Climate Risk, Economic Stability, and Tourism: A Cross-Sectionally Dependent Heterogeneous Panel Causality Analysis

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This research is designed to study the Granger causality between climate risk, economic stability, and tourism. It uses the heterogeneous panel Granger approach developed by Dumitrescu and Hurlin (2012). This approach is particularly useful for data with cross-sectional dependence and heterogeneity. The findings suggest that, on the one hand, tourism development will be beneficial to national economic stability and, on the other hand, it will contribute to the national climate crisis.

I. Introduction

Global extreme weather events have become increasingly frequent in recent years. As Germanwatch shows, more than 11,000 extreme weather events occurred worldwide from 2000 to 2019, directly resulting in more than 475,000 deaths and US\$2.56 trillion in losses (Eckstein et al., 2021). The Global Climate Risk Index (CRI), constructed by Germanwatch, measures the degree of national loss from extreme weather events. The loss includes two aspects: the death toll and economic loss. The CRI score reflects the vulnerability of a country exposed to extreme weather events.

Against such a background, the relation between climate risk and tourism has been a topic of intense debate. However, the conclusions in the literature are mixed. Some research indicates that climate risk has a negative impact on tourism (Dube & Nhamo, 2020; Scott et al., 2012). One possible reason is that, for a tourist destination, the period affected by extreme weather can become a tourism crisis that will threaten normal operations and the development of tourism. Moreover, damage to the travel destination's reputation will create a negative view of the destination. However, other studies point out that there is no such impact (Gössling et al., 2016). Furthermore, as the United Nations Environment Programme (UNEP, 2016) reports, the adverse effects of extreme weather, such as adaptation costs, are persistent, which could create high climate risk for years or even decades. However, the impact of extreme weather on tourism is immediate and the impact period is short. Therefore, the impact of climate risk on tourism is uncertain. What if there were a causal link from tourism to climate risk? The excessive development of tourism will also exert pressure on the environment. Natural resources will

be overexploited and domestic garbage will not be able to be effectively treated. An unbalanced ecosystem can also easily lead to extreme weather (Neto, 2003). Hence, it is impossible to accurately grasp the relation between climate risk and tourism.

In addition, it is widely believed (Jahn, 2015; Milazzo, 2021) that extreme weather is destructive to national economic growth. However, this impact could be overestimated (Marshall et al., 2013). Modern industry is highly flexible. To accommodate changes in weather, resource conditions, and market prices, modern technology can be used to adjust an industry's development focus (Malcolm et al., 2012). For example, tourism services can adjust to climate change risks and embrace technologies that mitigate the effects of such risks. Similarly, agriculture can adjust crop types and rotation cycles. Such adjustments can effectively alleviate or even eliminate the adverse effects of climate risk on national economic markets and help stabilize the national economy.

This paper is aimed at capturing the Granger causality between climate risk, economic stability, and tourism. The key contribution is as follows. First, previous studies on climate risk are mostly focused on the micro level, such as companies and institutional investors (Huang et al., 2018; Kling et al., 2021). From a macro perspective, this paper will help understand the global trend of climate risk more comprehensively and representatively. Second, few studies pay attention to the interaction between climate risk and tourism. We therefore offer fresh insights on this relation, allowing future research to explore other aspects of the tourism-climate relation using our study as motivation. Third, this paper uses a novel and powerful panel Granger non-causality technique proposed by Dumitrescu and

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Hurlin (2012). This approach considers the heterogeneity of the causality between variables and the heterogeneity of the model for the simultaneous testing of causality. This ensures robust evidence of the relation between climate risk and tourism as a starting point for future research.

The remainder of the paper is organized as follows. Section II presents the data sources. Section III describes the methodology. Section IV discusses the empirical results. Section V presents the conclusion of this study.

II. Data

This paper examines the interrelation between climate risk, economic stability, and tourism. It employs panel data on 60 countries from 2005 to 2018. The climate risk indicator is the CRI published by Germanwatch,¹ where a lower CRI means a higher country ranking and climate risk level. Following Abbes et al. (2019) and Ewing (2020), economic stability (*ES*) is calculated by the standard deviation of the per capita gross domestic product growth rate. Thus, a larger standard deviation represents a more unstable economy. Tourism (*TOU*) is measured by the number of international tourist arrivals, and the *ES* and *TOU* data are from the World Development Indicators database.

Before the empirical analysis, the variables are transformed into logarithmic form. Since *CRI* and *ES* are negative indicators, following Huang et al. (2018), we multiply the transformed variable by -1. Panel A of Table 1 presents the basic descriptive statistics of the variables.

III. Methodology

To explore the heterogeneity between climate risk, economic stability, and tourism, the model is specified as follows:

$$\ln TOU = f(\ln CRI, \ln ES) \quad (1)$$

where $\ln TOU$, $\ln CRI$, and $\ln ES$ denote the natural logarithms of tourism, climate risk, and economic stability, respectively. Note that $\ln TOU$, $\ln CRI$, and $\ln ES$ should be stationary.

Granger (1969) was the first to propose the Granger causality test, which is important for disclosing essential links between two variables. Up till now, Dumitrescu and Hurlin's (2012) approach has been optimal in determining the direction of the causal link. It is particularly useful for estimating a model with cross-sectional dependence and heterogeneity. The model is specified as follows:

$$y_{it} = \alpha_i + \sum_{k=1}^k \gamma_i^{(k)} y_{it-k} + \sum_{k=1}^k \beta_i^{(k)} x_{it-k} + \varepsilon_{it} \quad (2)$$

Dumitrescu and Hurlin (2012) propose an average Wald statistic. In this context, the original hypothesis states that there is no Granger causal link between individuals, whereas the alternative hypothesis states that one or more individuals have a Granger-causal link: $(H_0 : \forall \beta_i = 0, i = 1, 2, \dots, N; H_1 : \exists \beta_i \neq 0, i = 1, 2, \dots, N)$.

