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Climate Risk Measures: A Review

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The increasing concern about the far-reaching effects of climate change-related risk on sustainability has engendered the need to develop alternative indices to measure it. In this study, we review the existing measures of climate risk and offer useful areas for future research. We hope to revisit this exercise as new developments unfold and more robust measures become available.

I. Introduction

In this study, we succinctly review the literature on the various measures of climate risk ranging from text-based to weather-related measures. This exercise is motivated by the far-reaching impacts of climate risk and the increasing prominence of climate change-related issues both at the national and international levels.[1] Recent evidence, among others, suggests substantial global socioeconomic impacts of climate change owing to its severe consequences on human beings, as well as on physical and natural capital. Thus, developing measures to assess climate change impacts is crucial for effective planning both from investment and policy perspectives. Currently, the measures assess different aspects of climate risk ranging from its socio-economic impacts to policy responses including risk management tools as well as adaptation and mitigation.

The review is not only conducted to highlight the various components of these measures but to also provide useful suggestions for future research by identifying the gaps in the literature. Therefore, this study is relevant to investors, policy makers and academics. As new developments unfold in the near future with alternative measures and policy actions different from those documented in this study, we would update our review accordingly.

A review of the climate risk measures is rendered in the immediate section, discussion of gaps in the literature follows, while the final section concludes the paper.

II. Measures of Climate Risk

Researchers have deployed different indicators to measure climate risk or risks associated with climate change. These measures can be broadly categorized into three. First, the text-based measures; second, measures based on weather conditions, and third, measures based on weather-related losses. These are reviewed in the following sub-sections.

A. Text-based measures

Climate risk has been measured based on its frequency and frequency of its related words in the news, which is an indication of the threat of climate change to human endeavours. Engle et al. (2020) make the first attempt to develop a text-based measure of climate risk by developing the Climate Change News Index, which involves deriving climate change-related texts from the Wall Street Journal. Essentially, this index is computed as the proportion of the texts in the Wall Street Journal that are devoted to issues on climate change each day. The choice of keywords in this regard is in line with the Climate Change Vocabulary. These include temperature, global warming, emissions, greenhouse gas, weather, carbon dioxide, climate system, etc. For ease of interpretation of magnitudes, the index is scaled by a factor of 10,000.[2]

Another text-based climate risk index is the one developed by Bua et al. (2021), which clearly demarcates between transition and physical climate risks based on related vocabularies.[3] The cosine-similarity approach of Engle et al.

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1 Recently, the Bank of International Settlements (2021) provides some conceptual and methodological issues on climate-related financial risk and their practical implementation by banks and supervisors.

2 See Ye (2022) for recent applications of the index.

3 For instance, keywords, such as ecosystems, sea level, and precipitation, are more related to the physical risk topic, while words like hydrofluorocarbon, bioenergy and greenhouse gas are better suited for the transition risk (Bua et al., 2021).

(2020) is employed to distinguish the former from the latter. The process of generating the risk data involves obtaining a list of relevant texts on climate change and filtering the content into physical and transition risks. Thereafter, in order to measure the unexpected change in the two risks, the authors estimate an autoregressive model of order one for each risk data and the corresponding residuals constitute the risk indices. In other words, the residual term from the autoregressive model for physical risk is described as the physical risk index, while following the same procedure for transition risk produces the transition risk index.

Still on the text-based climate risk measures, we find another index by Faccini et al. (2021) that equally separates climate risks into different categories based on certain risk factors.[4] Basically, Faccini et al. (2021) employ the Latent Dirichlet Allocation (LDA) technique to construct climate-risk factors and distinguish between climate change risks. The process involves obtaining textual information on four climate-related topics (natural disasters, global warming, U.S. climate policy, and international climate-change summits) and dividing them into physical (consisting of natural disasters and global warming) and transition (consisting of U.S. climate policy and international summits) climate risks. The textual information contains words, such as weather, drought, flood, and storm under natural disasters; temperature, heat, greenhouse, emission and Celsius under global warming; Kyoto, protocol, summit, and Copenhagen, under International summits; and Clinton, environmental, and congress and campaign under US climate policy, published in Thomson Reuters News Archive between January, 2000 and November, 2019.

Recently, Wang et al. (2022) propose another text-based measure of climate risk, which is a climate risk concerns ratio developed using text mining approach. This measure is an aggregation of four ratios of climate risk concerns, namely transition risks, acute physical risks, chronic physical risks, and climate-related opportunities. The computational procedure involves the following steps: (i) launching "Jieba"-Traditional Chinese's 'dictionary' and 'stopwords'; (ii) importing climate risks 'keywords dictionary'; (iii) importing text content of CSR reports through *pdfplumber*; (iv) organizing each keyword mentioned times and total number of words from each CSR report; and (v) lastly, creating climate risk concern ratio.

B. Measures based on Weather conditions

Weather conditions have also been used as an indicator of climate risk in the literature (see, for example, Bressan & Romagnoli, 2021; Sheng, Gupta, & Cepni, 2022; Wiklund, 2021). This measure tends to focus more on the physical aspect of climate risk including heat waves, heavy precipitation events, drought, and tropical cyclones (Wiklund, 2021). Basically, measures of climate risk based on weather conditions are usually defined by temperature and some related factors. Bressan and Romagnoli (2021) define climate risk in terms of temperature when examining the role of climate and weather derivatives as instruments to hedge climate risk. In their study, Bressan and Romagnoli (2021) explain aggregate temperature indices over a certain period as the composite of Heating Degree Days, Cumulative Average Temperature, and Cooling Degree Days. Wiklund (2021) defines climate risk in terms of the three most commonly identified physical risks, namely extreme weather events, changes to precipitation patterns, and rising temperatures.

