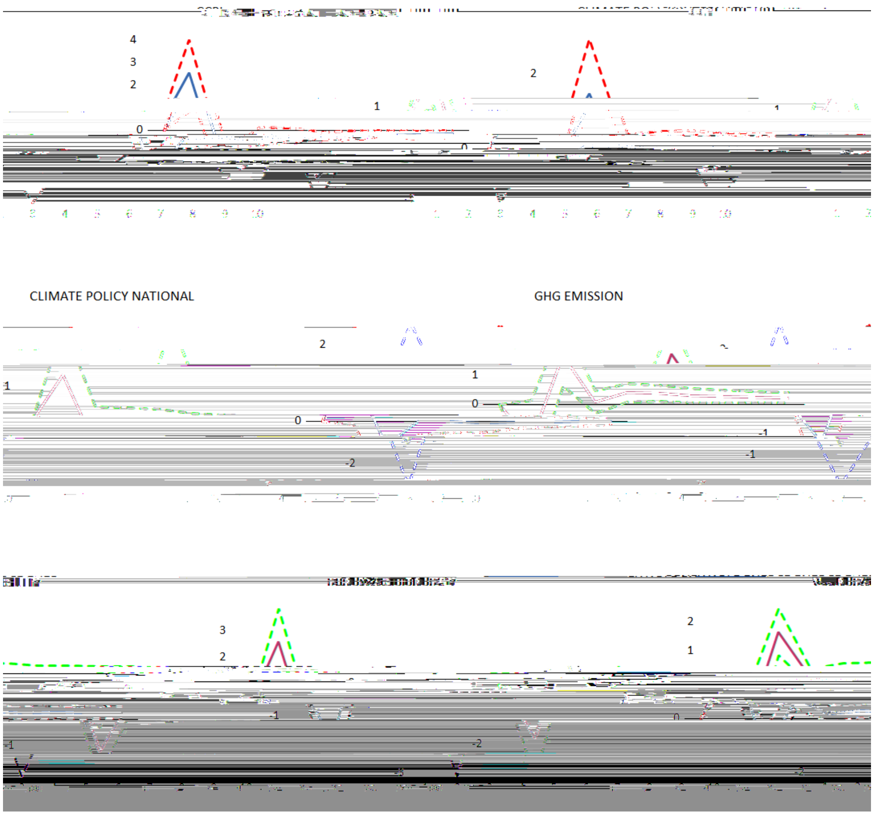
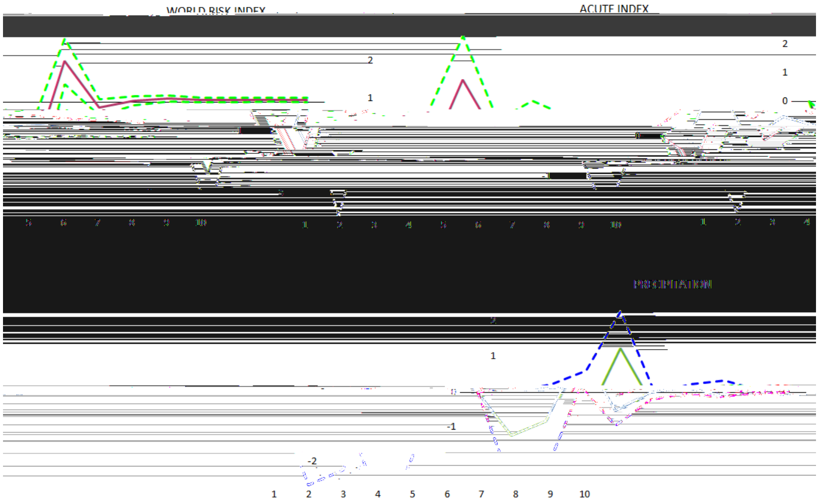


Figure 1b: IR of stock market returns to climate (physical) risk shocks – Full sample



Notes: See the notes to Figure 1a. Precipitation refers to the year-on-year change in precipitation.