First, the average Wald statistic—obeying the null ho-

mogenous non-causality (HNC) hypothesis—is computed as

$$W_{NT}^{HNC} = \frac{1}{N} \sum_{i=1}^N W_{it} \quad (3)$$

where W_{it} is the individual Wald statistic; i and t denote individual and time, respectively. When T is infinite, W_{NT}^{HNC} and W_{it} both follow a chi-squared distribution.

The number of degrees of freedom of W_{NT}^{HNC} is K ; therefore, its corresponding standardized statistic is

$$Z_{NT}^{HNC} = \sqrt{\frac{N}{2K}} (W_{NT}^{HNC} - K) \xrightarrow{d} N(0, 1) \quad (4)$$

where, for infinitely large N and T , Z_{NT}^{HNC} follows a standard normal distribution.

For a small T sample, we can use an F -distribution to approximate the distribution of individual Wald statistics. The correspondingly approximated standardized statistic $\tilde{Z}_{NT}^{HNC}$ is thus

$$\tilde{Z}_{NT}^{HNC} = \frac{\sqrt{N} \left[W_{NT}^{HNC} - \frac{1}{N} \sum_{i=1}^N E(W_{it}) \right]}{\sqrt{\frac{1}{N} \sum_{i=1}^N Var(W_{it})}} \quad (5)$$

However, for fixed T and N distributions, W_{NT}^{HNC} and Z_{NT}^{HNC} do not converge to a standard distribution. Instead of using asymptotic critical values, Dumitrescu and Hurlin (2012) use bootstrapped critical values. Therefore, when W_{NT}^{HNC} is greater than the bootstrapped critical level, it can be rejected.

IV. Empirical Results

Following Liddle (2020), this paper first adopts Pesaran's (2004) cross-sectional dependence test to examine the cross-sectional dependence of the three variables (i.e. $\ln CRI$, $\ln ES$, and $\ln TOU$). The null hypothesis is that the variable is cross-sectionally independent. Further, based on the properties of the variables, this paper uses Pesaran's (2007) cross-sectionally augmented Im-Pesaran-Shin (CIPS) unit root test. The null hypothesis is that the variable is a unit root process.

Panel B of Table 1 displays the results of the cross-sectional dependence and unit root tests. The three variables are cross-sectionally dependent and stationary. Hence, we employ the Dumitrescu–Hurlin (2012) Granger non-causality technique. The results are presented in Panel C of Table 1. We find unidirectional Granger-causal relations from tourism to climate risk, from climate risk to economic stability, and from tourism to economic stability. The results are summarized in Figure 1.

Tourists' consumption and tourism-related demands can stimulate the continuous development and improvement of various tourist destination facilities and indirectly promote the development of multiple industries, which is conducive to the formation of a more stable national economic system. However, the rapid expansion of tourism can strain local natural resources and ecosystems, leading to extreme weather, which will further aggravate national climate risk. Moreover, when extreme weather events occur, countries

¹ Germanwatch's Global CRI is obtained from <https://germanwatch.org/en/crri>.

Table 1. Summary statistics, CD and unit root tests, and Granger causality test results

Panel A: Summary statistics					
Variable	Obs	Mean	Std. Dev.	Min	Max
lnCRI	840	-3.877	0.642	-4.838	-0.604
lnES	840	-0.465	0.799	-2.336	2.108
lnTOU	840	15.678	1.656	11.002	19.172
Panel B: CD test and unit root test results					
Variable	CD test		CIPS test		
lnCRI	10.820***		-3.387***		
lnES	63.250***		-2.218**		
lnTOU	100.720***		2.088**		
Panel C: Heterogeneous panel non-causality test results					
H ₀	Z-bar		Z-bar tilde		
lnES does not Granger-cause lnCRI	1.794		0.277		
lnCRI does not Granger-cause lnES	3.735**		1.545**		
lnTOU does not Granger-cause lnCRI	6.750*		3.515*		
lnCRI does not Granger-cause lnTOU	3.301		1.262		
lnTOU does not Granger-cause lnES	9.504**		5.314**		
lnES does not Granger-cause lnTOU	8.595		2.570		

The table reports the summary statistics, CD and unit root tests, and heterogeneous panel non-causality test results. The lag order of the variable for the Granger causality test is selected using the Akaike information criterion. The *p*-values for the Granger causality test are computed using 1000 bootstrap replications. ***, ** and * refer to a significance of 1%, 5% and 10%, respectively.

with a high-risk climate will sustain more frequent and greater losses, such as extra burdens and rising adaptation costs, which will affect the stability of the national economy.

V. Conclusions

This paper mainly investigates the dynamic linkage between climate risk, economic stability, and tourism, using a sample of 60 countries from 2005 to 2018. Considering potential cross-sectional dependence and heterogeneity, the paper employs the approach of Dumitrescu and Hurlin (2012). Empirical study shows that climate risk Granger-causes economic instability; however, it does not Granger-cause tourism growth. Moreover, tourism is Granger-caused by climate risk and economic stability, respectively. Thus, our findings suggest that, although the impact of climate risk on tourism is overestimated, it does threaten national economic stability. In addition, tourism is a double-edged sword. On the one hand, the development of tourism can bring about a stability national economy; on the other hand, uncontrolled tourism will increase the national climate risk.

Figure 1. The digraph of Granger causality

The digraph shows the theoretical connection between these three variables.

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