Furthermore, Sheng et al. (2022; Sheng, Gupta, & Cepni, 2022), while analysing the impact of climate risks on economic activities of some selected states in US, define climate risk in terms of temperature growth or its volatility. Sheng et al. (2022; Sheng, Gupta, & Cepni, 2022) proceeded by collecting data for the average temperature of each state (in degrees Fahrenheit) and using the monthly temperature data to first calculate the month-on-month growth in temperature, and then fit the stochastic volatility (SV) model to obtain the corresponding volatility of state-level temperature.

C. Measures based on Weather-related losses

Another category of climate risk measures involves those that are weather-related rather than text-based. In other words, this category considers indicators of economic losses (such as income loss) as well as fatalities (such as number of deaths) suffered due to extreme weather-related events. Extreme climate events usually cause physical damages to the environment with attendant negative consequences on socio-economic activities. Such damages and disruptions will negatively affect economic benefits of business (Huang et al., 2018). These measures capture both physical and transition effects of climate change, in addition to other direct effects on human life. While material damage to the environment directly caused by natural disasters (i.e., forest fires, drought, floods, hurricanes) can be described as physical risk, the fallouts of these environmental changes in terms of adaptation and sudden policy responses are seen as the transition effects of climate change (Ren et al., 2022).

One of the prominent measures of climate risk in this category is the Global Climate Risk Index, which is being managed by Germanwatch and whose report is recently published in Eckstein et al. (2021).[5] The index essentially measures the extent of damages suffered by countries and regions from extreme weather-related events, such as storms, floods, and heat waves. Based on the outcome of the index, countries and regions are ranked accordingly. This index is particularly suitable for country-specific analyses and appears to be more useful when formulating

4 See Gupta and Pierdzioch (2022) as well as the original paper of the index for recent applications.

5 See Islam and Wheatley (2021), Ozkan et al. (2021), Ren et al. (2022), among others, for recent applications of the index.

policies bordering on climate change both at the national and international levels.

Another measure in this category is the Climate Risk Assessment of Infrastructure Tool. The index as developed by Arup Group, SOAS University of London, and local collaborators in Shanghai in 2016/2017 for cities in the Yangtze delta region of China (see, also, Sun et al., 2019). This index focuses on the effect of climate change on infrastructural system in a particular city, facilitates assessment of the current and future climate resilience of these systems, and incorporates relevant adaptation policies. The later version by Tian et al. (2022) entails more quantitative analysis and adaptation measures.

III. Gaps in the Literature

The existing measures of climate risk are not exhaustive and we further discuss some other important areas that we believe should attract the interest of researchers in the near future. The first area relates to the need to develop relevant methodological approaches for pricing climate risk. While investors and organizations are encouraged to invest in eco-friendly assets, such as those that meet the criteria of Environmental, Social, and Governance, among others, there appears to be no standard methodological approach that effectively measures the opportunity cost of meeting these criteria and how such can be introduced into the pricing of conventional assets. The second issue relates to the need to measure climate risk mitigation and adaptation strategies from the perspective of the receiving end where individual countries are ranked based on their response to mitigate their exposure to climate change. For instance, the negative impacts of climate change due to extreme weather conditions relate to increasing costs of healthcare, food insecurity, rising cost of energy, increased costs of maintaining infrastructure, among others (Gasper et al., 2011). The suggested measure is expected to assess the provisions by national, regional, and international entities to account for these inherent costs of climate change. It should also cover the various strategies adopted to adapt to climate change and to mitigate its potential damage. In other words, this measure will serve as a barometer for evaluating commitments at all levels of legal entities in relation to climate change-related risks. The Global Climate Risk Index (see, Eckstein et al., 2021) is an effort in the right direction as it covers the extent countries and regions have been affected by the impacts of weather-related loss events (storms, floods, heat waves, etc.) and the associated fatalities and economic losses. However, there is no standard measure of assessing the response of countries and regions towards compensating for these fatalities and economic losses as well as their climate change adaptation and mitigation strategies.

Finally, another important gap relates to the need to evaluate the predictive value of the existing measures of climate risk in order to examine whether their information contents can be useful when making projections on variables that are affected by climate change. Other gaps which we are not able to present in this short paper for want of space include but not limited to issues bordering on: (i) the frequency of climate risk measures, which is relatively low (monthly, quarterly and annual), whereas most experts whose investments are threatened by climate change and whose stocks are traded on stock exchange would appreciate high frequency (daily or weekly) measures ; (ii) carbon emission allocation-based risk measure whereby the various criteria used in allocating carbon emissions (see for a review, Zhou & Wang, 2016) are used to construct different risk measures and by extension their outcomes can be comparatively evaluated.

IV. Conclusion

We offer a brief review of the alternative measures of climate risk ranging from text-based measures to those derived from weather-related conditions. We highlight areas of application in the literature and also identify existing gaps for future research. We believe that analysts, academics, and policy makers who require information on the extent of climate risk to make informed judgments would find this review insightful. We hope to update it as new issues capable of challenging our current knowledge of the subject matter become evident.

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