Figure 2a: IR of stock market returns to climate (

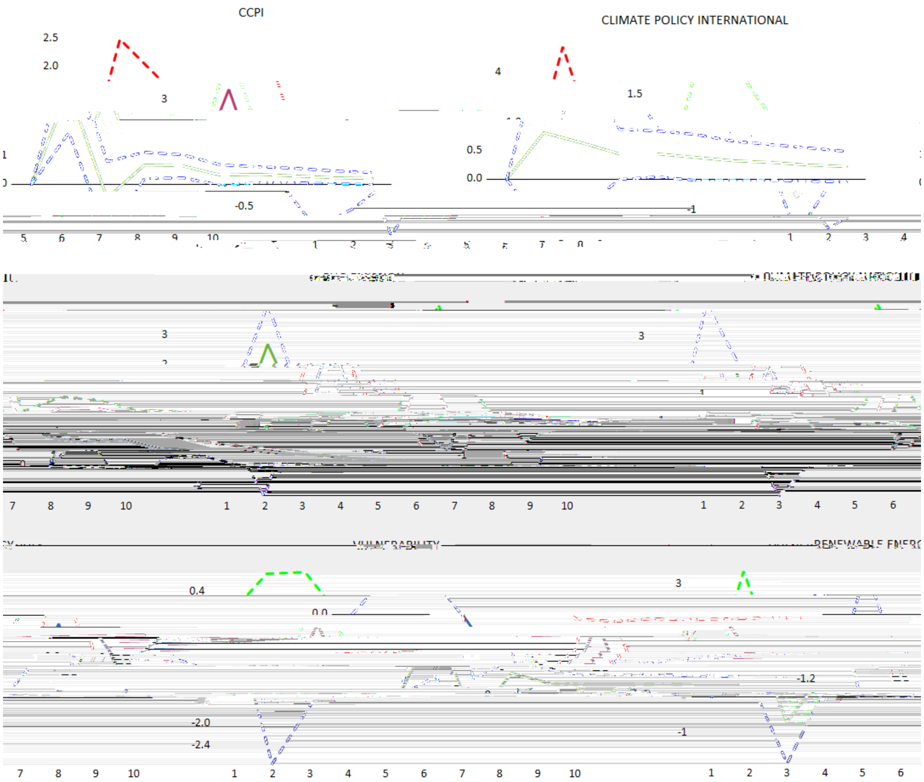
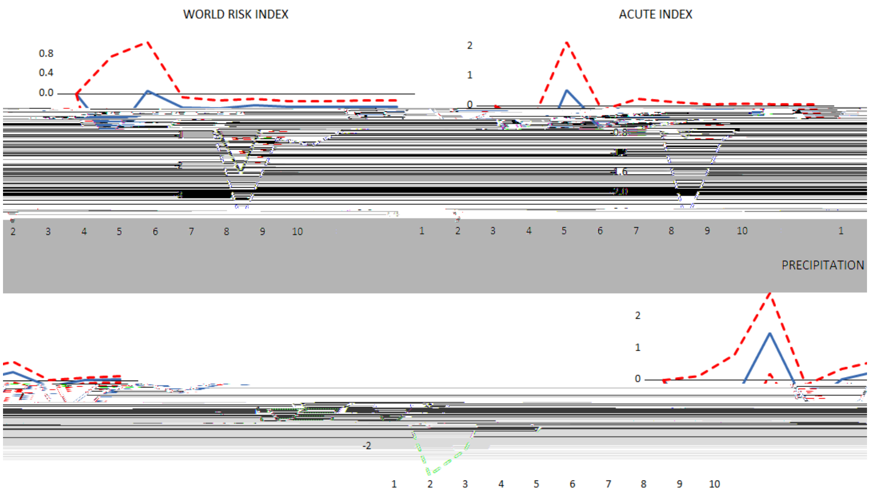
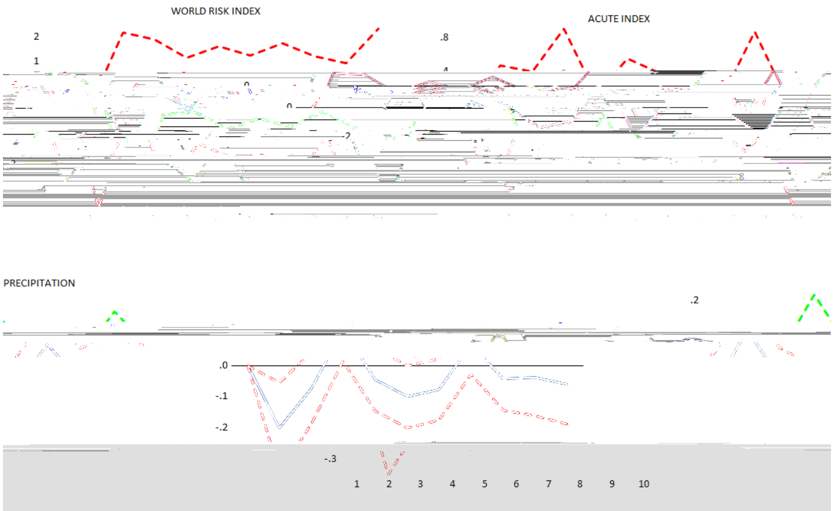


Figure 2b: IR of stock market returns to climate (physical) risk shocks – EU-28



Notes: See the notes to Figure 2a.

Figure 3b: LP of **stock market returns to climate (physical) risk shocks – Full sample**



Notes: See the notes to Figure 3a.

Figure 4a: LP of stock market returns to climate (transition) risk shocks –EU-28

Notes: See the notes